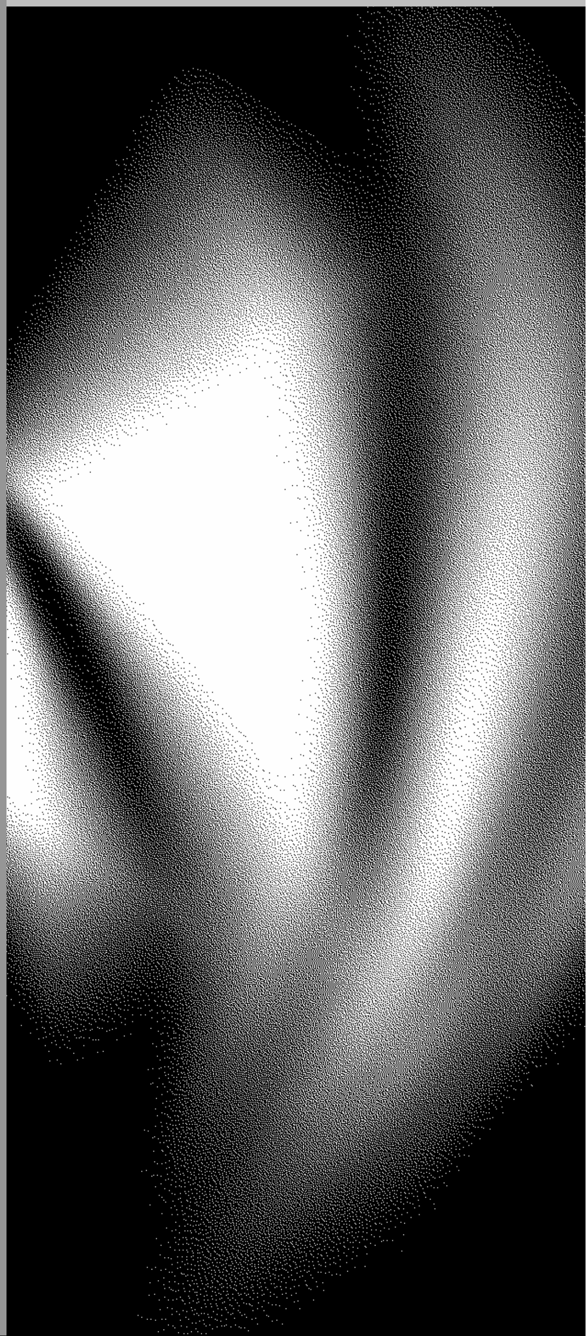
Australian Government
Productivity Commission

Public Support for Science and Innovation

Productivity Commission Research Report

9 March 2007



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The Productivity Commission

The Productivity Commission, an independent agency, is the Australian Government's principal review and advisory body on microeconomic policy and regulation. It conducts public inquiries and research into a broad range of economic and social issues affecting the welfare of Australians.

The Commission's independence is underpinned by an Act of Parliament. Its processes and outputs are open to public scrutiny and are driven by consideration for the wellbeing of the community as a whole.

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Foreword

Governments direct significant public resources to science and innovation. The focus of this study is on the benefits that arise from this public support and how they can be enhanced. The impacts that need to be considered are not just the gains that end up in gross domestic product or other statistical measures of economic performance, but the social and environmental benefits as well.

The study looks at institutional and regulatory frameworks, as well as how funding levels are determined, and how programs are designed, administered and delivered. Consistent with its terms of reference, the Commission has sought to draw broad lessons and conclusions for future funding and programs, rather than undertaking detailed analysis of individual programs or the appropriate levels of public support for them.

In preparing its report, the Commission has benefited from information provided in a large number of submissions, as well as from consultations with governments, public research agencies, universities, businesses and other relevant organisations and research bodies. The Commission thanks all those who have contributed.

The study was overseen by Commissioners Mike Woods and Steven Kates, with a staff research team headed by Ralph Lattimore.

Gary Banks
Chairman

March 2007

Terms of reference

PRODUCTIVITY COMMISSION ACT 1998

The Productivity Commission is requested to undertake a research study on public support for science and innovation in Australia.

Background

The Australian Government has identified science and innovation as one of its strategic priorities, recognising its contribution to Australia's economic and social prosperity. The Government has provided significant support for science and innovation, which it has augmented since 2001 through Backing Australia's Ability (BAA) , and funding now exceeds $5 billion per annum. In light of this investment, the Government considers that a study of public support for science and innovation is warranted. This study will complement the ongoing and planned reviews of BAA programmes.

Scope of the study

The Commission is requested to:

1. **Report on:**
   - **the economic impact of public support for science and innovation in Australia and, in particular, its impact on Australia's recent productivity performance;**
   - **whether there are adequate arrangements to benchmark outcomes from publicly supported science and innovation and to report on those outcomes as measured by the benchmarks.**

   The analysis should cover all key elements of the innovation system, including research and development, taking into account interaction with private support for science and innovation, and paying regard to Australia's industrial structure.

2. **Identify impediments to the effective functioning of Australia's innovation system including knowledge transfer, technology acquisition and transfer, skills development, commercialisation, collaboration**

between research organisations and industry, and the creation and use of intellectual property, and identify any scope for improvements.

3. **Evaluate the decision-making principles and programme design elements that:**

   a. **influence the effectiveness and efficiency of Australia's innovation system; and**

   b. **guide the allocation of funding between and within the different components of Australia's innovation system;**

   and identify any scope for improvements and, to the extent possible, comment on any implications from changing the level and balance of current support.

4. **Report on the broader social and environmental impacts of public support for science and innovation in Australia.**

Although the Commission is not requested to review individual programmes, it can, where necessary, undertake case studies of particular types of public support for science and innovation. It should also draw on relevant international experience.

The Commission is to produce a draft report and a final report within 12 months of the receipt of this reference. The report is to be published.

CHRIS PEARCE

[Reference received 10 March 2006]

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Abbreviations

ACIS	Automotive Competitiveness and Investment Scheme
ADO	Australian Defence Organisation
AIC	Australian Institute for Commercialisation
ANSTO	Australian Nuclear Science and Technology Organisation
ARC	Australian Research Council
ATN	Australian Technology Network of Universities
AUQA	Australian Universities Quality Agency
AVCC	Australian Vice-Chancellors' Committee
BAA	Backing Australia's Ability
BCA	Business Council of Australia
BCR	Benefit–cost ratio
BERD	Business expenditure on R&D
BIHECC	Business, Industry, and Higher Education Collaboration Council
CHASS	Council for the Humanities, Arts and Social Sciences
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEST	Department of Education, Science and Training
DSTO	Defence Science and Technology Organisation
EPI	Environmental performance index
ESI	Environmental sustainability index
FASTS	Federation of Australian Scientific and Technological Societies
GERD	Gross expenditure on R&D
GOVERD	Government intramural expenditure on R&D
HECS	Higher Education Contribution Scheme

HERD	**Higher education expenditure on R&D**
HREC	**Human Research Ethics Committee**
IAC	**Industries Assistance Commission**
IC	**Industry Commission**
IP	**Intellectual property**
MFP	**Multifactor productivity**
MRI	**medical research institute**
NCRIS	**National Collaborative Research Infrastructure Strategy**
NHMRC	**National Health and Medical Research Council**
NRPs	**National Research Priorities**
OECD	**Organisation for Economic Co-operation and Development**
PC	**Productivity Commission**
PFRA	**Publicly funded research agency**
PSRA	**Public sector research agency**
R&D	**Research and development**
RAE	**Research Assessment Exercise (of the UK)**
RQF	**Research Quality Framework**
RRDC	**Rural Research and Development Corporation**
RRTMR	**Research and Research Training Management Report**
S&I	**science and innovation**
SMEs	**Small and medium enterprises**
TPA	***Trade Practices Act 1974***

OVERVIEW

Key points

- There are widespread and important economic, social and environmental benefits generated by Australia's $6 billion public funding support of science and innovation.
  – On the basis of multiple strands of evidence, the benefits of public spending are likely to exceed the costs.
  – But, given a host of measurement and methodological issues, it is not possible to provide anything other than broad estimates of the overall return to government contributions.
- Major improvements are needed in some key institutional and program areas.
- The adequacy of existing program evaluation and governance arrangements is mixed, with some notable shortcomings in business programs.
- The net payoff from the R&D Tax Concession could be improved by allowing only small firms access to the 125 per cent concession, changing the thresholds for tax offsets, amending the base for the 175 per cent incremental concession and considering a narrower, more appropriate, definition of R&D. This should increase the amount of new R&D induced per dollar of revenue and achieve more spillovers.
- Strong public support of Rural R&D Corporations with a public good orientation is justified, but the level of government subsidies for *some* narrower, industry-focused arrangements is likely to crowd out private activity and produce weaker external benefits outside the supported rural industry. However, industry will need time to adjust to new arrangements.
- Collaboration can generate significant benefits. The CRC program is, however, only suited to longer-term arrangements. There are complementary options for business collaboration with public sector research agencies and universities that could provide more nimble, less management-intensive, arrangements.
- There are grounds for dealing with problems in the governance and intellectual property frameworks of universities, weaknesses in their commercial arms and shortcomings in proof-of-concept funding.
  – However, the pursuit of commercialisation for financial gain by universities, while important in its own right, should not be to the detriment of maximising the broader returns from the productive use of university research.
- The structure of funding for higher education research has increasingly eroded the share of block grants. Further erosion would risk undermining their important role in enabling meaningful strategic choices at the institutional level.
- The costs of implementing the Research Quality Framework may well exceed the benefits. The benefits from the 2008 RQF round could be improved if its funding scales provide more significant penalties for the poorest research performers than apparently currently envisaged. In the long run, a transition to less costly approaches, such as those that target poor performing areas, should be considered.

Overview

Innovation is critical to Australia's growth and its preparedness for emerging economic, social and environmental challenges. Governments play a major role in shaping the innovation system through the design and governance of institutions, in supporting the education and training of scientists and engineers, and in funding high-value research that would not otherwise be undertaken by businesses. Governments also play a direct role through their own public sector research agencies and by financing R&D in universities and businesses. Overall funding was around $6 billion in 2004-05.

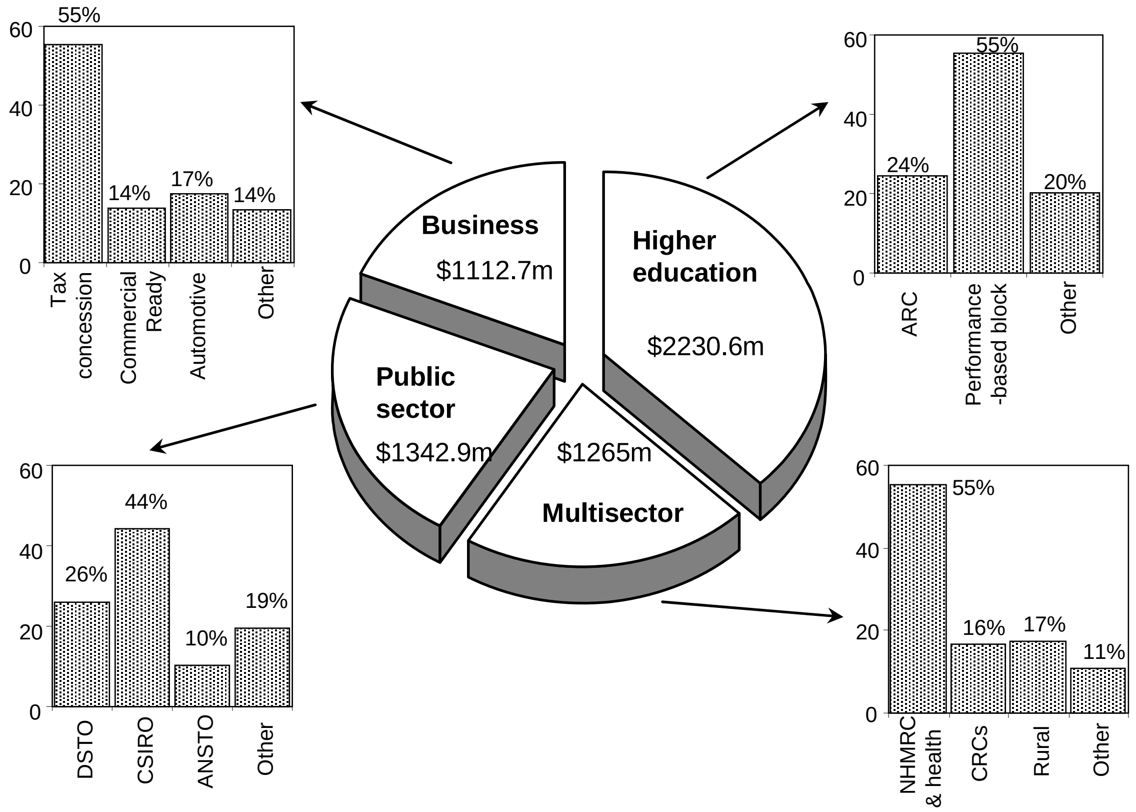
This report examines the impacts of such public support for science and innovation, and considers the prospects for improving outcomes by eliminating impediments to innovation or by changing the way government support is channelled to its various competing uses. The Commission was not requested to systematically review all individual programs. It has therefore adopted a strategic approach, identifying particularly important programs or funding areas and investigating the grounds for their reform.

The overall conclusion is that public support for science and innovation has, by and large, provided widespread and important benefits for Australians. Nevertheless, there is room for considerable improvement in key areas of Australia's innovation system, spanning ineffective business programs, a sometimes excessive focus on the commercialisation stages of innovation, problems in scientific labour markets, inadequate evaluation methods and problematic funding models.

There are strong rationales for public funding support

Public funding support for research and development, an important input into innovation, is substantial. The Australian Government plays the most prominent role (figure 1), but State and Territory Governments are also increasingly active. Accordingly, support should be based on clear and credible rationales, which should then underpin the evaluation criteria used to assess the net benefits of each program.

Figure 1 **Australian Government spending on science and innovation**
2005-06



There are two strong rationales for public funding support of science and innovation. The first is that publicly funded R&D is a significant contributor to innovation in the functions performed by government. Governments need to invest in research to improve the products and services they offer or to better discharge their functions, just as does the private sector. For example, expenditure on research and innovation is pivotal to effective environmental management, the provision of education, defence, and social welfare and health services. It does not follow, of course, that such publicly funded research must be undertaken within the public sector.

The second significant rationale is the existence of 'spillovers' from innovation. These are benefits that cannot be captured by the innovator — ideas that can be used, mimicked or adapted cheaply by firms or others without payment to the originator. Spillovers may arise through the development of basic knowledge capabilities or diffusion of new ideas among firms and others. Such spillovers arise from research undertaken in universities, businesses and public sector research agencies.

The mere presence of spillovers, does not, in itself, justify public support:

- Many investments that produce spillovers have sufficient private returns for firms to invest without that support.
- Some spillovers accrue to foreigners, and so are generally not relevant to the appraisal of net benefits for Australia.

The challenge for public policy measures is to elicit private investments that would not otherwise have been made ('additionality') *and* that generate total private and spillover returns that are still sufficiently positive to exceed the costs associated with the policy measures. These costs include the efficiency distortions of taxation required to finance the measures, the utilisation of resources on administration and compliance, and the consequences of poor choices when selecting projects to be funded. Programs need to be designed to ensure that public funds stimulate genuinely new R&D rather than displacing privately funded R&D.

There are various other rationales for public support. Those found during the study to have some validity include:

- intangible factors — the values that science elicits and entails (for example, national identity and curiosity); and
- the asymmetric tax treatment of highly risky investments — profits are taxed now whereas the tax value of losses fall through discounting as they are carried forward.

Imperfections in capital markets that could affect the availability of finance to risky or uncertain investments in small firms and start-up companies may provide a rationale, though they may merely reflect high, but unavoidable, transaction costs of dealing with some firms.

Other rationales often given for support — the indivisibility of very large research projects; business myopia; and the goal of transforming Australia's industry structure — have little merit.

Public funding support produces sizeable benefits

Given the significant public funding of R&D, a key question is what gains Australians derive from this spending. No single method for appraising the effects of R&D on productivity or more intangible national outcomes can be definitive. Accordingly, the Commission pursued many approaches to assess impacts.

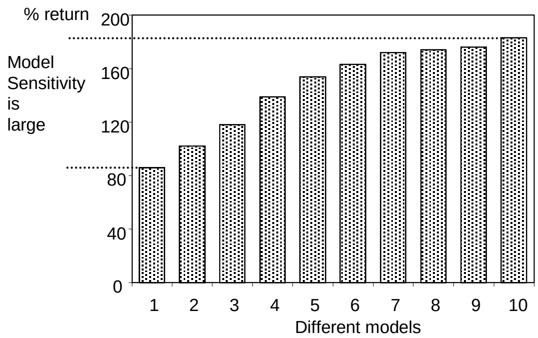
The aggregate time series approaches used by the Commission suggest positive spillover rates of return to business R&D. This is also buttressed by the Commission's analysis of the sources of economic growth over time among

Australian States and Territories, which suggested high rates of return to total and business R&D. Similar studies undertaken across countries and time also usually find significant returns. But none of these quantitative methods can realistically measure rates of return with precision (box 1).

Box 1 **The problems with numbers**

Aggregate time series studies — often the basis for estimates of the productivity effects of R&D — cannot realistically measure spillover rates of return accurately. This reflects the complex causal pathways through which R&D affects productivity growth, an inadequately short span of data, measurement errors, the potentially long lags from the conduct of R&D to ultimate benefits, and difficulties in controlling for the other factors that also influence productivity. Accordingly, the econometric modelling of the kind used in this report or the companion analysis by Shanks and Zheng (2006) can find it difficult to measure the effects of R&D with any precision.

This variation is illustrated by the multiplicity of estimates of R&D spillover effects obtained for Australian business R&D from time series analysis undertaken by the Commission in recent years. The most statistically adequate models of productivity presented by Shanks and Zheng find a spillover return to domestic R&D of around 50 per cent, while the present report finds considerably higher returns — between around 85 and 180 per cent. These high spillover returns have wide confidence intervals, however, and are highly dependent on model specifications as shown in the chart below. On the basis of other evidence on the sources of economic growth, these point estimates are likely to be implausibly large. Another method, for example, suggested numbers lying in the much lower range from 35 to 100 per cent, but these bounds could readily be exaggerations or underestimates too.



Overall, the results from such modelling cannot realistically aspire to produce accurate estimates of the spillover rates of return from R&D. However, the empirical evidence adds weight to the hypothesis that R&D produces large returns to the market sector through productivity increases that are not captured by the firms undertaking R&D.

In the case of other methods, such as case studies, the evidence relates to average R&D project net benefits, not the benefits of new, marginal, projects, which are relevant to decisions about incremental funding levels. Such case studies are also affected by problems of bias in their selection and the more general problem of data inadequacies.

While it is useful to measure the returns to R&D as a whole, the public policy issue is the magnitude of benefits from *publicly supported* science and innovation, not from R&D in total. The bulk of such public funding (about five dollars in every six) is provided to universities or public sector agencies. To have the possibility for positive returns, such funding must not significantly displace private financing of R&D in these institutions or in businesses. There is strong evidence that displacement is small.

A second condition for public support is that the benefits of this research must be sufficient to justify the investment. The Commission examined many strands of evidence — industry analyses, qualitative assessments, international cross-sectional time series studies and case studies relating specifically to R&D undertaken in universities and public sector agencies. Overall, these also suggested good returns. In some instances, such as R&D for many environmental purposes, the net gains are mostly not measurable as short-run changes of GDP, but are nonetheless worthwhile. R&D from these organisations has:

- increased preparedness and reduced risks in some areas;
- been widely adopted in a range of settings (public health, risk abatement in the environment and social and educational policy);
- developed advanced problem-solving skills among Australian graduates; and
- provided spillovers to business, for example in the mining industry.

Other indirect indicators of impacts, such as academic quality, suggest that Australian scientists are performing well by comparison with those in other advanced economies.

Business programs are likely to have generated smaller net returns to Australia than publicly conducted R&D. This reflects several factors:

- a large share of the R&D eligible for tax concessional treatment would have taken place in the absence of public funding support;
- a considerable amount of public support has been directed at incremental, catch-up R&D, where the spillover benefits are likely to be lower; and
- a few relatively declining sectors — such as the auto industry — have benefited disproportionately through special sectorally-specific R&D programs.

Innovation system impediments

Participants in this study identified a range of possible impediments to the operation of the innovation system. Many of these related to perceived deficiencies in the level of funding, structure, multiplicity and administration of the public support programs. These issues are discussed later.

The remaining innovation impediments that were identified related to apparently poor commercialisation; science workforce issues; some unexpected consequences of specific regulations; factors that may weaken the capacity for knowledge diffusion in basic research; and broader institutional settings, such as taxation and general skill levels.

Problems in commercialisation and knowledge diffusion mechanisms

There is evidence of widespread success in commercialisation across all sectors of the Australian economy, which belies a commonly expressed pessimistic view of Australia's capabilities. But the Commission has identified a range of potential impediments to commercialisation and diffusion, particularly in universities, that may merit action:

- There appears to be an excessive variety of arrangements for transferring intellectual property (IP) to firms, often within the same university, which increases the costs for firms seeking to commercialise university research.
- Some universities appear to have poor governance structures and incentives for commercialising IP — such as insufficient sharing of the benefit among the relevant parties.
- Only the largest research universities are likely to be able to develop dedicated commercialisation arms of sufficient scale and expertise to operate effectively. More flexible arrangements — including the use of private sector intermediaries — may allow universities to draw on the commercial expertise they need in a more efficient and cost-effective way.
- Universities can sometimes find it difficult to sell commercialisable IP to business because the concepts have not been adequately demonstrated ('proof-of-concept'). Since the claim is that such IP is inherently profitable to the universities, the Commission suggests that publicly funded support for it should (a) involve a non-contingent loan from the Australian Government; (b) be a last resort after other avenues for private funding have been demonstrably exhausted; and (c) be piloted before any substantial funding is committed.
- There is likely to be some scope for universities to improve their linkages with firms in other ways, but this does not necessitate a dedicated new funding stream, such as 'third stream' funding. Current metrics used to identify problems in such linkages tend to accentuate only specific kinds of mechanisms, such as company spinoffs or IP licensing, and fail to recognise the importance of diffusion arrangements that already work well, such as informal networks, conferences and publications. But new intermediary arrangements aimed at better diffusion are being trialed and will provide a useful experiment.

Claims that public support is required for a whole range of other apparent problems in the commercial exploitation of know-how — such as inadequate venture finance and poor entrepreneurship and management skills — are either ill-founded or overlook programs that already exist.

A balance is needed when considering the role of public support for commercialisation activities in universities, public research agencies and businesses. Placing undue emphasis on commercialisation for financial gains may have unintended effects.

- Universities' core role remains the provision of teaching and the generation of high quality, openly disseminated, basic research. Even where universities undertake research that has practical applications, it is the transfer, diffusion and utilisation of such knowledge and technology that matters in terms of community wellbeing. Commercialisation is just one way of achieving this. The policy framework for universities should encourage them to select the transfer pathway that maximises the overall community benefits, which will only sometimes favour commercialisation for financial gains.
- Apparent cultural barriers between universities and businesses may reflect, in part, the preferences of researchers, who can be more motivated by curiosity and research excellence than commercial opportunities. Addressing any cultural 'barrier' requires prudence because it poses risks for the research functions of universities and some of the motivations for science career choices.
- While public spending to support business commercialisation is smaller than the support given at the earlier stages of the innovation process, business programs are increasingly oriented at commercialisation objectives. However, there are fewer clear-cut spillovers at this later stage, which weakens the rationale for programs directed to this end. There are also large potential private returns to commercialisation — failure to commercialise gives rivals the time to poach the pre-existing R&D knowledge. So public support risks financing some investments that would occur anyway.
- Calls for governments to assume the risks for highly risky commercial ventures also have a poor basis since such an approach would merely transfer commercial risks from firms to taxpayers.

There are barriers to the future growth of human capital

Some areas of concern about the supply of scientists— such as the 'brain drain' — are not well-founded. Australia gains considerably in net terms in immigration of scientific personnel.

However, while most science occupations are not in short supply, there is a recognised shortage of engineers and of secondary school teachers in science and mathematics. The shortage of engineers is partly self-correcting as it has elicited a rapid growth in salaries for both graduate and experienced engineers, encouraging entry into the profession. In the case of science and mathematics teachers, shortages have instead been accommodated by using teachers without adequate skills in these areas. This may adversely affect student performance and engagement and decrease future university enrolments in the sciences. In teaching, price signals have not been able to respond to shortages due to the inflexible pay levels and structures. This should be subject to reform.

Job satisfaction amongst scientists appears to be falling, with potential consequences for productivity and future recruitment. This morale problem reflects scientists' concerns about poor career pathways, excessive use of short-term contract employment and a burgeoning non-research workload. Many of the issues are best addressed by negotiation and agreement between employers and employees. However, job satisfaction can also be increased through:

- longer-term funding certainty;
- carefully designed performance assessment processes that reward higher performing institutions, research teams and individuals;
- a level of academic freedom consistent with the strategic interests of the employing institution; and
- the minimisation of non-research workloads.

The need for better use of physical research infrastructure

There is a diverse range of pricing and sharing arrangements for infrastructure between public institutions that may sometimes result in inadequate utilisation. The Commission broadly supports the recommended pricing approach of the National Research Infrastructure Taskforce. Fixed and standing operating costs should be met through public funding. Prices of major infrastructure should then be set at marginal costs for research users — with congestion charging for infrastructure that is over-utilised. A stocktake of existing research infrastructure would also help identify areas where assets could be better shared.

There are some signs of inadequate infrastructure in universities. Infrastructure spending has not kept pace with other public funding and there is a growing backlog of deferred maintenance. However, the real extent of problems across the university system is obscured by measurement problems.

Possible impediments to diffusion in the basic research community

There are several possible barriers to knowledge dissemination in basic research.

Legal uncertainty about the use of patents for research has the potential to impede knowledge dissemination. One option proposed by the Australian Law Reform Commission and the Advisory Council on Intellectual Property is to introduce a provision in the Patents Act for exempting researchers from infringement when they make experimental use of patented intellectual property. This model has been applied in the United Kingdom, several European countries and Japan, and recently in New Zealand. The intention is to reduce legal uncertainty about the use of patents for research, without affecting commercial incentives to invest in innovation. However, the extent to which such legal uncertainty acts as a barrier to innovation is unclear, as are the costs and risks of any unintended consequences of implementing the proposed model.

The growth of the internet has made it possible to lower to zero the marginal costs of disseminating much basic scientific knowledge. Current models of scientific publication, while changing, have nevertheless been perceived as limiting the possibilities of diffusion of publicly supported research because they restrict access. Major funding bodies in the United Kingdom and the United States have already instituted reforms. There is further scope for the Australian Research Council (ARC) and the National Health and Medical Research Council (NHMRC) to progressively play a more active role in achieving open access to the results of their sponsored research.

Privacy and ethics regulation may constrain some research

Complexities associated with privacy regulation across jurisdictions and multi-site ethical review processes can adversely affect the conduct of some types of research, particularly in the medical field. This report recognises the valid aims of both regulatory approaches. However, streamlining the ethical review of multi-site research and introducing national consistency in privacy regulation of health information can achieve the objectives of the regulations, while imposing fewer costs on researchers.

High quality performance evaluation is an imperative

Effective performance evaluation and benchmarking are vital tools in the allocation of funding, both across programs and to projects within programs.

The adequacy of existing performance evaluation and benchmarking is mixed. Programs with significant budgetary implications are not always subject to routine, transparent and independent evaluation, nor always use rigorous methods to determine program effects. The results of evaluations are not always used to change programs that are not working well. There are some notable shortcomings in the arrangements for evaluating business programs, and most recently *R&D Start*, the predecessor to *Commercial Ready*. Reforms are needed.

There are also deficiencies in the assessment of the quality and impacts of higher education block funding for the purposes of funding allocation. The proposed Research Quality Framework (RQF) is intended to remedy this but, as noted below, has its own limitations.

Institutions such as the CSIRO, the ARC and the NHMRC are constantly developing their research management and evaluation approaches. CSIRO's process involves:

- identifying new-to-the-world R&D with strong potential impacts;
- staged financing of R&D that depends on re-assessments of future impacts; and
- a peer reviewed ex post assessment of impacts and quality.

This approach should be assessed alongside their own approaches by other mission-focused research institutions, but is less relevant to university research because of the more basic nature of the research and the high transaction costs of assessing many thousands of small projects.

Business programs need adaptation

Australia's current suite of business support programs could be improved to target more effectively the twin objectives of encouraging research activity with high social benefits beyond the firm (spillovers), which would not take place without public support (additionality).

Reforms of general business R&D funding arrangements

The R&D tax concession — including its incremental component — is the largest single mechanism for public funding support of business R&D. It has an advantage over grant programs in that it leaves businesses with the flexibility to undertake the kinds of R&D suited to their own strategies and needs. Its total budget costs were over $600 million in 2005, which was around 60 per cent of total direct business R&D support by the Australian Government.

One of its major limitations is that the criteria for the basic 125 per cent tax concession do not screen out R&D that would have happened anyway — the bulk of business R&D. This increases the costs to revenue from stimulating any additional R&D and reduces the magnitude of net benefits from the program. At present program settings, the net benefits of the program are not large and could be negative.

The net payoff from the concession could be substantially improved by maintaining access to the concession for small firms only. Smaller firms' R&D is more responsive to the flat rate subsidy, is less affected by 'washout' of the subsidy through the dividend imputation system and could less readily benefit compared with large firms from an incremental R&D scheme of the kind preferred by the Commission.

The activity thresholds determining access to the arrangements for concessional deductions for R&D companies in tax loss (the *Tax Offset*) should also be amended to address the perverse incentives associated with the current expenditure and turnover limits.

The Commission considers that there are also grounds for enhancing the existing 175 per cent incremental tax concession scheme by:

- adopting a fixed base of an R&D to sales ratio as the basis for payment, rather than the current rolling base;
- giving start-up firms access to the premium component from which they are currently largely excluded, but taking account of the fact that such firms usually commence with high R&D to sales ratios;
- assessing the merits of relaxing the beneficial ownership requirement by allowing foreign subsidiaries that hold their IP abroad to have access to the incremental concession only; and
- potentially even increasing the concession rate for the premium component, or introducing a tiered system with progressively higher subsidy rates that depend on the extent of the increase in a firm's R&D activity.

Such an incremental system will not function well for companies whose ratio of R&D to sales is very volatile. But it is expected that it could play an important role in stimulating additional R&D for large firms, which account for a large share of total R&D and whose R&D intensities are more stable. The administrative data to check the exact effects of this and alternative incremental designs are not yet available, and the precise design should be contingent on the Department of Industry, Tourism and Resources undertaking simulations of their likely effects and risks.

More generally, a narrower definition of R&D in line with international conventions should be considered, which requires eligible R&D to be innovative *and* highly risky (rather than the present condition for R&D to be highly innovative *or* highly risky). If administratively feasible, this change has a higher chance of generating spillovers.

As noted previously, the increasing focus of some business programs on later-stage commercialisation, rather than research, runs the risk of supporting R&D that might have occurred anyway and of shifting support away from the stage of R&D where spillovers are most likely. The evaluation evidence available to the Commission points to this as being a substantive risk for the Commercial Ready program. Analysis by the Commission of international evaluations of other R&D grant programs has shown that some countries appear to get better outcomes from their grant programs. Why this is the case will depend on specific features of the programs and the evaluations, and should be investigated further. Introducing loan repayment mechanisms, rather than straight grants, may be part of the answer.

The various manufacturing industry-specific programs, while generously funded, should be evaluated in part against a broader objective of facilitating structural adjustment — the automotive industry program being a case in point.

Subsidy rates for some types of RRDCs should be re-calibrated — with a lead time

The governance design of the Rural R&D Corporation model is inherently sound. Levies that are decided by, and apply to, all beneficiaries of the R&D overcome free-riding and the resultant under-provision of rural research. There are strong grounds for significant public co-funding of those RRDCs where there are spillover benefits beyond industry members and where that research would not proceed in the absence of support (for example, research into improving salinity-damaged areas).

But *some* industry-focused RRDCs should be less reliant on public co-funding. They receive significant subsidies without a demonstration of commensurate induced spillovers. There are grounds for adjustments of subsidies for these RRDCs, though the precise corrections should be determined through independent review processes on a case-by-case basis. RRDCs should be given a lead time for any changes, so that they can adapt to the new policy.

There may be grounds for a complementary program to CRCs

The Cooperative Research Centre (CRC) program received mixed responses from participants, some arguing there are high returns while others pointing out low ultimate impacts, high start-up costs and ongoing compliance burdens. Current cost-sharing arrangements seem to direct high levels of subsidies to the business collaborators, as they are primary beneficiaries of the Centres.

Several options may improve collaborative arrangements of this kind.

The original objectives of the program should be reinstated — namely, the translation of research outputs into economic, social and environmental benefits, rather than focusing public support on the commercialisation of industrial research alone.

The CRC program is geared toward large-scale, longer-term research programs, which are more suited to big research users. There are relatively cumbersome avenues for CRC partners to enter and exit the venture and a heavy compliance burden. There is scope for complementary options for business collaboration with public sector research agencies and universities that could provide more nimble, less management-intensive arrangements than the present CRC program. Some eligibility criteria for a new program are mooted by the Commission. Any new arrangement should be piloted. The merits of other forms of intermediation between business and research organisations are discussed in the report.

Funding arrangements for higher education

Funding of higher education research accounts for over 40 per cent of total Australian Government financial support for science and innovation. Universities receive block funding direct from the Australian Government (about $1100 million in 2004). They are also the primary recipient (about $700 million in 2004) of the competitive funding programs administered by the ARC and the NHMRC.

The conceptual arguments for dual streams of funding of higher education research are sound. They encourage researchers to compete on quality and impact (competitive grants), while providing institutions with a base research funding level intended to allow them to make their own strategic choices (block grants) with reduced transaction cost burdens compared with external grant applications. But changes to funding for higher education research have increasingly eroded the share of block grants. The Commission assesses that further shifts away from block grants would risk undermining their important role.

Block grants are currently allocated on a formula-basis that does not include direct peer review or direct assessment of economic, social and environmental benefits. This is set to change with the implementation by the Australian Government of the Research Quality Framework (RQF). This will use peer review and other indicators to review quality and impact as a basis for the distribution of some university block funding. The Commission agrees that the RQF may well allow the development of better measures of quality and impact.

However, while the RQF may bring some benefits, the UK and NZ experiences suggest that these would have to be substantial to offset the significant administrative and compliance costs. But since a decision on its implementation has now been made by government, the relevant policy goal is to achieve the benefits intended at the minimum possible administrative and compliance costs.

The maximum benefit from the 2008 RQF round could be obtained only if its provisions allow scope for significant change in funding outcomes compared with the existing block funding formulae. Accordingly:

- safety nets should be minimal; and
- scales should be set so that there are significant penalties for achieving low quality and impact grades — a linear funding scale, as apparently envisaged, could be counterproductive.

The first round RQF 2009 evaluation should consider the merits of other, less costly, ways of promoting quality and impact in higher education research. These would include auditing approaches that uncover those areas with the highest risk of poor performance, in conjunction with modified formula-based approaches to funding.

If the RQF is to continue beyond 2008, then consideration should be given to bringing forward the 2014 round and/or conducting a partial round in the intervening period — this would provide an earlier basis for assessing the effects of the RQF in promoting quality and impact improvement.

In regard to competitive funding, little, if anything, would be gained through amalgamating the ARC and the NHMRC.

National Research Priorities give some guidance

The Australian Government has articulated the broad direction of its priorities for publicly-funded science through its National Research Priorities (NRPs), though these are neither binding nor quantitatively expressed.

The Commission supports the retention of the priorities in the present level of detail as these usually provide sufficiently meaningful signals of areas for research. Any marked loosening or tightening of the priorities would be problematic. Central government control would lack the flexibility and information to prescribe more precise research agendas. Any broader level of prioritisation would no longer usefully guide research at all.

How big should the pie be? — funding issues for science

Although the study's terms of reference seek guidance about where and how public funding should be allocated, several participants also addressed concerns about the level of funding — unsurprisingly the majority of these submitting that it should be increased.

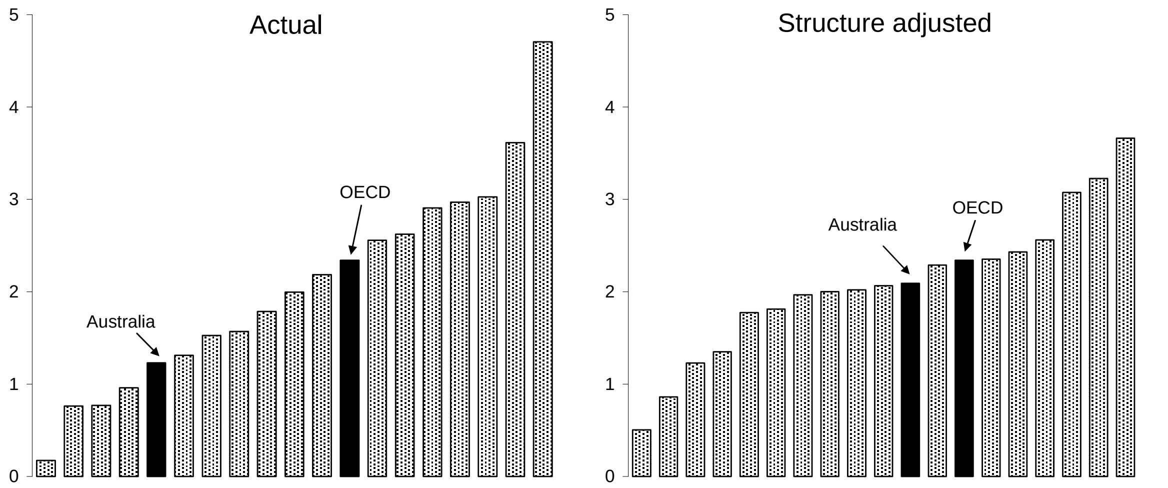
There are several indicators and processes that help guide whether funding levels are appropriate. International comparison is a useful broad indicator of adequacy, but must be undertaken and interpreted carefully. Some participants in this study claimed the apparently low Australian R&D to GDP ratio is an indicator of significant under-investment, requiring redress through increased government funding. However, the apparent disparity in business R&D intensity mainly reflects differences in industry structure, rather than an inherently low R&D orientation (figure 2). And the area where the most concern about inadequate funding was raised — higher education — is not towards the low end of the distribution of R&D spending to GDP among OECD countries.

Other macro indicators — economic growth, innovation rates and multifactor productivity growth — suggest that Australian businesses are generally making sound decisions about their current R&D and other innovation costs.

The Commission also considered a range of indicators of the degree of stress in the innovation system — such as human capital adequacy, scientific outputs and quality, and the capacity for solving local problems. Some study participants pointed to the high impacts from public spending as evidence that more should be spent. But, as noted above, the Commission's analysis of the impacts of publicly funded science and innovation demonstrates a favourable outcome, but is insufficiently precise to calibrate funding levels. In any case, the benefits of past research is not the only relevant criterion for funding. New spending measures also have transaction costs associated with compliance and unexpected incentive effects, as well as the costs of raising finance through distortionary taxes (or those associated with displacement of other public spending). A decision to spend more has to balance the marginal benefits against the marginal costs.

Figure 2 **The R&D 'gap' narrows considerably once industry structure is taken into account**

BERD/value-added ratio (per cent), 2002[a]



[a] The structure-adjusted estimates use the (OECD average) industry structure.

At an aggregate level, the available evidence suggests that Australia's public support of science and innovation is not in the 'danger zone' of demonstrable over- or under-funding. But as the Commission has highlighted, there are some stresses on the system, including:

- emerging pressures in the academic and teaching scientific workforces, stemming from aging and ongoing workplace inflexibilities;
- *possible* infrastructure inadequacies in universities;
- expanding needs for public good research, given new environmental, energy and climate challenges; and
- the need for more effective collaborative arrangements between businesses and universities.

But equally, there are areas where potential savings might be realised:

- the base R&D tax concession and some other business programs; and
- diminishing requirements for public funding for some traditional areas of research, including research undertaken by public agencies for industry on non-commercial terms.

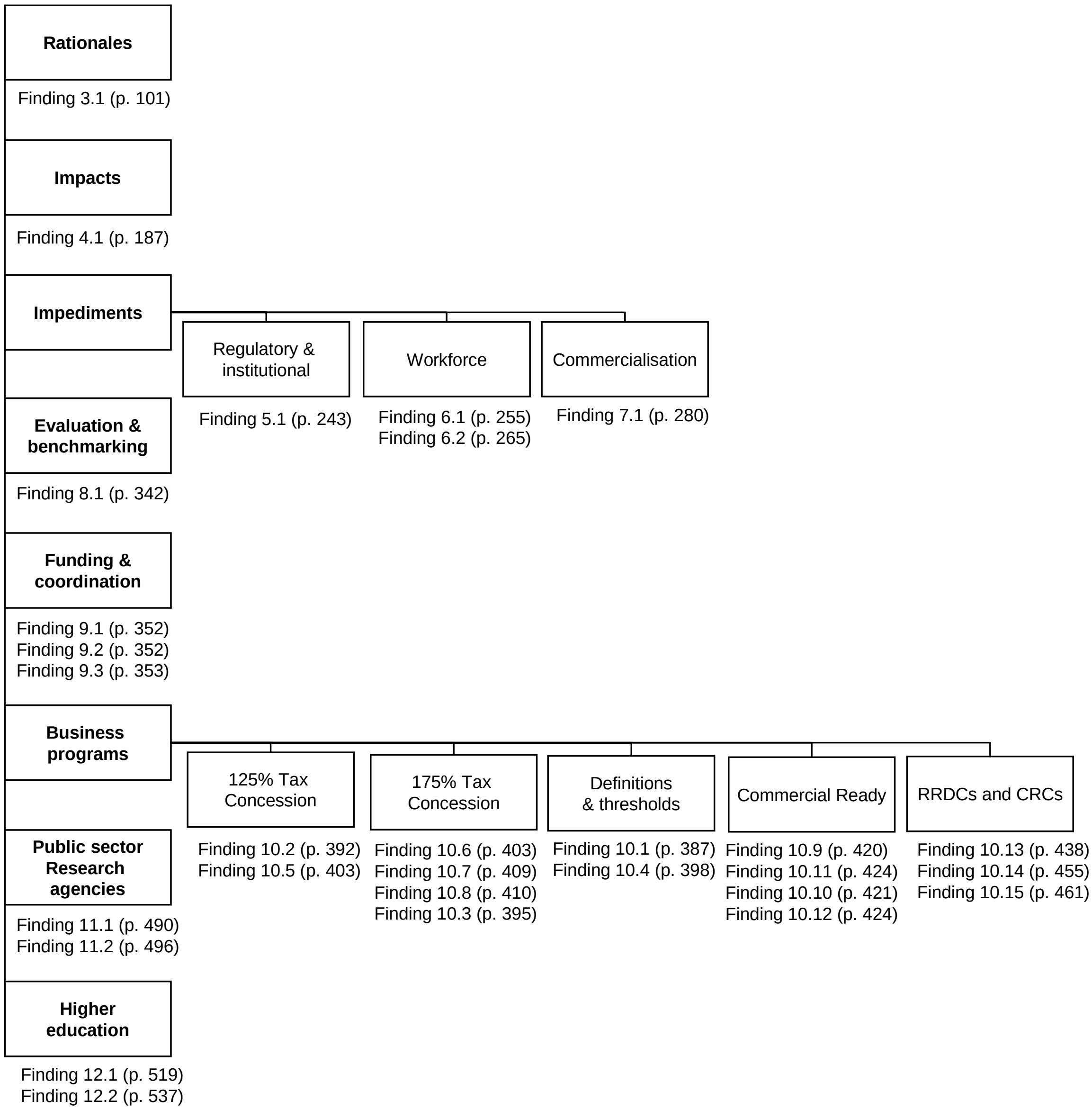
The net balance of these contrary pressures is not clear. Nor is the balance between emerging needs in science and innovation compared with competing priorities of government spending, such as health or education, or lower taxation burdens for Australians. Given that public spending on science and innovation is not in the 'danger zone', aggregate funding is best determined by a bottoms-up approach. This would involve judgment on a case-by-case basis in a budgetary context, supported by Australia’s existing institutional processes and structures. While this process usually works adequately, it needs to be informed by high quality evaluations as well as other detailed evidence. Current practices are poor in some evaluation areas.

Several participants considered that the balance of public support had shifted inappropriately towards applied R&D and commercialisation at the expense of basic and strategic R&D. While there is no absolute standard against which to judge the appropriateness of this shifting balance, when assessed against the rationales for public support for R&D, there are dangers if the trend goes too far.

Australia’s State and Territory Governments are increasingly active in the provision of public support for R&D. At the intergovernmental level, federalism risks program proliferation, poor coordination and overlaps, but also creates some unique experiments in new program design.

Findings

A guide to the Commission's findings



Rationales

FINDING 3.1

The need for government to fund research to discharge its own functions and the existence of benefits from innovative activity that cannot be captured by the innovator provide strong rationales for the provision of public funding support for science and innovation. But some commonly given reasons are not soundly based.

Impacts

FINDING 4.1

Taking account of multiple sources of evidence, there are likely to be significant aggregate economic, social and environmental benefits from publicly supported science and innovation, but quantitative estimates are unreliable.

Impediments

FINDING 5.1

Several key impediments to the functioning of the innovation system should be addressed:

- *major publicly-funded research infrastructure should be priced to maximise efficient utilisation and to avoid congestion;*
- *there should be national consistency in the application of privacy regulation and in ethical review of multi-centre research; and*
- *published papers and data from ARC and NHMRC-funded projects should be made progressively, yet expeditiously, freely and publicly available.*

FINDING 6.1

Greater flexibility in pay and related reward structures for teachers would help to address the ongoing shortage of high quality science and mathematics teachers.

FINDING 6.2

Changes in the broader science and innovation policy environment could have a positive effect on researchers' working conditions and job satisfaction, but the details of working arrangements at individual workplaces are best left to negotiation and agreement between individual employers and their workforces.

FINDING 7.1

The policy framework for universities should be focused on maximising the social return from public investment in R&D through the transfer, diffusion and utilisation of knowledge and technology. The pursuit of financial returns from the sale or licensing of intellectual property, and the creation of university spin-off companies, *while important pathways in their own right, should not be to the detriment of this overarching objective.*

Benchmarking and evaluation

FINDING 8.1

Performance evaluation and reporting arrangements have developed significantly in recent years, particularly through the adoption of an outputs/outcomes focus. There are, however, examples of deficiencies. Arrangements should be reviewed against the following criteria.

- *Outputs and intended outcomes should be defined in relation to the rationales for public support and to the community benefits expected from that support.*
- *Evaluation should be developed in a cost–benefit framework, balancing greater precision against administrative and compliance costs.*
- *Where undertaken, selective case studies of impacts should be placed in a supplementary rather than central evaluation role.*
- *Assessment should be undertaken with adequate frequency — this might vary between different types of measure.*
- *Assessment should be as independent and transparent as reasonably possible.*
- *Feedback mechanisms should be implemented to ensure that performance evaluation findings are drawn on to enhance the future benefits of public support for science and innovation.*

Funding and coordination

FINDING 9.1

Any science and innovation spending targets for Australia should be expressed in relation to Australia's aspirations and needs, rather than in relation to overseas levels or targets.

- *Even so, Australia's level of government financed R&D spending has remained consistently at, or above, the average for OECD countries over the past decade.*
- *When intercountry differences in industry structure and other factors are taken into account, Australia's business R&D expenditure is broadly in line with that of other OECD countries.*
- *Australia performs strongly relative to other developed countries across a wide range of economic, social and environmental indicators.*

FINDING 9.2

The available evidence suggests that the level of public support for science and innovation is neither notably inadequate nor excessive in terms of Australia's own science and innovation aspirations and needs.

- *There are, nevertheless, likely to be benefits from changing public support levels, up or down, in particular program areas. These are matters for judgment in a budgetary context, supported by Australia's existing institutional and regulatory processes and structures, and informed by the available evidence.*

FINDING 9.3

There are risks associated with the continuing diversion of public funding to applied science and innovation activity at the expense of basic and strategic science and innovation.

Business programs

FINDING 10.2

The extent to which the basic R&D tax concession stimulates additional R&D is low, particularly for large firms.

FINDING 10.5

Access to the 125 per cent R&D tax concession should be restricted to small firms.

FINDING 10.6

The 175 per cent premium R&D tax concession should be maintained for both small and large firms.

FINDING 10.7

The base on which the incremental subsidy is paid should be changed to a firm's ratio of R&D-to-sales at a given, fixed date.

FINDING 10.8

Access to the incremental scheme by start-up firms could be improved by assigning an appropriate benchmark value against which to compare current R&D-to-sales ratios.

FINDING 10.3

The beneficial ownership requirement for subsidiaries of foreign-owned firms should be relaxed for the incremental scheme alone.

FINDING 10.1

The definition of R&D contained in section 73B of the ITAA 1936 should be reviewed and, if practicable, amended to focus on activity that is more likely to involve high levels of spillovers. That definition alone should be uniformly applied to meet all corporate reporting requirements to reduce the complexity associated with current arrangements.

FINDING 10.4

The design of current expenditure and turnover limits for eligibility to the tax offset create perverse incentives against undertaking R&D above a certain amount. The design of the threshold arrangements should be amended.

FINDING 10.9

There is robust evidence indicating that the Commercial Ready program supports too many projects that would have proceeded without public funding assistance.

FINDING 10.11

The introduction of a repayment mechanism in the Commercial Ready program offers scope to improve the inducement rate associated with the program.

FINDING 10.10

Governance arrangements relating to business programs need to change. Options include:

- *shifting responsibility for commissioning program evaluations to an independent third party or establishing an inter-departmental working group to oversight such evaluations; and*
- *requiring full public disclosure of the results and recommendations and a timely response on the action to be taken.*

FINDING 10.12

A detailed comparative assessment of the design features of successful grant programs in other countries should be undertaken.

FINDING 10.13

There are strong grounds for significant public co-funding of RRDCs that provide spillover benefits beyond industry members where that research would not proceed in the absence of support. But the present substantial co-funding of some industry-centred RRDCs should be scaled back. The extent to which public funding is reduced should be determined by an independent assessment of the induced spillovers associated with that support. The intention to make changes should be announced well in advance.

FINDING 10.14

The CRC program could be improved in two ways:

- *the original objectives of the program — the translation of research outputs into economic, social and environmental benefits — should be reinstated. This is likely to produce greater community benefits than focusing public support on the commercialisation of industrial research; and*

- *the share of public funding should be aligned to the level of induced social benefits provided by each CRC, thereby reducing some of the large rates of subsidy to business collaborators.*

FINDING 10.15

A complement to the CRC program with broader collaboration goals should be introduced that supports smaller, shorter and more flexible arrangements between groups of firms either independently or in conjunction with universities and public sector research agencies. As a pilot for further evaluation, this should be achieved through an enhancement of the ARC Linkage program.

Public sector research agencies

FINDING 11.1

The current real level of public appropriation funding for CSIRO should not be reduced. Aspects of its approach to priority setting and performance management may have wider applicability to other parts of Australia's innovation system.

FINDING 11.2

The effectiveness of DSTO research is dependent on the appropriateness of the procurement practices and the research directions set in consultation with the Australian Defence Organisation.

Higher education

FINDING 12.1

Reductions in block funding levels would further limit the flexibility and discretion of higher education institutions to make meaningful strategic choices. Consequently, Australian Government block funding should not be reduced, either in absolute terms, or in relation to Australian Government competitive funding.

FINDING 12.2

The costs of implementing the RQF may well exceed the benefits. The following steps would help to increase benefits relative to costs.

- *The continuing detailed development of the 2008 RQF round should aim to minimise administrative, compliance and incentive costs wherever possible.*
- *The provisions of the 2008 RQF round should allow scope for significant change in funding outcomes compared with the existing block funding formulae. Accordingly:*
  - *safety nets should be minimal; and*
  - *scales should be set so that there are significant penalties for achieving low quality and impact grades — a linear funding scale could be counterproductive.*

- *The first round RQF evaluation proposed for 2009 should not just focus on fine tuning, but should consider the merits of other, possibly less costly, ways of promoting quality and impact in higher education research.*
  - *These would include auditing approaches that uncover those areas with the highest risk of poor performance.*
- *If the RQF continues beyond 2008, then consideration should be given to bringing forward the 2014 round and/or conducting a partial round in the intervening period — this would provide an earlier basis for assessment of the effects of the RQF in promoting quality and impact improvement.*

1 Introduction

Key points

- This study has three major aims:
  - to assess the impacts of public support for science and innovation;
  - to identify any major impediments that affect the operation of the innovation system and the scope for mitigating such impediments; and
  - to evaluate frameworks for assessing where and how public funding should be allocated, including any scope for improvements.
- The Commission's definition of innovation is a broad one and entails deliberative processes by firms, governments and others to add value to the economy or society by improving products, services, processes or organisational forms. Catch-up to global frontiers is included as innovation and is one of the most important drivers of economic growth.
- While there are strong private incentives for imitation and catch-up, these do not always apply to the generation of R&D. This is why, despite occupying a small part of the innovation terrain, policies relating to science and R&D justifiably occupy a large part of public innovation policy in general.

1.1 Why is this study timely?

Innovation is seen as crucial to future wealth and prosperity, and the capacity to tackle social and environmental challenges locally, nationally and globally. It is widely identified as increasing the adaptability of an economy to future global uncertainties. Australian governments play a major role in the innovation system, setting regulations, establishing institutions, shaping capabilities and through direct support. They provide significant support to science and innovation, mainly through financing R&D. Public support from all Australian governments accounted for over $6 billion of the nearly $16 billion of R&D undertaken nationally in 2004-05.[1]

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[1] Funding by governments is derived as the sum of the ABS estimates for State/Territory Governments and the Australian Government's (2006d) estimates of budget expenditures on science and innovation. The latter is used instead of ABS figures for the Australian Government, due to various omissions and inclusions in the ABS data for this level of government (chapter 2 and box 2.1). See box 1.3 for some of the definitional issues surrounding R&D.

Given the scale of government involvement in the provision of R&D, there are many questions about the future role of public support for science and innovation, the most important being how well past arrangements have worked and the manner in which the innovation system has functioned. What are the benefits of public support? Are the linkages between the supported parts of the system and innovation functioning well? How can governments' administrative and legislative arrangements for the supported parts of the system make their biggest contribution? Should there be a different orientation? Should the level of public support be raised, lowered or remain where it is?

This study — commissioned by the Australian Government in March 2006 — seeks to answer these questions. As specified by the terms of reference (reproduced at the front of the report), this study considers three major issues:

- *Economic, social and the environmental impacts.* To what extent does government support for science and innovation achieve something useful for Australians? The Commission interprets impacts widely (such as tangible new services, processes and products, reduced costs, 'feel good' factors, environmental benefits, reduced disease burdens and future risk reduction). However, as specified by the terms of reference, in considering economic impacts, particular emphasis is placed on the effects on Australia's recent productivity performance. The study also assesses whether there are adequate arrangements to measure outcomes from publicly supported science and innovation for performance management purposes.
- *Impediments.* The study aims to identify impediments to the effective functioning of Australia's innovation system, including whether there are impediments to knowledge transfer, technology acquisition and transfer, skills development, commercialisation, collaboration between research organisations and industry, or in the creation and use of intellectual property. It also aims to identify any scope for improvements.
- *Design of the system*. The study evaluates the decision-making principles and program-design elements that firstly, affect the performance of the innovation system as a whole and that secondly, guide funding allocation between its parts. Possible improvements to the system and the implications of changing the level of support or its mix are considered.

A companion to this study, released by the Commission in April 2006, assessed the impacts of business R&D on Australia's productivity performance over the last three decades (Shanks and Zheng 2006). That study is used as an input into chapter 4 of this report. This stream of work continues a sustained examination of innovation by the Productivity Commission (box 1.1).

Box 1.1 Past Commission research on science and innovation

The Commission (or its institutional antecedents) has undertaken many studies/inquiries that directly examine the innovation system or its impacts. In the last decade these include the inquiry into R&D (IC 1995); the consideration of R&D programs in the ICT (IC 1998) and telecommunications industries (IC 1998); the role of training and innovation in workplace performance (Laplagne and Bensted 1999); the evaluation of the Pharmaceutical Industry Investment Program (PC 2003a); and the companion study to this report by Shanks and Zheng (2006).

If a broader view of innovation is taken, the Commission has also undertaken studies that have considered the impacts of the *adoption* of innovation and technological change. Among these are studies into the role of information technology changes in productivity growth (PC 2004; Gretton et al. 2002, 2003; Parham 2002a, b; Parham et al. 2001), medical technology (PC 2005) and the links between technology change and skilled employment (Laplagne et al. 2001). The Commission has also considered parts of the innovation system that are critical to its effective functioning, such as the patent system (Gruen et al. 1996), the wider intellectual property rights system (Revesz 1999); and university resourcing (PC 2002c).

1.2 What we are *not* doing

It is important to indicate the limits to this study's ambitions. The Commission was not requested to systematically review all individual programs. It has therefore adopted a strategic approach, identifying particularly important programs or funding areas as case studies and investigating the grounds for their reform.

The second limit revolves around the choices for detailed analysis. Some limits to the scope of the study are provided by the definitions employed (section 1.3). Even then, science and innovation is a vast area. In the Commission's 1995 inquiry into R&D, Dr John Stocker, the then chief executive officer of CSIRO, commented that in just a few months CSIRO had participated in 66 different reviews (IC 1995, p. 46). More reviews of the system and many statistical and analytical reports have been conducted since (box 1.2). Many of these reviews and reports provide useful information about the performance and nature of the innovation system. On the basis of this developed field, the Commission has made strategic choices about areas of emphasis, and in particular, has decided to undertake less study of areas where quality expert analysis has already taken place. For example, this report does not duplicate the detailed descriptive picture of the system that is annually completed by DEST (in its *At a Glance* and *Snapshot* series), though it draws on this information for different types of analysis.

Box 1.2 **Recent government reviews and reports on science and innovation**

Department of Education, Science and Training (DEST) 2005b, *Australian Science and Technology at a Glance* and 2005a, *Australian Science and Innovation System — A Statistical Snapshot*. These draw on ABS, budget information and OECD data to provide an insight into the trends, structure and performance of Australian science and innovation.

Fell, C. (Chair, External Reference Group) (DEST 2004c), *Evaluation of Knowledge and Innovation Reforms*. The evaluation was asked to provide an assessment of the arrangements by which the Australian Government distributed block research funding to Australia's universities via the Research Training Scheme, the Institutional Grants Scheme and the Research Infrastructure Block Grants Scheme.

Sargent, M. (Chair, National Research Infrastructure Taskforce) (DEST 2004e), *The Final report of the National Research Infrastructure Taskforce*, DEST considered the important elements of an Australian research infrastructure strategy.

McGauchie, D. (Chair) (DEST 2004f), *Review of Closer Collaboration Between Universities and Major Publicly Funded Agencies*, DEST.

Grant, J. (Chair) 2004, *Sustaining the Virtuous Cycle For a Healthy, Competitive Australia: Investment Review of Health And Medical Research, Final report*, (Grant Report), December, Commonwealth of Australia, Canberra. This assessed impacts of additional investment made in health and medical research following the Wills Review (1998) and the organisational fitness of the National Health and Medical Research Council (NHMRC).

Science and Innovation Mapping Taskforce (DEST, DITR, DCITA) (DEST 2003c), *Mapping Australian Science and Innovation*, McMillen, Canberra. This stock take of Australia's science and innovation system, identified strengths, weaknesses and opportunities.

Batterham, R. (Chief Scientist) 2002*, Review of the External Earnings Targets Policy Applying to CSIRO, ANSTO and AIMS*.

Having examined past research, the Commission has chosen to focus on the three key analytical issues of interest, building on and sythensising previous Australian studies, but with the following differences.

- The aim is to consider a wider assessment of impacts, in contrast to past Australian studies, which have tended to concentrate on specific methods or on specific parts of the system.
- A greater variety of analytical methods will be applied than have normally been used in single Australian studies. For example, this study will include more sophisticated approaches to international comparisons, longitudinal approaches assessing whether commercialisation strategies have contributed to the growth of

firms, innovation measures, a meta study of case studies, measures of environmental impacts of science research, the use of panel data methods for considering the impacts of R&D on Australian productivity and bibliometric approaches that assess academic impacts between States and Territories.

- The final aim is to consider the governance and design aspects of the system more deeply than has usually been analysed previously in Australian assessments, one exception being the previous broad Industry Commission inquiry.

1.3 What is science and innovation?

The study of science and innovation is laden with old terminology put to new uses. This sometimes invites futile debates about which semantic boundaries are 'right'. For example, there are disputes about the difference between the 'information economy' and the 'knowledge economy'. But while it is often useful to distinguish knowledge from information, it appears that, in *this* context, nothing is particularly lost in using one over the other. A pragmatic approach is adopted in this study. Definitions that best convey an understanding of the underlying concepts and relations have been chosen.

The definitions of science and R&D are considered first below. Although science and R&D are important, they are ultimately best understood in their role as inputs into the innovation process. Then the central concept of this report, innovation is examined, and the innovation system in which it takes place.

Science

Science is the methodical, replicable, accumulation of knowledge and perspective about the nature of 'things' (the natural world, social systems, the economy), based on conjectures that can be subjected to empirical tests. Another approach is to define science as what scientists do, which is useful when counting the resources devoted to science in universities or public agencies. These are not precise definitions. Mathematics is not an empirical subject, yet would usually be included as a science because of its requirements for internal coherence and the usual capacity for demonstration of the validity of its conjectures through proofs. In any case, it is one of the fundamental tools of science.

The study clearly covers the physical, biological and mathematical sciences, including engineering. The humanities and social sciences are also included in the scope of this study as they are increasingly seen as part of the sciences, such as by the European Science Foundation. This was a point emphasised by the Australian Academy of the Humanities (sub. 64), CHASS (sub. DR171) and the NTEU (sub. DR128). (In this, the Commission has widened its definition since the draft report). These disciplines share the evidence-based approaches of other sciences. They may have their own direct beneficial impacts, as in applications in public health, or they may add value by increasing the productive use of the physical sciences within the innovation system (University of New England sub. 17, p. 7).

Further, in this study, science education and teaching are included to the extent that they affect skills development and may promote, or present obstacles to, the effective functioning of the innovation system. Similarly, scientific and technological services are generally excluded, except where deficiencies in these affect the innovation system.

Gans (sub. 10, pp. 5–6) proposes an alternative definition of science as a:

> … particular way of allocating resources, that is, an institution. … science is a way of deciding which projects should be undertaken. First, it is scientist driven in that scientists propose the projects and scientists review them. Second, it has a priority-based reward system whereby there is a commitment to give a reward to those scientists who are first to establish a new fact or way of understanding the world ... those rewards are paid upon success through citation and academic promotion and notoriety.

Gans' definition valuably describes some of the common features of basic science as an institution for allocating resources within universities and it is a useful framework for discussing some of the processes used by government in the design of the system. However, it is incomplete as a description of science as an institution outside universities and basic research.

While science is sometimes supported for its own sake (chapter 3), the predominant interest in science in this report centres on its role *within the innovation system* (see below) — the mechanisms that determine choices about how much to do, in which institutions, for what innovative purposes, its impacts on innovation and impediments to its useful diffusion and adoption.

Research and development

The conventional definition of R&D is:

> … creative work undertaken on a systematic basis to increase the stock of knowledge including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. Any activity classified as research and experimental development is characterised by **originality**, should have **investigation** as a primary objective and should have the potential to produce results that are sufficiently

> **general** for humanity's stock of knowledge (theoretical and/or practical) to be recognisably increased. (DEST 2005c, p. 9)

R&D is a major part of the innovation system[2] — accounting for a major share of the activity of government research institutions and approximately one third of Australian business expenditure on innovation. It can take various forms, at the broadest level being categorised as 'basic', 'applied' or 'experimental' (box 1.3). Even though much basic research is not directed at developing new or improved products or services (in the short term), it often plays the most crucial role in supporting successful innovation over the medium to longer term — thus, all forms of R&D associated with science and innovation are relevant to this study.

R&D should not just be judged on its immediate promise of improvements in products, services or processes, but also on its ability to provide the capacity for better decision making in the future. For example, the Defence Science and Technology Organisation's (DSTO's) capabilities are intended to assist in making more informed future procurement decisions.

Innovation

In this study, innovation is defined as deliberative processes by firms, governments and others that add value to the economy or society by generating or recognising potentially beneficial knowledge and using such knowledge to improve products, services, processes or organisational forms.[3] From the perspective of this study, these improvements may be specific to the entity, to the industry, country or world, and could be incremental or novel.

Innovation can be distinguished from knowledge generation per se, since to comprise innovation, any knowledge must be productively incorporated into an entity's activities and outcomes, often using core resources and decision making processes (Rogers 1998).

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[2] Whether R&D is included as innovation per se depends on how broad a definition of innovation is used. Most business R&D has the purpose of improving business performance and so, in an ex ante sense, should be included as part of innovation. Pure basic research has no specific application in mind, and is often not regarded as an innovation in itself, though it may support subsequent innovation. But either way, R&D has an important function within the innovation system, and debates about where precise boundaries may lie are probably not very useful.

[3] This process should not be misunderstood as a linear one of having an idea for innovation and then implementing it sequentially (though this is still important in firms), but rather the process of always being alert for opportunities, and then using them when they are identified.

Box 1.3 **Definitions of R&D**

The common understanding

In common parlance and within a commercial context, R&D is undertaken with the aspiration that it will, at some point, be used to develop new (typically commercial) applications, even when no specific application is apparent during the research phase. In other words, the *goal* of development is an important aspect of the categorisation of an activity as R&D. This distinguishes R&D from research, and indeed many university scholars would use the term research for their activities, but not R&D. This does not mean that research cannot be useful; in fact it often is. But research need not be undertaken in a context that has useful applications in mind, whereas this is a necessary feature of R&D as commonly understood by its actors.

The statistical and policy conventions

In policy documents and statistics on R&D a wider definition is adopted, in which research without development is termed part of R&D. Accordingly, in ABS, DEST and OECD statistics (and analysis of) R&D, ancient history is defined as R&D because it involves research. The difference between this convention and the more commonly understood meaning should be noted.

In this report, most statistics relate to the second definition because it is the basis on which data are gathered and that inform policy discussions. However, wherever possible, the Commission attempts to break down the data and analysis into types that have connections with the commonly understood use of the term. This is possible because three types of R&D are recognised that allow these distinctions to be drawn.

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. (Sometimes basic research is divided into **pure basic research** and **strategic basic research**, with the latter directed at acquiring knowledge towards specified broad areas in the expectation of useful discoveries.) As shown in chapter 2, most basic research is undertaken within universities, though they also undertake other forms of R&D.

Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.

Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. R&D covers both formal R&D in R&D units and informal or occasional R&D in other units.

Source: Commission analysis and material adapted from OECD 2002, *Frascati Manual*, Proposed standard practice for surveys on research and experimental development, p. 30.

Innovation is not just technological in nature. Entities can be highly innovative but undertake little or no R&D. A recent study of Australian business innovation (broadly defined) found that R&D was a very poor predictor of innovation (Jensen and Webster 2004). Less than 3 per cent of the variation in innovative behaviour between firms was explained by variation in their R&D expenditure.

The Commission's approach shares many common features with that used by the Australian Bureau of Statistics in its definition and measurement of innovation, though the most distinctive difference is the Commission's inclusion of non-businesses and gradual catch-up to global technological frontiers (box 1.4).

Box 1.4 **How does the ABS define (and measure) innovation?**

The ABS defines (business) innovation as the process of introducing new or significantly improved goods or services and/or implementing new or significantly improved processes. New goods or services or new processes may involve the development of new technology, an adaptation of existing technology to a new use (for example, electronic commerce), or may be non-technological in nature (for example, organisational and managerial change, some changes in marketing). Innovation has been classified into three categories. A new good or service means any good or service (or combination of these) that is new to a business. Its characteristics or intended uses differ significantly from those previously produced. A new operational process is a significant change for a business in its methods of producing or delivering goods or services. A new organisational/managerial process is a significant change to the strategies, structures or routines of the business that aim to improve performance.

While the Commission's approach is similar, it differs in three respects.

- Governments, communities and their agencies are included, as well as businesses.
- Gradual catch-up to technological frontiers is included. In contrast, the ABS approach would exclude many incremental changes to products, services or organisations, that when cumulated, represent major changes over a longer period of time (for example, the gradual diffusion of some information technologies throughout firms and governments).
- It also incorporates preparedness — an enhanced capacity for dealing with future uncertainties. For example, a water utility may have undertaken research that, while not resulting in any changed practices now, may nevertheless be seen as having a significant option value because it reduces future risks.

That said, the choices made by the ABS are pragmatic for the purpose of *measuring* business innovation through survey methods. If all the factors encompassed by the Commission's definition were counted as innovation, every organisation would be recorded as innovating. This would render meaningless simple counts of the frequency of innovating versus non-innovating firms and invalidate international comparisons of business innovation.

Source: ABS (2006a).

The Commission's definition is also generally commensurate with the broad approach of Schumpeter (1934) and modern adherents, such as Baumol (2002, p. 10)[4], Fagerberg (2003), Lundvall (2000, p. 8) and, in an Australian context, the

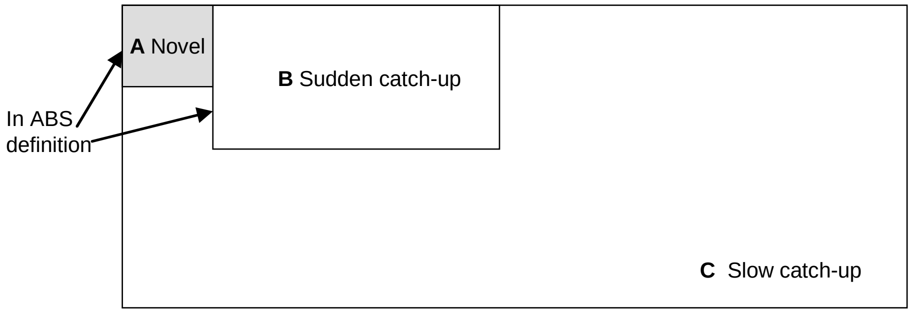
4 Baumol defines innovation as the 'recognition of opportunities for profitable change and the pursuit of those opportunities all the way through to their adoption in practice; in particular, as the activity of recognising economically viable inventions and doing whatever is necessary to bring them to market or to ensure their effective end use by some other means.' Baumol's

BCA (2006, p. 2).[5] The broad approach has slowly gained ascendancy as the more appropriate conceptualisation of innovation because it more satisfactorily explains economic growth and the dynamism of the service sector than historical approaches centred on major technological innovations in manufacturing.

Innovation is multi-dimensional

Innovation has many dimensions. It can be categorised by actor, location, knowledge source and by type. In this study it is important to distinguish three different types of innovation (figure 1.1).

Figure 1.1 **Novel innovation is a small corner in a big room**



First, there are novel innovations, which are innovations that occur across products, processes and organisational forms at the global technical frontier (partition A). These comprise a small share of actual innovation in Australia (figure 1.2), even using the narrower ABS definition (box 1.4). This form of innovation is dynamically critical to economic growth and to social and environmental advances, since catch-up is premised on the existence of the original breakthroughs and revolutionary applications. In an Australian context, while it comprises the non-dominant form of innovation, novel innovation has played a particularly important role in industries close to Australia's natural endowments, such as agriculture and mining.

Second, there is sudden catch-up, which represent significant improvements in products, processes and organisational forms, but that do not occur at the global technical frontier (partition B).

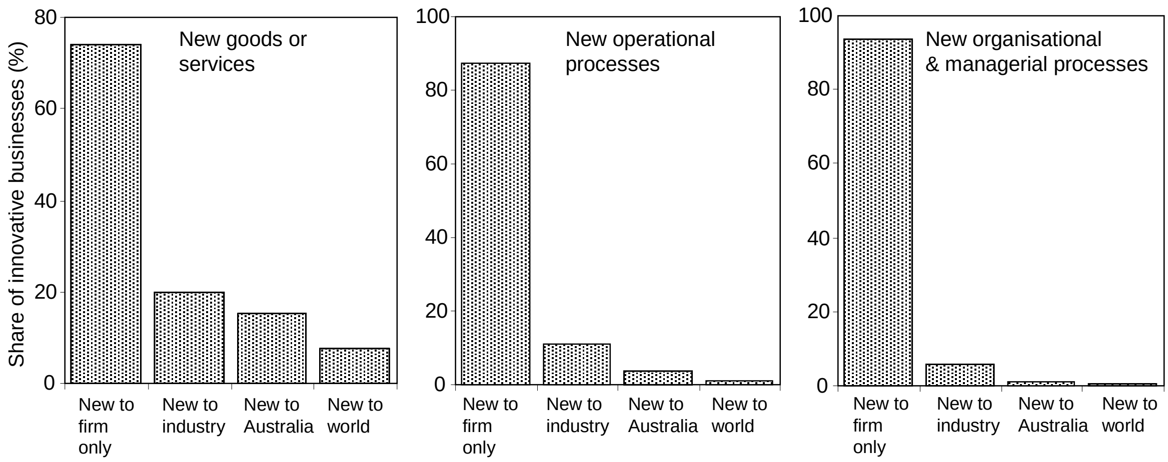
definition valuably indicates that innovation is a *process* that includes recognition of opportunities and which is purposeful, not just the culmination of an effective end-use. However, his definition excludes imitation, which he categorises as another (though often complementary) strategy (pp. 208ff). This is the most distinctive difference from the definition adopted by the Commission.

5 The BCA describes it as 'the application of knowledge to create additional value and wealth' through improved goods, services, processes, management and organisations.

Finally, in the Commission's schema, there is slow catch-up, which represents changes that occur gradually on the path to the global technical frontier (partition C). Undoubtedly, a large part of the economic growth of every country reflects the steady application and adaptation by firms of knowledge and innovations that are quite dated from an international perspective, but are new to their own productive practices. To look only at novel or even rapidly diffused new knowledge (partitions A and B respectively in figure 1.1) is to miss out on an extremely important source of economic growth (partition C).

Figure 1.2 **Many innovations are not very novel**

Australia, innovations introduced by innovation type, 2004 and 2005



a The shares exclude non-innovating businesses and relate to the proportion of innovating business in each category.

Data source: ABS 2006, *Innovation in Australian Business, 2005*, Cat. No. 8158.0, December.

Some commentators argue that major inventions with a high degree of novelty are the most beneficial form of innovation, but this confuses the issue when catch-up (both rapid and slow) is the way in which new innovations are diffused in practice. Catch-up is dependent on innovations at the frontier. The importance of catch-up innovation (B and C) is especially significant in small open economies that undertake, from a global perspective, only a very small share of innovation at the frontier.

Implications of a wide definition

The Commission's wide definition focuses policy on broader impediments frustrating the performance of the innovation system. It is usual to accentuate impediments such as access to finance by firms to commercialise highly novel technologies, the design of licensing arrangements, the problems of non-appropriable spillovers for innovators and adequate protection of intellectual property. These mostly relate to the small part of innovation represented by partition A in figure 1.1.

If the broader view of innovation is adopted, additional relevant factors that may impede innovation become apparent. They can comprise: general skill levels; competitive pressures that affect the motivations for firms and their staff to improve continuously; deficits in intermediaries that provide technical advice; and the impacts of taxes and regulations that may frustrate adoption (for example, workplace demarcation rules or inappropriate standards). The BCA (2006, pp. 40–50) has highlighted these policy-related impediments in its recent report on innovation, rather than those factors usually identified in studies that focus on novel, technological innovation.

The broader view also explains some of the links that might exist between economywide productivity growth and public support for science and innovation. Catch-up in firms and in other parts of society may, for example, rely on the human capital and capabilities of the more narrowly conceived science and innovation system. So increases in A may not just increase B and C by shifting outwards the frontier for which catch-up is a target, but increase the capacity for catch-up as well.

While it is important that government establish appropriate macro and micro conditions for innovation to flourish, most forms of innovation, at least within businesses, do not need *direct* public support. This is because there are strong incentives for rivalrous firms to routinely innovate. Baumol (2002) has persuasively outlined the autonomous mechanism for innovation within businesses:

> Under capitalism, innovative activity — which in other types of economy is fortuitous and optional — becomes mandatory, a life-and-death matter for the firm. And the spread of new technology, which in other economies has proceeded at a stately pace, often requiring decades or even centuries, under capitalism is speeded up remarkably, because, quite simply, time is money. (p. 1)

However, this general principle is not necessarily true for innovations based on certain kinds of R&D nor on its closely complementary activities (an issue explored closely in chapter 3).

In this study, the Commission has been asked to examine the parts of the system that receive public funding support. These primarily comprise the most narrow aspect of innovation — partition A, of figure 1.1 — and indeed, mainly just one fragment of this, innovation resulting from public support for technological R&D.

This is why, despite occupying a small part of the innovation terrain, policies relating to science and R&D occupy a large part of public innovation policy in general.

But while this study focuses on partition A, it is important to remember that the wider impacts of innovation, and the policy issues surrounding these, are complementary factors in economic growth. The implications of the links and contrasts between both ends of the innovation continuum are drawn out at various points in this study. They are particularly relevant in interpreting how public support for science and innovation might have economic and social impacts and in identifying impediments to the operation of the innovation system.

Non-business innovation also matters

While the measurement of innovation has been most developed in a business context, this study includes non-business innovation (box 1.5) because it is an important target of public support for the science and innovation system.

- Considerable publicly-funded social and economic research is undertaken by universities, which is then used by government agencies to improve the delivery or design of their services. Governments have explicitly recognised their role as innovators in various innovation and economic policy statements (for example, Queensland Government, 2006) and that influences their demands on the knowledge generating capabilities within the publicly-funded system.
- The DSTO provides research services directly to the Australian Defence Organisation for use in its decision making.
- Research on the environment by universities and the CSIRO has been important in tackling various environmental issues. Regulations can sometimes also be seen as innovative responses to new knowledge generated in this way.
- Health research, while also raising significant opportunities for innovation within firms, has also been directly diffused through public agencies.
- Research within universities and the CSIRO has been used for community innovation.

The value of innovations undertaken by governments and communities are generally harder to measure than business innovations. But their exclusion from the definition of innovation would miss many of the important applications of knowledge generated in the publicly supported system and one of the major rationales for public funding support of science and innovation.

From whose perspective is improvement gauged?

The categorisation of innovation involves a normative assessment that the change is, or is even just likely to be, an improvement with that assessment conventionally based on whether the innovation serves the interest of the innovator or their immediate customers, rather than the world at large. However, sometimes innovations impose costs that are not borne by their users or progenitors.

Box 1.5 **Examples of non-business forms of innovation**

The Higher Education Contribution Scheme, used as a major source of financing of Australian university teaching, was devised by Bruce Chapman of the Australian National University (and member of the Wran Committee).

CSIRO has undertaken research into biodiversity, weed control, water management and soil degradation that has been widely diffused in farms and in the general environment. A specific example is the development of a successful biological control of Salvinia, which is an aquatic weed that chokes lakes and slow moving rivers. CSIRO found and released the Salvinia weevil, which eats the stem of the weed and its terminal buds. This brought the weed under control.

Australian diagnosis related groups (DRGs) and casemix funding provides an illustration of innovation that brought together overseas research, public authorities, clinicians and university researchers. DRGs are used to classify inpatient stays into clinically meaningful categories of similar levels of complexity that consume similar amounts of resources. DRGs were initially developed by Professor Robert Fetter of Yale University to assist with quality assurance programs, but were subsequently adopted in the US for hospital funding systems — the so-called 'casemix' funding model. Australia then adopted this model, but altered the DRGs to reflect Australian clinical practices. The Australian Commonwealth Department of Health and Ageing created its own DRG version, in consultation with the Clinical Casemix Committee of Australia, clinical coding and classification groups, the National Centre for Classification in Health (based at the University of Sydney and the Queensland University of technology), State and Territory Health Authorities and other organisations (http://www.rch.org.au/casemix_rch/).

Sulphur dioxide emissions trading reflects both scientific knowledge about environmental damage developed in universities and other research agencies and economic knowledge about efficient abatement methods.

The first prospective evidence on the risks to sudden death of the prone positioning of infants was obtained by the Tasmanian Menzies Institute in 1991 using the Tasmanian infant cohort. The research led to a rapid public health policy response that cut sudden infant death syndrome (the most common postneonatal cause of death in Australia at the time) by around 80 per cent over the next 10 years (Van der Weyden 2003).

Research within universities and non-profit research agencies has played a major role in the evaluation and generation of policies in school education. For example, the Australian Council for Educational Research, a non-profit organisation, has (among other things) undertaken or coordinated detailed and influential research on school education based on a unique longitudinal data set — the Australian Longitudinal Study of Youth.

Plowman et al. (2003) from the University of Queensland undertook research that showed that differences in the attitudes to change and creativity between otherwise similar rural towns were fundamental in determining whether they declined or prospered. The Queensland Government is diffusing this research for community change through its *Engaging Ideas* initiative.

- Many innovations with large benefits for business productivity (and therefore consumers) have also imposed significant environmental costs. Fertilisers and pesticides, for instance, have had large impacts on agricultural productivity, but have also imposed collateral environmental costs through damage to water supplies and ecosystems. In these cases, the benefits have outweighed the costs, but the costs should not be neglected in analyses of the impacts of innovation. Many subsequent innovations provide benefits by abating the costs of historical innovations (as in greenhouse abatement technologies or pest-resistant crops that do not require pesticide use).
- A firm's organisational or operational innovation that decreased competition in an industry may benefit shareholders, but decrease overall public benefits. For example, it has been argued that various innovative patent strategies — such as patent blocking and patent thickets — have been used to reduce competition from rivals (Shapiro 2001). New standards, tying and bundling arrangements may sometimes also have these effects.[6]

This study adopts the conventional stance by defining innovations by their ex ante goals, but it avoids the sometimes associated non sequitor that particular innovations are consequently always good from a public benefit perspective. This is most relevant to case studies.

The science and innovation system

The notion of an innovation system is a very simple idea, though its simplicity is often concealed by unhelpful over-abstraction. The idea is that many things and actors contribute to innovation and that they affect each other (figure 1.3):

> Popular folklore notwithstanding, the innovation journey is a collective achievement that requires key roles from numerous entrepreneurs in both the public and private sectors (Van de Ven et al. 1999, p. 149).

So it is not usually the case that someone in a laboratory has an idea, which is developed, prototyped, and then commercialised in an orderly linear sequence. This is the appropriately rejected 'linear' model.[7]

The usefulness of looking at innovation as a system is that, firstly, it suggests that improved outcomes might occur through any of the factors that influence innovation

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[6] A recent Australian instance is the alliance between retailers and petrol stations, noted as a minor innovation by the Business Council of Australia (BCA 2006 p. 18). Views about the consumer benefits of these arrangements is contested (Gans and King 2004 cf ACCC 2004).

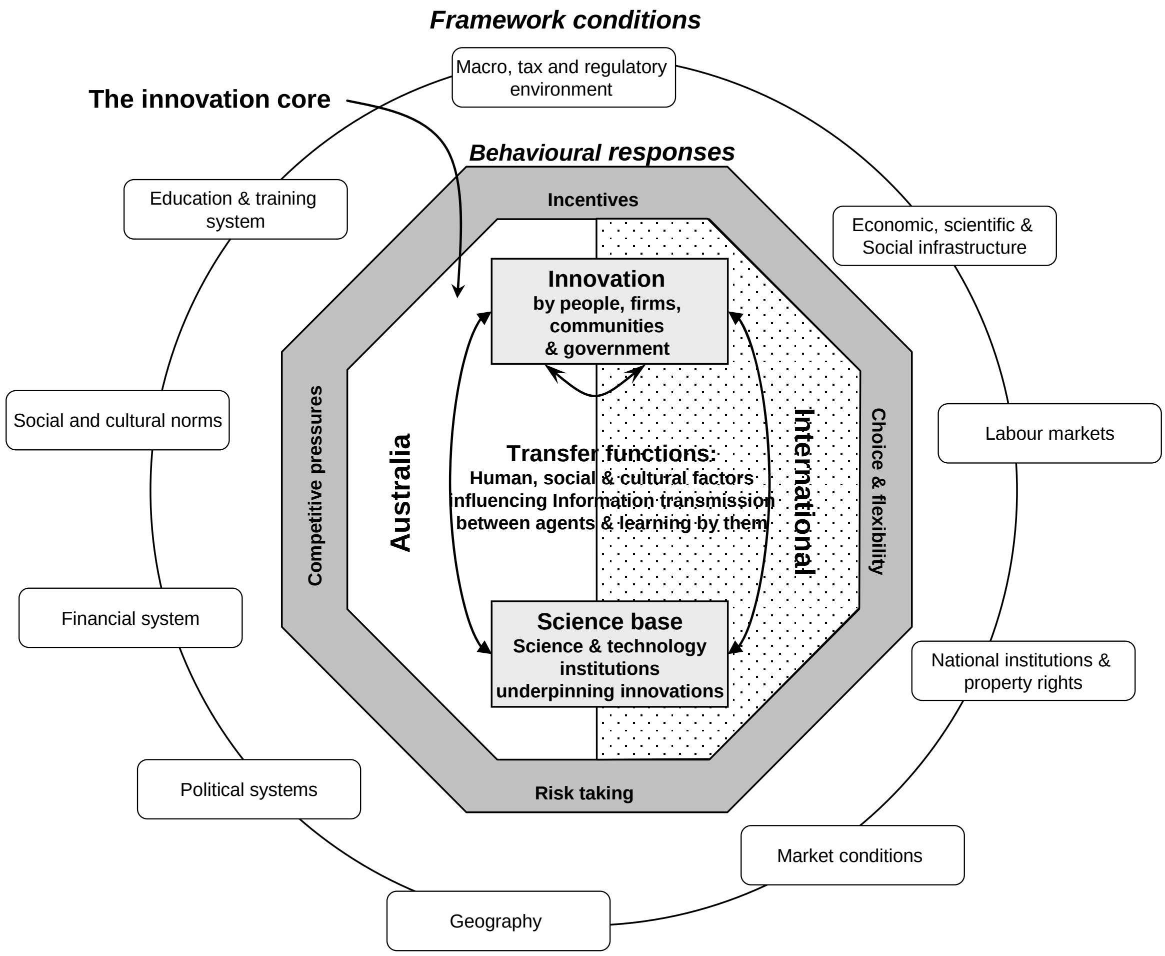
[7] Some participants in this study, however, said this does reasonably describe biotechnology innovation.

and that, secondly, it reinforces the point that innovation is much broader than just technological invention. The principal components of the system are:

- the relevant institutions that pursue innovation (for example, businesses, universities, government-funded science-based organisations and communities) or that organise it (for example, DITR, DEST, the ARC and the NHMRC);
- the embedded economic and social incentives that encourage or discourage innovation, such as systems of intellectual and other property rights, standards making, subsidies, social capital and cultural norms on the positive side, and various forms of taxation and inappropriate regulation that can slow the innovation process;
- the capacity for diffusion of knowledge and innovation, which can occur through:
  - individuals who take knowledge and skills from one enterprise or entity to another;
  - the existence of a diverse group of information intermediaries who can help firms and government agencies discover new product technologies or processes, or can assist them to adopt these when they have been discovered;
  - adopt appropriate technologies and management systems;
  - the development of technologies that facilitate diffusion (for example, libraries, databases and the availability of good telecommunications and internet services);
  - linkages between the parts of the system; and
  - an increasingly global dimension to the system, which is accentuated for a small open economy like Australia. The links between the international innovation system and Australia's were highlighted by DITR (sub. DR185, pp. 7, 20, 37, 40). It noted that multinational enterprises undertake at least two thirds of global business R&D and that much of this is internationally footloose. Almost all of the top 50 R&D conducting firms in Australia are multinational enterprises (domestically and foreign owned). Most of the world's science is conducted outside Australia. IP institutions are strongly influenced by global arrangements. Progressively more of the specialist human capital underlying complex scientific capabilities is globally mobile.
- a skilled and capable workforce (not just scientists), entrepreneurship and high-quality training and education;
- the stability and sophistication of the financial system; and
- the multiple feedbacks in the system that can enhance or frustrate the prospects for learning, diffusion, and innovation. These feedbacks imply, for example, that

customers can be the trigger for innovation, and play active parts in R&D and commercialisation, rather than just act as passive beneficiaries at the end. It means that not only does scientific knowledge generate technological developments, but that technological development can also generate new scientific knowledge. It also implies that research can occur throughout the process of commercialisation as new problems emerge and that this, in turn, can generate, surprising new commercial opportunities.

Figure 1.3 **The innovation system**



a There are many different and useful representations of the innovation system (such as DITR sub. 93, the 2nd Oslo manual and OECD 1999). While drawing from these, the representation shown here gives primacy to the framework conditions that set the range of opportunities for innovation, the behavioural responses (and feedbacks) these conditions elicit and the actors that respond to (and craft) them. Some depictions only see firms as innovators, but in the context of this study, all agents are regarded as potential innovators.

Source: Productivity Commission.

Faults in innovation systems — weak incentives, social and economic instability, bad infrastructure and inadequate human capital — reduce the capacity to develop and apply knowledge innovatively, and to close any gap with global best practice.

With this interpretation, the Australian innovation system has a prime influence on the nature, extent and impact of innovation undertaken in Australia, including the emulation and adoption of innovations and knowledge developed overseas.

Governments worldwide continuously try to improve framework conditions — infrastructure, effective regulation, taxation and skills — to get closer to world's best practice in business and government services. This is often labelled as micro economic reform, though it could equally be labelled as 'innovation reform' policy. DITR, for example, drew attention to the critical role of such framework conditions for effective innovation policy (sub. DR185, p. 17). This report acknowledges the central importance for innovation of government settings in these areas. The key issue in this report is to identify any missing elements of the current agendas for micro reform needed to make the innovation system function better.

In practice, much of what is termed 'innovation policy' around the world still focuses on the innovation core in figure 1.3 — R&D and its related concerns of an adequate science base (including science and engineering personnel), financing, diffusion, adoption, commercialisation and any direct impediments affecting the smooth functioning of these factors. As noted earlier, that is also the major orientation of the terms of reference given to the Commission.

1.4 Participation in the study

The Commission has consulted with a wide range of businesses, people, institutions and governments about the functioning of the science and innovation system (appendix A). Roundtables were held in November 2006. Submissions were sought from interested parties and 105 were received prior to the publication of the draft report and 107 prior to final publication.

1.5 Structure of the report

Chapters 2 provide a brief snapshot of the inputs into the system, while chapter 3 explores the appropriate (and inappropriate) rationales for public support. These condition the nature of impacts, the possible source of impediments and the design of public support arrangements.

Chapter 4 presents information on the impacts of Australia's science and innovation system, addressing the appropriate methodologies and findings. This report distinguishes standard economic impacts (on such factors as living standards, employment and productivity) from social and environmental impacts (such as poverty reduction and cleaner air).

Impediments to the efficient operation of the science and innovation system are considered in three chapters. Chapter 5 examines general impediments to the system, often of a regulatory nature. Chapter 6 considers the extent to which workforce issues may affect the performance of the innovation system. Chapter 7 then examines issues related to commercialisation, diffusion and utilisation of research.

The remaining chapters examine the main actors in the innovation system and the institutional, budgetary and legislative arrangements that affect their functioning. The study looks at performance management (chapter 8), how funding and coordination is determined in the system (chapter 9), the design and performance of the key business programs (chapter 10), the role of public sector research agencies (chapter 11) and the university sector (chapter 12).

Supporting material is provided in appendices.

2 A snapshot of Australia's science and innovation system

Key points

- Direct government support for science and innovation has been concentrated on research funding undertaken by universities, CSIRO and other public agencies, rather than in business.
- Where business support is provided by the Australian Government, it is overwhelmingly aimed at stimulating R&D, rather than commercialisation or diffusion of ideas.
- The Australian Government is the principal funder of basic research, to which it allocates around half of its direct funding support.
- The main areas to which the Australian Government directs its support are industrial production and technology, followed by human health, which has been assuming a greater importance. The relative importance of support for agricultural research has been falling.
- It is common to assert that the various research-performing institutions fulfil relatively rigid roles in the Australian system. This is true for some sectors. Business principally undertakes applied and experimental R&D; public sector research agencies tend to undertake strategic basic and applied research. But higher education institutions undertake a broad mix of research types and not primarily basic research, as often thought.
- International comparisons suggest Australia has about the average business innovation propensity, but a low relative BERD to GDP ratio and patenting rate. There are many reasons why such unadjusted comparisons should not be used as a basis for policy arguments for changes in public support.
  – For example, variations in business R&D intensities across countries only weakly explain variations in business sector innovation propensities.
- Australia has been converging to have a pattern of R&D more like that of the typical OECD country, with a greater weight towards business R&D.
- Among a wide group of innovation indicators, Australia has a relatively high international ranking in those factors that are most strongly associated with economic prosperity. However, countries can be equally prosperous with quite different settings in their innovation systems.

2.1 Introduction

A major goal of this study is to assess the outputs and impacts of public support for Australia's science and innovation system. A useful starting point is to identify the amount of public spending in the system and the types of activities that have been supported. This is the goal of this chapter. Given that some studies have already compiled comprehensive statistics on these features (as noted in chapter 1), the Commission has chosen to summarise the main features of the system and, sometimes, to provide new views of existing data. (The conventional statistical definitions defined in box 1.3 in chapter 1 are usually adopted as this is the basis on which the data are available.)

2.2 An overview of investment in knowledge capital

Given the broad (and elusive) nature of innovation, a comprehensive measure of investments across the economy is not available. However, some indicators are available, which collectively suggest that Australian society invests substantially in science and innovation.

- Gross domestic spending on R&D in 2004-05 for governments, businesses, the higher education sector and others was around $15.8 billion (in current prices) or about 1.76 per cent of GDP (ABS 2006c, pp. 3, 9). Real total spending was about 50 per cent more than 1996-97, which is about twice the growth rate of GDP. Expenditure growth has been strong in all R&D-performing sectors, except government, which has been virtually static in real terms. Australia's total R&D to GDP ratio has increased at a much faster pace than most other OECD countries in recent years (2000-01 to 2004-05).[1]
- Non-R&D innovation spending by business in 2004-05 (which does not include the significant investments in non-R&D innovation by governments) was around $22.5 billion or 2.5 per cent of GDP (ABS 2006d, p. 10).
- Australia's investment in 'knowledge' — a synthetic measure covering expenditure on R&D, investment in ICT and expenditure on tertiary education — equalled some 4.1 per cent of GDP in 2002 (OECD 2005b).

[1] Growth was 0.25 percentage points of GDP (ABS Cat. no. 8112.0 2006). Of the 30 OECD countries covered by the OECD's Science and Technology database, only Switzerland, Korea and Austria have experienced a bigger increase as a share of GDP. While not all countries have published data for 2004-05, on the basis of trends, no country other than these three appear likely to have outpaced Australia's growth over this period.

The emphasis of public funding support on R&D, rather than on support of other parts of the innovation system, reflects the view that this is where the risk of private underinvestment is highest. However, it also arises from a definitional issue. As is apparent from its science and innovation budget tables (appendix B), the scope of what is recognised by the Australian Government[2] as explicit support for innovation is relatively narrow. The government resources used to establish the legal and regulatory framework, the funding of education, and defence procurement have important influences on the innovation system, but they are not counted as innovation support, in part because they also serve other roles.

A chapter that gave a snapshot of all of the factors underpinning the innovation system in figure 1.3 would either be superficial or very long. For that reason, this chapter principally focuses on the factors, mainly R&D, explicitly recognised as receiving budgetary support by governments. However, it briefly considers some broad indicators of the relative performance of Australian innovation system in section 2.9. The most relevant facets of the innovation system are explored from a policy perspective in chapters 5 to 12 of the report.

Direct government funding support for science and innovation has been concentrated on research in universities, CSIRO and other public agencies, rather than on business R&D and other knowledge assets (appendix B). Where business support is provided by the Australian Government, it is overwhelmingly aimed at stimulating R&D, rather than commercialisation or diffusion of ideas (table 2.1). Government exercises two roles in the direct funding support of science and innovation: it undertakes R&D (GOVERD) and it is a major funder.

2.3 Government undertakes R&D

The Australian Government is a major R&D performer through Australian government agencies (such as the CSIRO, ANSTO and the DSTO), with R&D expenditure by federal research agencies of about $1.6 billion in 2004-05 (ABS 2006c, p. 11).[3] State and Territory government research agencies like the Queensland Department of Primary Industry and Fisheries also undertake

[2] The Commission has followed the recent convention of using the term the ‘Australian Government’ to denote the Commonwealth or Federal Government. The term ‘Australian governments’ will be used to denote the Australian and State and Territory governments.

[3] While more recent data on R&D *performance* of Australian Government agencies are not available, there is information on R&D *funding* by the Australian Government for *major* Federal research agencies. In 2005-06, the estimated actual funding of these by the Australian Government was $1343 million, up in current prices from $1304.6 million in 2004-05 for the same group of agencies, but effectively constant in real terms (Australian Government 2006d).

significant R&D, with collective spending of around $980 million in 2004-05 (ABS 2006c, p. 11). The overall importance of State and Territory government research agencies as R&D performers has increased over the long run compared with Australian Government research agencies (DEST 2005a, p. 51).

Table 2.1 **The focus of the Australian Government's public support for business innovation is on R&D, rather than business diffusion or commercialisation**

2004-05 to 2006-07[a]

Type of measure	*2004-05*	*2005-06*	*2006-07*
Support value	$m	$m	$m
Support for industry performed R&D[b]	887.6	1001.7	1140.7
Business commercialisation and diffusion programs[c]	98.6	105.1	160.0
Other industry-centred R&D programs not typically undertaken in industry	1 123.3	1 183.4	1 187.3
Non-industry centred R&D	3 328.9	3 661.2	3 486.0
Total	5 438.4	5 951.4	5 974.0
Shares of total support	%	%	%
Support for industry performed R&D[b]	16.3	16.8	19.1
Business commercialisation and diffusion programs[c]	1.8	1.8	2.7
Other industry-centred R&D programs not typically undertaken in industry	20.7	19.9	19.9
Non-industry centred R&D	61.2	61.5	58.4
Total	100.0	100.0	100.0

[a] The table is based on allocating each Australian Government innovation program to the four categories. Some programs span more than one category. In these cases, judgment has been used to allocate them to a specific group. [b] The Commercial Ready program is included as support for industry-performed R&D as it principally acts as a support mechanism for R&D for commercially promising products in small and medium enterprises. However, it also provides some finance for commercialisation of already developed ideas. [c] Included are measures used to diffuse technologies, best practice or information to business, as well as financing measures for commercialisation.

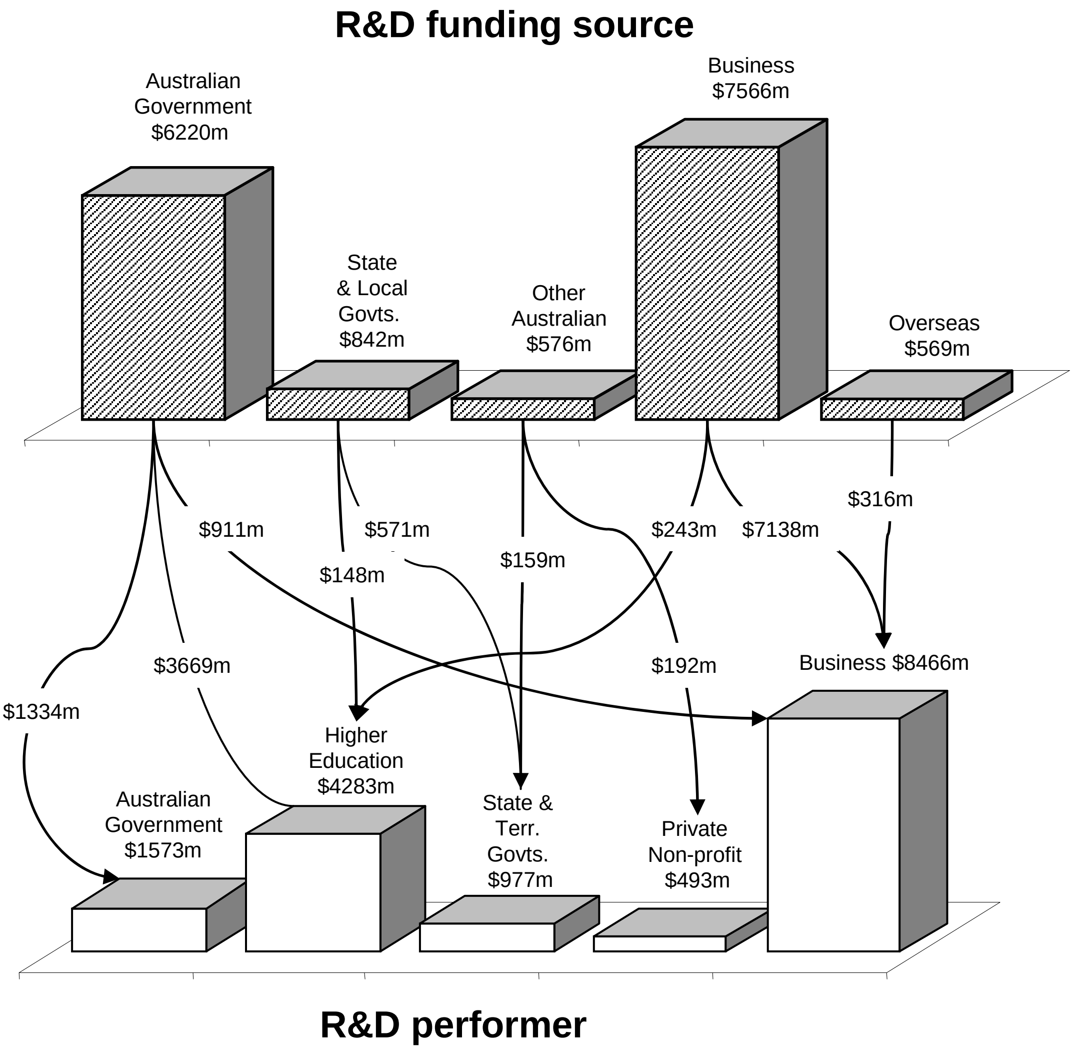
Source: Commission calculations (appendix B) based on Australian Government (2006d).

2.4 Governments are major funders of R&D

Government — overwhelmingly, the Australian Government — funds the bulk of its own and most higher education R&D (HERD) from consolidated revenue (figure 2.1).

Figure 2.1 **Apparent flows of funding and spending**[a]

Major flows, Australian R&D funding and spending 2004-05



[a] Only the major flows are shown and the sectoral descriptions are those of the ABS. 'Other Australian' includes non-profit agencies, individuals, and others. The data are as shown by the ABS, but with one major exception. The original ABS data were in line with the OECD Frascati manual, which is applied by the ABS. However, this excludes some important funding measures, in particular, funding provided through the R&D Tax Concession to the business sector. Accordingly data on government spending on the tax concession in 2004-05 (of $580 million) have been added to Commonwealth funding and removed from business sector funding. It is also important to note the large anomaly (about one billion dollars) between Australian Government funding of higher education shown above and in the budget papers (cf. table 12.1).

Data sources: ABS 2006c, *All Sector Summary Research And Experimental Development, Australia*, Cat. no. 8112.0, 11 October; Australian Government (2006d).

The data presented in figure 2.1 indicate the major spending areas and funding sources across all Australian jurisdictions. It is important to note that the graph has been adjusted from its original ABS source to include the Australian Government's spending on the R&D Tax Concession ($580 million of spending in 2004-05). The adjustment was required because the international statistical framework used to measure government funding of business R&D has several deficiencies (box 2.1).

Box 2.1 **What is counted as R&D funding?**

Great care must be taken in interpreting figures on governments' funding of R&D. As in all statistical measures, conventions determine what is counted. In the case of R&D, the conventions set down in the Frascati manual provide a consistent framework for comparisons between OECD countries, but only of *direct* flows of R&D funding. In some instances, the Frascati principles mean that some important public sources of funds are excluded from the scope of the statistics. In particular, the implicit subsidy to business R&D from the R&D Tax Concession is not counted as a source of funds for the business sector from the Australian Government sector as it is not a direct payment for R&D.[4]

As a consequence of the scope of the definition used for R&D funding, the ABS, which applies the Frascati manual, indicates $331 million dollars of Australian Government-financed business R&D in 2004-05.

In contrast, budget estimates reveal that outlays by the Australian Government for business R&D and innovation were $992 million in 2004-05 (table 2.2), around three times higher than the flow from the Australian Government to business suggested by unadjusted ABS data. These aspects of the Frascati principles also need to be considered in comparisons between OECD countries of the extent of government funding of BERD. The OECD records an amount of government financing of business R&D in Australia that is well below the actual total amount.

However, no adjustment has been made for the large anomaly between the ABS data on Commonwealth Government's funding of higher education and those suggested by the Government's budget papers (appendix B and FASTS sub. DR144). Only part of the anomaly is explained by funds directed at multisector research, like the NHMRC and CRCs, that is predominantly undertaken in universities. FASTS suggest that it is due to the inclusion of General University Funding as a Commonwealth funding source only, when some of this funding stream can be attributed to foreign student fees and other non-government sources. The exact correction required is not certain, but is likely to be large. Aggregate spending by Australian governments may be closer to $6 billion in total in 2004-05, rather than the $7 billion shown in figure 2.1. These anomalies require correction.

Budget data for the Australian Government (table 2.2) give a generally more comprehensive indicator of funding patterns for this level of government than figure 2.1. The higher education sector is the single most important direct recipient of science and innovation funding from the Australian Government, commanding around four in every ten dollars. The remaining six in every ten dollars are roughly

4 Where some entities span sectors — such as CRCs — decisions about where to classify the joint entity can also affect the measured flows between sectors (ABS 2006b). CRCs are categorised as being principally in the higher education sector.

Table 2.2 **Summary of major Australian Government support for science and innovation through the budget and other appropriations**

1997-98 to 2006-07, current prices

Cost incurred in year (accrual basis)			*Estimated actual*	*Budget estimate*
	1997-98	*2004-05*	*2005-06*	*2006-07*
	$m	$m	$m	$m
Intramural expenditure on science and innovation				
Major Australian Government research agencies				
DSTO	212.1	314.4	349.1	340.7
CSIRO	466.8	577.1	593.9	607.2
Other R&D agencies	256.4	413.1	399.9	403.8
Subtotal	935.3	1 304.6	1 343.0	1 351.7
% of total	25.3	24.0	22.6	22.6
Extramural expenditure on science and innovation				
Business enterprise sector				
Industry R&D support	420.0	587.0	622.0	657.0
Other R&D support	20.0	47.9	63.4	81.6
Other innovation support	120.4	356.6	427.3	513.9
Subtotal [a]	560.4	991.5	1 112.7	1 252.5
% of total	15.2	18.2	18.7	21.0
Higher education sector				
Australian Research Council	0.0	480.9	546.2	570.3
Performance-based funding	0.0	1178	1 234.7	1214.3
R&D spending under former framework[b]	1 675.4	0.0	0.0	0.0
Other R&D support	2.5	589.2	449.7	449.7
Subtotal	1 677.9	2 248.1	2 230.6	2 234.3
% of total	45.4	41.3	37.5	37.4
Multi-sector				
NHMRC and other health	179.9	384.7	698.9	467.0
Cooperative Research Centres	144.3	194.6	208.2	189.4
Rural	140.5	213.6	220.7	221.4
Energy and the environment	25.2	43.7	64.1	140.6
Other science support	28.7	57.6	73.1	117.2
Subtotal	518.6	894.2	1265	1135.5
% of total	14.0	16.4	21.3	19.0
Total support	**3 692.2**	**5 438.4**	**5 951.2**	**5 973.9**
In constant prices (2002-03 prices $m)[c]	4 170.6	5 118.4	5 451.2	5 325.5

[a] Spending in the business enterprise sector shown above is different from the sum of 'Business commercialisation and diffusion programs' and 'Support for industry-performed R&D' in table 2.1. This is because some minor items in the broad sectors were re-categorised in table 2.1. [b] 1997-98 was prior to the introduction of performance-based block grant processes and the establishment of the ARC as an independent statutory body, which is why these are recorded as zero in that year. Data for the former framework are listed. [c] The deflator for 2006-07 used to derive the measure of real science and innovation spending is based on the economywide inflation rate of 2.75 per cent estimated in the 2006-07 Australian Government Budget.

Sources: Based on classifications, data from DEST (2005a) and Australian Government (2006d).

evenly distributed between government agencies, business and multisectors (NHMRC, CRCs and other research activities that are allocated to more than one sector).

2.5 A plurality of modes of delivery

The Australian Government delivers its support to science and innovation activities through a variety of arrangements (box 2.2).

Box 2.2 Current funding arrangements for public support

In broad terms, the current arrangements used to provide public support for science and innovation in Australia involve competitive funding, block funding, tax concessions and subsidies (DEST 2003c, p. 395).

Competitive funding arrangements involve:

- *peer reviewed competitive grants* — allocation is on the basis of perceived quality in response to researcher initiated proposals (ARC and NHMRC research grants);
- *competitive tenders against predefined objectives* — precise project objectives and outcomes are specified by the funding agency (such as RRDC funded research); and
- *other competitive grants and loans* — all other competitive grants and loans for which project objectives are not specified in advance. For example, this includes CRC grants, Commercial Ready (combining R&D Start and other industry R&D support programs) and industry-specific grants like Pharmaceutical Partnerships Program (P^3) and the vehicle producers' component of ACIS.

The main types of block funding used are:

- *mission driven block grants* — funding provided to public agencies with defined missions in which the recipient agency is responsible for internal allocations of this funding (for example, funding for CSIRO, ANSTO, DSTO etc); and
- *formula based block grants* — grants for which the funding between competing recipients is determined entirely or to a large part by a formula (for example, university operating grant funding expended on R&D).

Tax concessions and subsidies without a competitive element include:

- the R&D Tax Concession and Tax Offsets for any firm undertaking eligible R&D activities; and
- subsidies and grants. For example, this includes industry specific support such as that provided to the automotive sector though ACIS and to the TCF industry through the Strategic Investment Program.

The percentage distribution by mode of delivery for 2003-04 is estimated as follows: formula-related block grants — 32 per cent; mission driven block grants — 27 per cent; peer reviewed competitive grants — 15 per cent; other competitive grants and loans — 10 per cent; tax concessions and other subsidies — 9 per cent; and competitive tenders against pre-defined objectives — 7 per cent.[5]

2.6 Where are resources allocated?

Public support for science and innovation in general, and for particular programs, can have a range of economic, social and environmental objectives. Although there are detailed data that break down total R&D *expenditure* by socio-economic objective in the Australian system, readily available data on the distribution of *public funding* among competing priorities are only readily available for the Australian Government (table 2.3).

Table 2.3 **Australian Government support for science and innovation by socio-economic objective**

Share of total support, 1996-97 and 2005-06

Objective	*1996-97*	*2005-06*	*Change*
	%	%	Points
Exploration and exploitation of the earth	5.5	5.4	0.0
Infrastructure and general planning of land use	1.1	1.6	0.5
Control and care of the environment	1.0	3.9	2.8
Protection and improvement of human health	6.5	14.3	7.8
Production, distribution and rational use of energy	2.2	2.6	0.4
Agricultural production and technology	7.5	4.3	-3.2
Industrial production and technology	22.5	23.9	1.4
Social structures and relationships	0.6	1.9	1.2
Exploration and exploitation of space	0.0	0.6	0.6
Defence	6.0	6.2	0.2
Objective not specified			
Research financed from general university funds	45.9	29.5	-16.4
Non-oriented research	1.1	5.7	4.6
Other civil research	0.0	0.1	0.1
Total	100.0	100.0	0.0

Sources: DEST (2005a, table 2.1.9) and Australian Government (2006d, table 5).

Some of the objectives shown can have economic, social and environmental overlaps. The data reveal that industrial production and technology are the principal targets of Australian Government support, followed by human health. The biggest

[5] Calculated from DEST (2003c, figure 5.41).

shifts in priorities for funding have been to human health and the environment, away from agricultural production and from untargeted research financed from general university funds. As observed by FASTS (sub. DR144, pp. 5–10), more sophisticated mapping of the allocation of scientists within detailed categories of research may, with other indicators, help determine weaknesses in resourcing relevant to Australian needs.

It is not known with accuracy how much public support is channelled into basic research versus other types of R&D. Nevertheless, Commission estimates (table 2.4) suggest that around half of the R&D support of the Australian Government is directed at pure and strategic research, significantly more than any other funder in the system, although State, Territory and Local governments do direct about one third of their spending to these types of research.[6] Relatively little funding from governments (around 13 per cent) is directed to experimental development, which remains the research priority of projects funded by business (62 per cent).

Counting all R&D conducted in the economy, regardless of its financing source, pure basic research accounted for 9 per cent of GERD, strategic basic research 14 per cent, applied research 37 per cent and experimental development 39 per cent in 2004-05 (table 2.4).

Overall, from a funding perspective, basic research is primarily dependent on Australian Government funding support, experimental development is the priority of business, and applied research is funded equally by the Australian Government and business.

Roles of the R&D-performers

Turning to who undertakes that research, it is common to assert that the various R&D-performing institutions fulfil relatively rigid roles in the Australian system: business undertakes applied and experimental R&D; public sector research agencies undertake strategic basic and applied research; and higher education institutions undertake basic research. (Non-profit private entities are different again,

[6] The estimates in table 2.4 are likely, if anything, to underestimate the importance of basic research to the Australian Government. The estimates are based on the assumption that basic research in any given performing entity — such as businesses — are funded in proportion to the overall source of funds to that entity. So, as the Australian Government funds 4 per cent of business R&D, it is assumed that it funds 4 per cent of the (small amount of) basic research that business performs. In fact, it is likely that government programs tend to favour the riskier end of the R&D continuum in business, so that the true estimate should be higher than 4 per cent.

specialising almost entirely in just two fields, biological sciences and health and medical sciences, with a substantial orientation to basic research.)

Table 2.4 **Who funds what type of research in the Australian innovation system?**

Estimated shares (%), 2004-05[a]

	Funding source					
Type of research	*Aust. Gov.*	*State & Local Gov.*	*Bus.*	*Other*	*Overseas*	*Total*
Priorities of spending within each funding source						
Pure basic research	20.4	9.7	1.8	10.2	8.6	9.4
Strategic basic	24.8	22.9	5.0	27.5	14.6	14.2
Applied research	42.1	53.7	31.6	45.8	36.5	37.2
Experimental	12.7	13.7	61.6	16.5	40.3	39.1
Total	100.0	100.0	100.0	100.0	100.0	100.0
Allocation of research type by funding source						
Pure basic research	77.4	5.5	9.8	4.0	3.3	100.0
Strategic basic	62.5	8.6	18.1	7.1	3.7	100.0
Applied research	40.4	7.7	43.8	4.5	3.5	100.0
Experimental	11.6	1.9	81.3	1.5	3.7	100.0
Total	35.8	5.3	51.6	3.7	3.6	100.0

a It is not possible to determine exactly whether any given funding entity funds pure basic research or other forms of R&D, since data by funding source are not collected on this basis and entities may not earmark funds for a particular type of R&D. Nevertheless, an indication of the underlying priorities of spending and allocation of research types across funding sources can be estimated by considering the extent to which funders provide funds to R&D performers that are intensive in a particular type of research. For example, it is known that business mostly performs non-basic research and that most of the funds provided for research in business are provided by business itself. Consequently, it must be the case that most business funding is directed at non-basic R&D. The data for the table above are estimated by first calculating the shares of funding to any given performer of R&D (k = business, higher education, public sector etc) that are sourced from various alternative funders (j = the Australian Government, State and local governments, business, overseas, other), so that:

$Share_{jk} = Source_{jk}/Spend_k$ where j is the jth source of funds and k is the kth performer of R&D. Then the amount of research of any given type (m=pure basic, strategic basic etc) for each funder (j) is estimated by applying these shares to the spending on this research activity by the various performers.

$Research_{jm} = \sum_{k=1}^{5} share_{jk} \times perform_{mk}$ where $perform_{mk}$ is the amount of research of type m undertaken by performer k. These are the basis of the shares shown above.

Source: Commission estimates based on ABS 2006, *Research and Experimental Development, All sector summary, 2004-05*, Cat. no. 8112.0.

This characterisation is reasonable from an aggregate perspective (table 2.5), but it ignores the large variations across fields within the higher university sector. Unlike the three other broad groupings of R&D performers, universities do not show a consistent pattern of selecting a particular niche within the basic-applied-experimental spectrum across scientific fields (figure 2.2).[7] Several fields — shown as group A, including mathematics and the physical sciences — are highly oriented to basic research. On the other hand, many fields — bunched together in the group C, principally in the social sciences — show a high orientation to applied and experimental R&D. Another group — group B — lies in an intermediate position. It is notable that disciplines with a strong connection to public policy and services (economics, education), general business (commerce), or to Australia's natural endowments (earth sciences, biology, agriculture) tend to have a stronger orientation to applied and experimental research.

Table 2.5 **R&D by type by performing sector**
2004-05

Sector	*All basic*	*Applied*	*Experimental*	*Total*
Value	$m	$m	$m	$m
Government	891.3	1 321.9	337.5	2 550.7
Australian Government	623.4	736.1	214.0	1 573.4
State/Territory	268.0	585.8	123.5	977.3
Private non-profit	233.5	198.2	61.5	493.2
Higher education	2 208.6	1 745.6	328.6	4 282.8
Business	391.9	2 607.5	5 446.8	8 446.2
Share of sector R&D	%	%	%	%
Government	34.9	51.8	13.2	100.0
Australian Government	39.6	46.8	13.6	100.0
State/Territory	27.4	59.9	12.6	100.0
Private non-profit	47.3	40.2	12.5	100.0
Higher education	51.6	40.8	7.7	100.0
Business	4.6	30.9	64.5	100.0

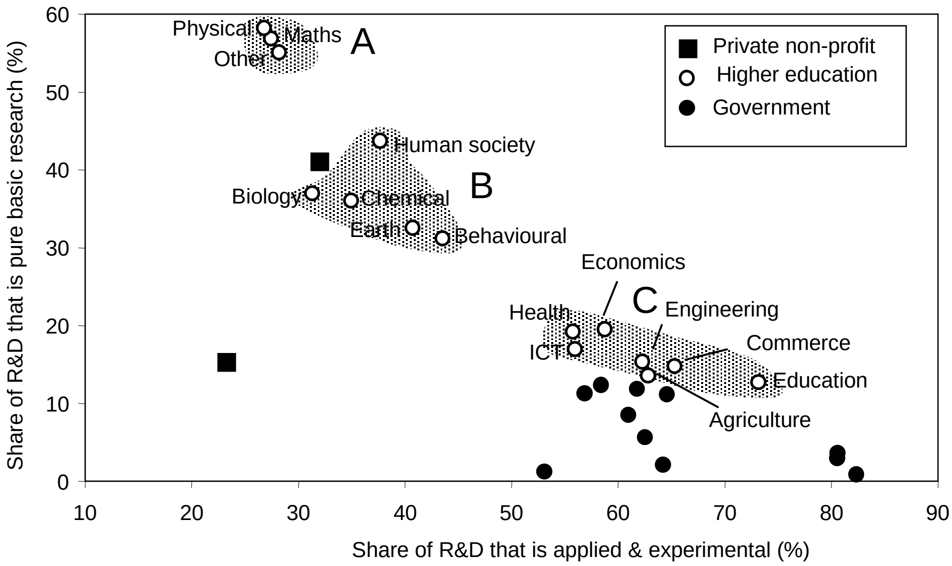
a 'All basic' includes pure basic and strategic basic research.

Sources: ABS Cat. no. 8104.0 (business), Cat. no. 8109.0 (government & non-profit) and Cat. no. 8111.0 (higher education).

7 Businesses are excluded from the figure because the data are not shown by field. Nevertheless, across all individual industries a consistent pattern of specialisation in applied and particularly experimental R&D is evident. As noted in table 2.5 overall, pure and strategic basic research accounts for only 4.6 per cent of total business R&D spending.

The other distinctive feature of higher education research is its variety. The four top spending fields in higher education research account for about 55 per cent of total spending.[8] The comparable figures for government performed and non-profit private R&D is around 70 per cent[9] and over 90 per cent[10] respectively. (Business research is not categorised in the same way.)

Figure 2.2 **Research in universities spans all types and forms[a]**
2002-03



[a] Each data point represents a field of research (such as biological sciences) undertaken within a particular sector, with an indication of the share of that field oriented towards pure basic or applied and experimental R&D. The reason all data points do not lie on a 45 degree line is that strategic basic R&D is excluded. Its value can be inferred as a residual after subtracting the values for applied, experimental and pure basic from 100. The shaded areas depict the three separate groups of higher education research orientation. Data are for 2002-03 since comparable information at the field level for 2004-05 has not been published.

Data source: As in table 2.5.

2.7 The business perspective

Most R&D in Australia is undertaken and self-financed by business. This spending is directed towards innovation in goods, services, processes and organisational forms (figure 2.3).

[8] The top four fields (from rank 1 to 4) are medical and health sciences; biological sciences; engineering and technology; and agricultural, veterinary and environmental sciences.

[9] The top four fields (from rank 1 to 4) are agricultural, veterinary and environmental sciences; engineering and technology; biological sciences; and earth sciences.

[10] The top four fields (from rank 1 to 4) are medical and health sciences; biological sciences; information, computing and communication science; and chemical sciences.

As observed in chapter 1, the ABS uses a definition of innovation for statistical purposes that is narrower than the conceptual definition used throughout this study. Using the ABS approach, an innovator is a firm that introduces any new or significantly improved products, services, processes, organisational or management methods. On this narrower basis, most Australian firms (65.2 per cent) say they did *not* innovate in the three years ending in December 2003.[11] Not surprisingly, given their greater scale, the likelihood of any innovative activity was significantly higher in larger enterprises than small and medium enterprises (SMEs). On the other hand, SMEs account for around 40 per cent of business R&D (a part of innovation) in Australia, which is much more than most other OECD countries.[12] Such SMEs are often the target of public support in Australia to increase aspects of their innovative activities.

Innovation does not necessarily require R&D. Indeed, more than two thirds (69.1 per cent) of innovating businesses said they undertook no R&D spending in 2002-03.[13] Spending on combined R&D and innovation by Australian businesses in 2002-03 was about $20 billion,[14] of which about one third assumed the form of research and experimental development. These data reveal two aspects that are important for this study.

- They confirm that firms' own R&D, the main focus of public funding support in the business sector, is not always a necessary feature of innovation, and where it is, only accounts for a part of total business spending on innovative activities (even when innovation is defined narrowly).
- The claim is often made that the rule-of-thumb ratio of expenditure on research, development and commercialisation is 1 to 10 to 100 (Floyd 2005; Allen Consulting 2003, p. 64). Were this accurate, this would suggest that innovation spending, which includes commercialisation, would be more than 9 times that of

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[11] In the *two* years ending in December 2005, 66 per cent of firms did not innovate (72 per cent of firms employing 5–19 persons cf 49 per cent of firms employing 100 or more persons). This is derived from the new ABS innovation survey (Cat. no. 8158.0) released in December 2006.

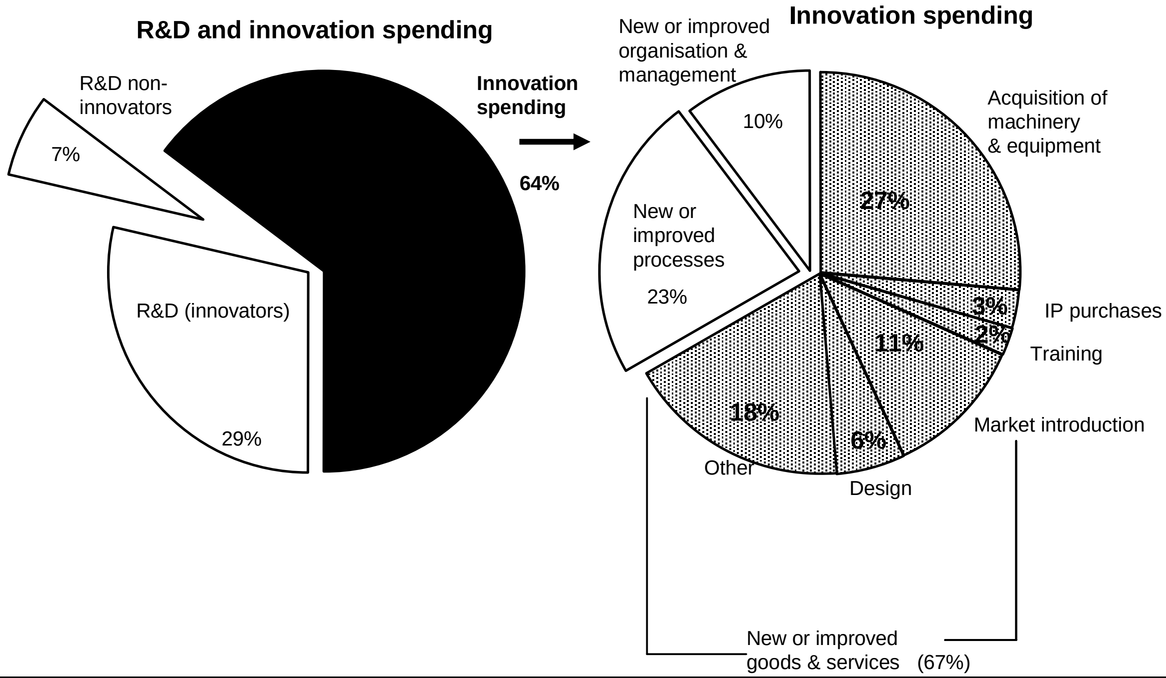
[12] The comparisons are adjusted for differences in the statistical definition of innovation in the Eurostat and ABS surveys and for differences in their scope.

[13] The comparable figure in 2004-05 was 73 per cent. Generally, results based on 2002-03 data are reported in this chapter because the published data for that year are more comprehensive. A minority (6 per cent in 2002-03 and 4 per cent in 2004-05) of non-innovating companies also report some R&D expenditure, which implies that sometimes R&D can take place without significant innovation.

[14] This excludes any entities out of the scope of the innovation survey (those in General Government; Government Administration and Defence; Agriculture, Forestry and Fishing; Education; Health and Community Services; and Personal and Other Services). The comparable figure for 2004-05 was about $30 billion (including about $8 billion on R&D)

R&D.[15] This would imply that firms should be barely receptive to subsidies directed at R&D alone, any more than people buying cars would respond to a reasonable subsidy on the tyres. More plausibly, the ABS data suggest that, on average, innovation spending may be more like two times that of R&D (figure 2.3).[16] This offers at least some potential for successful public support for business R&D.[17]

Figure 2.3 **The relative significance of R&D and innovation spending[a]**
2002-03, Australia



[a] The ABS refers to R&D as innovation-*related* spending, but excludes it from actual innovation spending in its survey. The ABS notes that there are relatively high standard errors of estimates of innovation spending, so that these estimates should be regarded as indicators. It should be emphasised (as discussed earlier) that for the purposes of the survey, the ABS excludes innovation that took the form of small incremental improvements. Consequently, the measure will understate, probably significantly, the extent of spending actually related to innovation.

Data source: ABS 2006, *Innovation in Australian Business 2003*, Reissue, March, Cat. no. 8158.0.

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[15] That is $if\ C = 10 \times D\ and\ D = 10 \times R\ then\ C/(R\,\&\,D) = 100/11 = 9.1$. In the ABS survey, innovation spending (I) includes commercialisation spending associated with R&D, but also other innovation spending (O) that is not related to any prior R&D. The ABS's definition of innovation spending excludes R&D spending. Therefore I=C+O. Accordingly, were the rule-of-thumb characterisation true, then it could be expected that I/R&D = (C+O)/R&D >9.1.

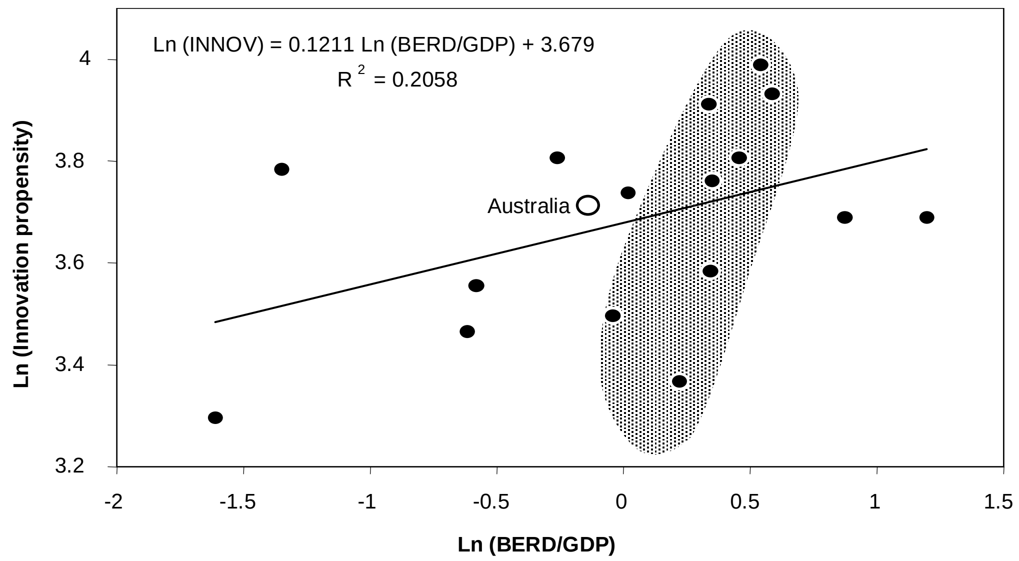
[16] Since some of this spending is associated with innovations that required no R&D, this implies that the commercialisation costs directly associated with R&D projects may be even less than $2 for each dollar of R&D.

[17] The BIE (1993, p. 116) also found that the non-R&D costs of completed innovations were much lower than the popularly applied estimate. Using midpoints of their cost share ranges, it is estimated that R&D to commercialisation costs were roughly 1:1. The BIE study includes incremental innovations.

The weak relationship between innovation at the firm level and R&D spending in Australia is replicated at the international level. Variations in countries' business R&D to GDP ratios 'explain' about 20 per cent of the cross-country variation in innovation propensities by their industries (figure 2.4). There are a whole range of countries — shown in the shaded area — that exhibit very little difference in their business R&D intensities, yet show substantially different innovation performances.

Figure 2.4 **High business R&D intensities only weakly predict high innovation propensities**[a]

Australia and European Union countries in the 2000s



a The Australian Innovation Survey results were adjusted by the ABS to make them consistent with the EU survey of business innovation. The Australian innovation data are for 2001–2003, while the EU data are for 1998-2001. The R&D data are typically for the year 2002, but data for the year 2001 were used for Greece and Sweden, while data for 2000 were used for Luxembourg. It should be emphasised that the diagram shows the relationship between innovation at a broad level and R&D. It may be that there are stronger relationships between R&D and more fundamental innovations, but the consistent cross-country data for that are not available to test this conjecture.

Data sources: As in figure 2.3 above and OECD, OECD *Main Science and Technology Indicators*, 2005-2, Electronic database, Paris.

The finding that other factors are *also* important for business innovation does not render R&D irrelevant. It simply means that innovation policy has to look at more than one explanatory factor and that these additional factors are of great importance. For example, governments have significant impact on the innovation system through policies relating to the general regulatory environment and the creation of infrastructure and human capital (section 2.9 and chapter 5).

Moreover, as one participant in this study noted, R&D effects can have 'stealthy' pathways — their business impacts are often hard to trace. A firm may improve without its managers categorising that as innovation, and without being aware that the improvements can be tracked ultimately to some R&D. For example, a firm may buy some new equipment in which the R&D is embodied or hire a new staff member, whose skills and knowledge have benefited from association with R&D.

In any case, public policy for R&D generally is not aimed at business innovation alone. It can also probe social and environmental problems or lead to government or community innovation. It may also have values that are not related to their immediate ends (as discussed later).

2.8 Public support and conduct is in flux

There have been significant changes in the role of the Australian Government public support of science and innovation over time.

Direct funding of Australian Government research agencies has barely grown in real terms over the past 25 years, compared with relatively strong growth for other components of funding (table 2.6). This has meant that Australian Government support of government agencies roughly halved as a share of GDP between 1981-82 and 2005-06 (figure 2.5). Part of the reason for this has been the growth of multisector funding (such as the CRC program), a component of which has been directed to Australian Government research agencies. Another contributing factor may be the greater supply of funding of such agencies from sources outside the Australian Government, which may have substituted to some extent for direct government payments.

All other funding streams have increased over the long run, both in real terms and as a share of GDP. However, business funding has fallen as a share of GDP from its apogee in the mid 1990s, with the alteration of elements of the R&D Tax Concession that were used as vehicles for gaining the maximum tax benefit, such as R&D Syndication, feedstock and pilot plant provisions (Lattimore 1996; Field 1996).

Total funding of science and innovation by the Australian Government has actually fallen slightly as a share of GDP between 1981-82 and 2005-06 (figure 2.6). But science and innovation funding as a share of total outlays by the Australian Government, which is a better measure of government priorities, is now significantly higher than it was in the early 1980s, and has increased strongly since 1997-98 with a series of major funding initiatives.

Table 2.6 **Australian Government research funding trends differ by destination[a]**

Various periods, 1981-82 to 2005-06, constant prices

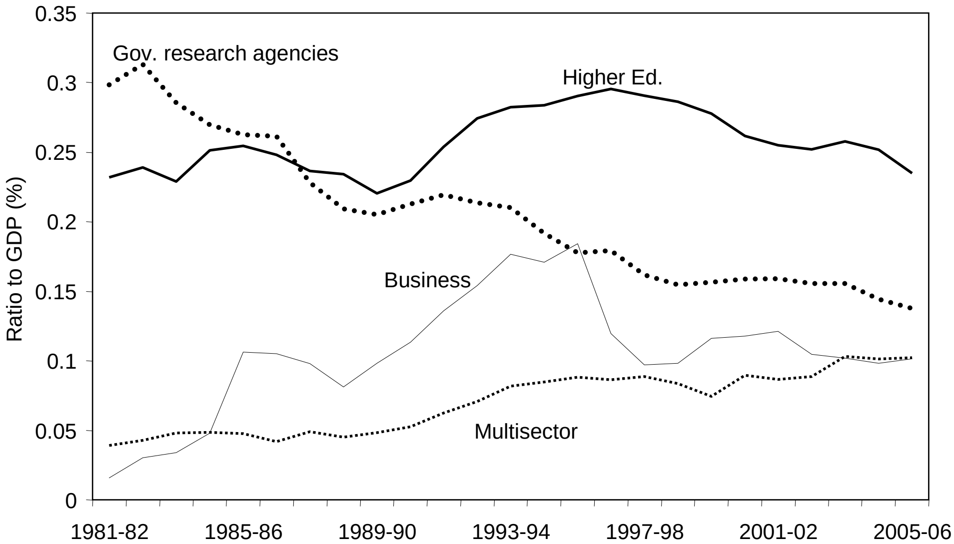
Sector	*The last 5 years*	*The last 10 years*	*The last 25 years*
	%	%	%
Government agencies	4.9	12.7	1.1
Business	4.3	-19.9	1 296.3
Higher education	8.6	17.6	121.9
Multisector	37.9	68.6	474.2
Total	11.0	13.2	115.7

a The last 5 years = 2000-01 to 2005-06; the last 10 years = 1995-96 to 2005-06 and the last 25 years 1981-82 to 2005-06. Note that funding shown in this table relates only to the Australian Government, not State and Territory governments. The data in this table (and figures 2.5 and 2.6) are constructed using budget data from DEST and do not exactly correspond to the (Frascati) framework used by the ABS and the OECD to categorise funding.

Source: Data on budget outlays were provided by DEST.

Figure 2.5 **Australian Government support for innovation and science**

By spending component, 1981-82 to 2005-06

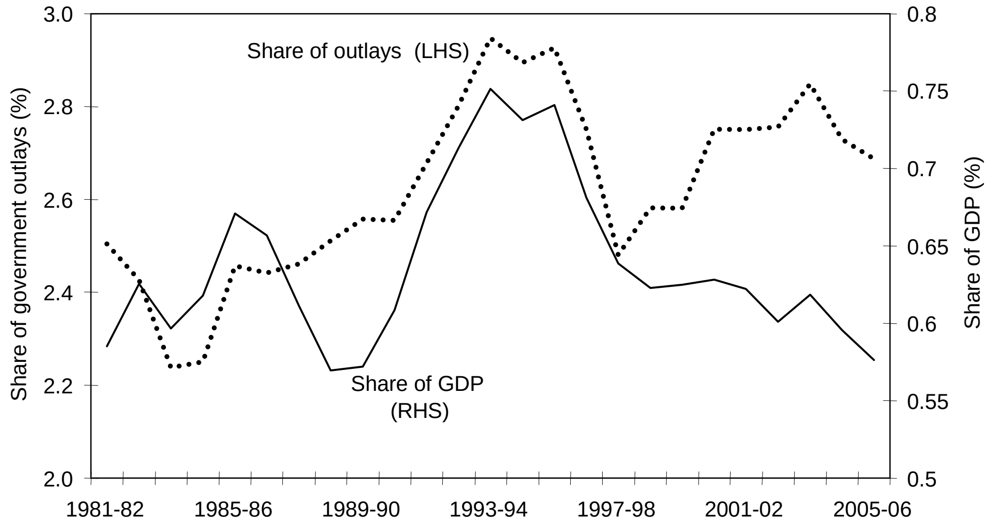


aThe GDP datum for 2005-06 was estimated on the basis of three quarters of annual data and extrapolation of the June quarter. Multisector may be accessed by several sectors including Commonwealth research agencies. It includes the NHMRC and other health, CRCs, rural research and energy and the environment.

Data sources: Data on budget outlays were provided by DEST. GDP data are from the ABS, *Australian National Accounts: National Income, Expenditure and Product*, Cat. no. 5206.0, released in June 2006.

Figure 2.6 **Total Australian Government support for science and innovation**

1981-82 to 2005-06



a See previous figure for notes and sources.

The picture of public support suggested by figures 2.5 and 2.6 and table 2.6, should not be taken to imply that the *conduct* of R&D by government research agencies has barely grown in real terms:

- governments other than the Australian Government are also funders and performers of own government research;
- funders outside government have, over the long-run, increased their investment in R&D within government research agencies, such as the CSIRO; and
- government research agencies have benefited from the strongly growing funding of multisector R&D (such as CRCs).

The real value of resources devoted to spending in government research agencies (across all Australian jurisdictions) has risen by around 50 per cent and their use of researchers by around 20 per cent from 1981-82 to 2002-03.[18] Recent data show a

[18] The real value of own-government R&D spending was $1169 million (PPP) in 1981 and $1786 million (PPP) in 2002 (Indicator 54, OECD 2005b). Full time equivalent researchers in government increased from 6794 to 8036 over the same period. Cost structures have been evolving too, with the amount of real GOVERD (comprising wages and other costs) per full-time equivalent researcher increased by about 30 per cent over the period from 1981 to 2002 (contrasting with a fall in EU15 countries collectively of around 20 per cent, OECD 2005b).

continued increase in researchers in these agencies, but a reduction in overall R&D personnel and real expenditure.[19]

Despite a long-run increase in the absolute amount of R&D conducted by governments (GOVERD), spending has not kept up with GDP growth, so that the ratio of spending to GDP has fallen. In 1981-82, GOVERD accounted for 0.43 per cent of GDP. This fell by 0.1 percentage points over the next 25 years to 0.33 in 2002-03[20] and most recently to below 0.29 in 2004-05.

And spending in these agencies now amounts to less than one in five dollars spent on Australian R&D — however funded — compared with nearly one in two dollars in the early 1980s (table 2.7). Some of this fall is illusory, reflecting the greater outsourcing and privatisation of activities formerly undertaken in government-owned agencies, such as Telstra. But mostly, the relative decline is due to the large absolute increase in business (and to a lesser extent, higher education) R&D activities. This pattern also holds for many other OECD countries, revealing the shift in balance in the allocation of research resources to business globally (figure 2.7). Within business, there has been a growing orientation to R&D within the service sector, reflecting its increasing importance in the economy (table 2.7). This re-orientation has been particularly marked for Australia compared with the European Union.

A similar shift in emphasis is apparent for the funding as well as the conduct of R&D. Over the long run, industry has played a larger (and Australian governments collectively a lesser) role as a funder of R&D, whether it be performed within industry itself, in higher education institutions or government research agencies.

Within the university sector, there has been a shift in the governance arrangements for funds. Relatively fewer funds are given directly to universities for them to determine where they should be allocated through their own governance arrangements. More is mediated through external, peer-review entities such as the ARC and the NHMRC.

[19] In the most recent ABS all sector summary for 2004-05 (Cat. no. 8112.0), all-of-government researchers increased from 8036 in 2002-03 to 8530 in 2004-05, but other R&D full-time equivalent employees fell from 10 505 to 8459. Real R&D expenditure fell by about 3 per cent over this period.

[20] The aggregate decline can be wholly attributed to Australian Government agencies (0.31 to 0.20 per cent of GDP) compared with those in the States and Territories (0.12 to 0.13 per cent of GDP) (DEST 2005a, p. 109).

Table 2.7 **Australia and many other countries have shifted the emphasis of their R&D spending in the last two decades**

1981 and 2002[a]

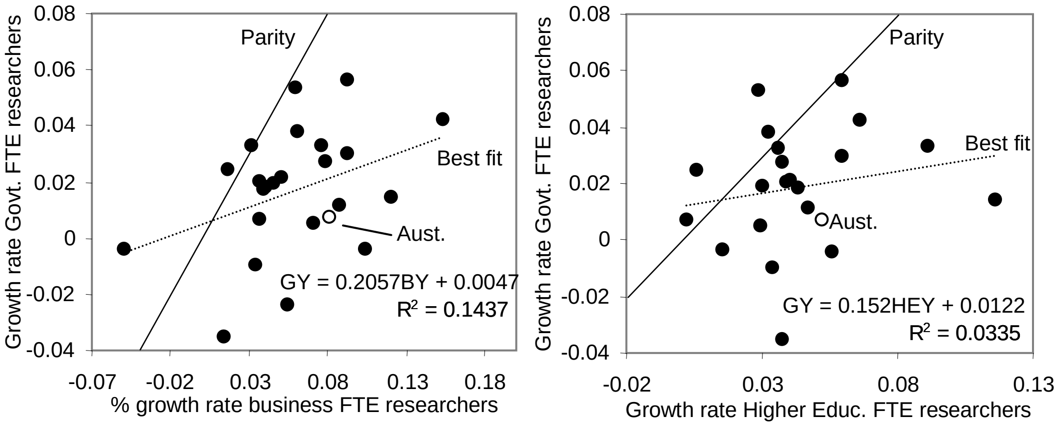
	Australia		*EU15*		*% change*	
	1981	*2002*	*1981*	*2002*	*Aust*	*EU15*
GDP shares						
GERD to GDP share (%)	0.94	1.69	1.66	1.91	79.8	15.1
BERD to GDP share (%)	0.24	0.87	1.03	1.23	262.5	19.4
HERD to GDP (%)	0.27	0.45	0.29	0.42	66.7	44.8
GOVERD to GDP (%)	0.43	0.33	0.31	0.24	-23.3	-22.6
Share of GERD, by performing sector						
Business (%)	25.0	51.2	62.3	64.3	104.8	3.2
Higher education sector (%)	28.5	26.7	17.6	21.9	-6.3	24.4
Government sector (%)	45.1	19.3	18.8	12.7	-57.2	-32.4
Not-for-profit sector (%)	1.3	2.8	1.4	1.2	115.4	-14.3
Share of BERD financed by:[b]						
A - Business (%)	88.6	90.3	77.2	81.9	1.9	6.1
B - Government (%)	9.8	4.0	19.0	7.3	-59.2	-61.6
C - Other national sources (%)	0.1	0.8	0.1	0.1	700.0	0.0
D - From abroad (%)	1.8	4.9	3.6	10.7	172.2	197.2
Full-time equivalent researchers						
Total number (‘000)	24.2	73.3	488.4	1044.1	203.0	113.8
Per 1000 employees	3.6	7.8	3.5	6.1	116.7	74.3
Share of full time equivalent researchers in:						
Business (%)	14.3	28.1	50.0	51.7	96.5	3.4
Higher education (%)[c]	56.2	58.3	32.0	35.3	3.7	10.3
Government (%)	28.1	11.0	16.0	11.8	-60.9	-26.3
Other measures						
Share of BERD undertaken in the services sector (%)	10.0	42.2	5.4	14.8	322.0	174.1
HERD financed by industry (%)	1.4	5.1	2.0	6.6	264.3	230.0
GOVERD financed by industry (%)	1.8	5.2	4.1	5.8	188.9	41.5

[a] The European Union, rather than the OECD, was used as the comparison group because some data for the OECD as a whole were missing or not sufficiently comparable to Australian data. Nevertheless, where OECD data were available, the results were very similar to that of the EU15. The correlation coefficient was 0.994 for 1981 and 0.999 for 2002 and of 0.70 for the percentage change from 1981 and 2002. [b] Data for Australia listed for 1981 are for 1984 and for the EU15 are for 1983. BERD financed from abroad is low for the EU15 (and nearly zero for OECD countries) because financing between member countries is excluded from the total. Since most financing from abroad is from industry, a reasonable indication of total funding from industry is given by totalling the amounts shown at A and D. [c] EU data listed for 2002 are for 2001.

Source: OECD *Main Science and Technology Indicators 2005-2*, Paris (Electronic database).

Figure 2.7 **Growth in R&D has favoured business and higher education research over government-performed research**

OECD countries 1981-2002



[a] The data relate to the average annual (log) growth rates of full-time equivalent researchers in each economy calculated over the period from 1981 to 2002 (or where data are missing, over a near comparable period). If growth in these parts were equivalent then they would be scattered around the line of parity shown in each diagram. In this instance, the share of researchers in government agencies would remain stable over time. However, the best fitting line is far from the line of parity. Australia is below the best fit line, showing that Australia has even less growth in government researchers than would be predicted on the basis of its experience of growth in business or higher education researchers.

Data source: PC calculations based on data from the OECD *Main Science and Technology Indicators 2005-2*, Paris (Electronic database).

Globally, Australia has converged to have a pattern of R&D spending and funding by sector more like that of the European Union and OECD countries (box 2.3). The percentage of the Australian pattern 'explained' by the OECD pattern was less than 3 per cent in 1981, but more than 40 per cent in 2002.

Box 2.3 **Measuring convergence of Australian and OECD patterns of R&D**

Data on 16 measures of R&D spending and funding were derived for Australia and the OECD as a whole for two years, 1981 (or thereabouts) and 2002 (or thereabouts). These were all of the data items in table 2.7 except the financing shares of BERD and the service sector share of BERD. This generates four series, each with 16 elements: $R_{Aust1981}$, $R_{Aust2002}$, $R_{OECD1981}$ and $R_{OECD2002}$.

To determine the extent to which variations within the OECD series 'explained' the variation within the Australian series, regressions of $R_{Aust1981} = \alpha_1+\beta_1\ R_{OECD1981}$ and of $R_{Aust2002} = \alpha_2+\beta_2\ R_{OECD2002}$ were undertaken (giving an R^2 of 2.8 per cent and 41.4 per cent respectively).

This approach provides a measure of the extent to which patterns of funding and spending in Australia have converged on those of the OECD as a whole.

2.9 The international perspective

Measuring the impacts of R&D is difficult, as shown in chapter 4. Because of this, policymakers and others often use international comparisons of R&D inputs as a proxy for impacts and to assess the adequacy of R&D investments.

The focus on R&D in such international comparisons is also driven by the availability of data. There are agreed definitions of R&D among national statistical agencies and many countries have collected data on a reasonably comparable basis for some period, in part because of the historical legacy of a focus on technological invention, rather than innovation more broadly. There is far less data on innovation, a more central determinant of growth prospects (though some is shown in figure 2.4).

Figure 2.8 shows the distributions of R&D intensities across different countries, with Australia's position shown within each distribution. Data for 2002 are used, rather than more recent information, to increase the number of comparison countries. More recent data show that this pattern has not qualitatively changed. Such international R&D comparisons reveal that:

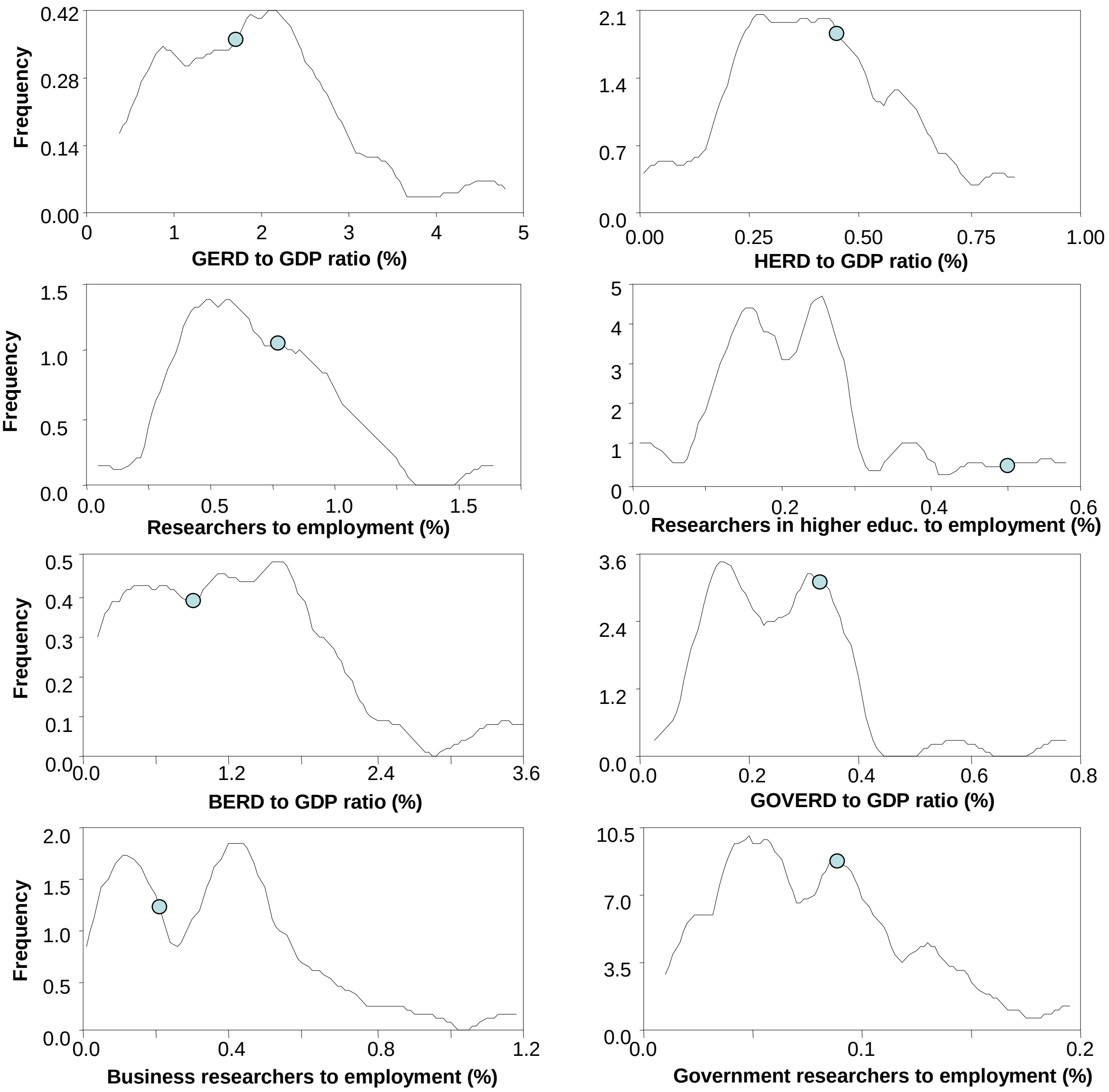
- Australian BERD to GDP is lower than those of advanced economies generally, as is the business researcher to employment ratio. Business R&D still is the most important component of GERD, so low BERD to GDP translates to low relative GERD to GDP ratios; and
- Spending on government and higher education R&D to GDP (GOVERD and HERD) is around the median of advanced countries, and in higher education, surprisingly, towards the higher end of researchers to employment rates.

Data, such as that presented in figure 2.8, often assume an iconic status as 'proof' of endemic underinvestment in business R&D in Australia, especially among those wishing to attract more funding. However, comparisons of input ratios are usually a conceptually unsound basis for assessing optimal investment in R&D. Nothing says that 'high' input ratios are necessarily better than 'low' ones, since it is possible to both under- or over-invest in R&D. For most other inputs — such as labour or capital — the usual interest is not in maximising inputs per output, but rather maximising its inverse (output per input or productivity).

Such input ratios can be somewhat useful as soft indicators of potential sub-optimal investment if they identify a striking disparity with other countries that cannot be readily explained. But, first, Australia is not at the end of the distribution in R&D input ratios shown in figure 2.8 — which is probably the more sensible trigger for policy investigation.

Figure 2.8 **Are Australian R&D inputs low by world standards?**

International distributions of R&D ratios, 2002[a]



[a] The data generally relate to 2002, except where the OECD notes otherwise. Countries are from the OECD plus a range of rich non-OECD countries like Israel and Singapore. The growth rates in GERD relate to the period from 1992 to 2002. The densities are estimated using an Epanichenikov kernel using RATS v.6.1. The dots mark Australia position in the distributions.

Data source: OECD *Main Science and Technology Indicators*, 2005-2, Electronic database, Paris.

Second, it *is* possible to identify factors that provide a partial explanation of why Australia has ‘low’ R&D intensities. These include an industry structure that largely omits the highest R&D intensive sectors (defence, aerospace and pharmaceuticals); the higher relative importance of small firms as R&D performers in Australia; the apparently lower price of R&D labour inputs; and the role of foreign multinationals, which tend to import their knowledge capital, rather than creating it in Australia.

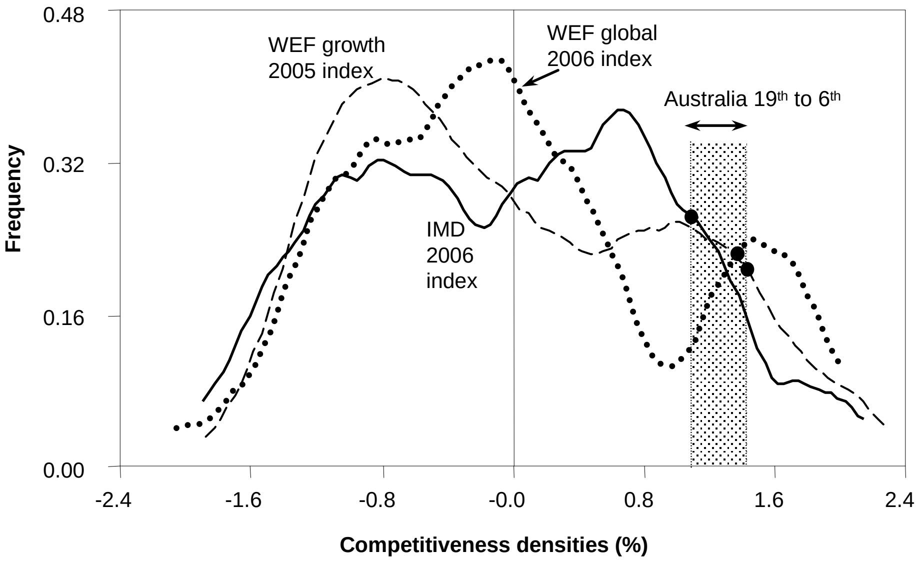
Third, other indicators suggest that notwithstanding its ranking in global R&D intensities, Australia’s overall innovation and economic performance has been good compared with many high R&D performing countries. Critically, as noted by many during this study, an innovation system comprises far more than R&D and, if anything, the shift towards a more service sector based economy will accentuate the importance of other innovation factors. As shown in figure 2.4, Australian business sector innovation propensities are about average by international standards and generally not well predicted by R&D intensities. Several international indexes of fundamental competitiveness suggest that Australia is a good global performer (figure 2.9), though the most recent index, the Global Competitiveness Index suggests a flagging relative performance. Australia’s multifactor productivity growth record — probably the best summary measure of innovation performance — has been strong over the decade since 1991.[21] And GDP per capita in Australia remains as one of the world’s highest.

That said, big discrepancies between Australia’s R&D to GDP ratios and that of other countries should be investigated routinely to find out why they occur. The nature and source of these discrepancies is explored more thoroughly in appendix C. The Commission’s analysis suggests that many of the discrepancies that currently exist in BERD to GDP can be explained by benign differences between Australia and other OECD countries. In that case, unadjusted league tables of R&D to GDP ratios should not be used to assess whether Australia’s R&D performance is good or bad.

When combined with measures of productivity, innovation or other indicators of wealth generation, international variations in patterns of R&D are also useful for exploring the economic impacts of R&D. This is the approach, for instance, used in Gans’ estimates of the returns to R&D (sub. 10) and in chapter 4.

[21] It has slowed since then, but it is hard to ascribe this to poor R&D performance, since there has been strong recent growth in business R&D (which has the most impact on short-term measured productivity performance).

Figure 2.9 **Australia ranks well in international competitiveness indexes**
WEF and IMD indexes[a]



a The WEF *Growth* Competitiveness index is for 117 countries in 2005-06 (Australia was 10th), the more recent WEF *Global* Competitiveness Index is for 125 countries in 2006 (Australia 19th) and the IMD index is based on scores for 53 nations for 2006 (Australia 6th). All indices were converted to standardised Z scores by subtracting their mean values and dividing by their standard deviation. This means that any figure on the horizontal axis can be interpreted as the number of standard deviations away from the mean value. Australia's position in the three indices is shown as three marks and the range is shaded.

Data sources: IMD World Competitiveness Year Book 2006 and the WEF is from the Global Competitiveness Report 2005-06.

Broader international indicators of innovation system performance

The competitiveness indices underlying figure 2.9 are built up from many separate indicators. These indicators provide a useful basis for considering the relative performance of Australia's innovation system from a broader perspective than technological and scientific capability alone. The Australian Business Foundation (sub. 72), for example, emphasised the importance of many diverse indicators of innovation capabilities and performance.

The Commission examined the large number of indicators underlying the most comprehensive and recent of the competitiveness indices — the World Economic Forum's (WEF) Global Competitiveness Index (GCI).[22] Of this large suite, a group of indicators that spans the most important features of Australia's innovation system were selected (table 2.8).

22 One feature of these indicators is that many are based on surveys. While these usefully pick up intangible aspects of innovation, they reflect subjective assessments of strengths and weaknesses, rather than objective ones. They can therefore be subject to biases.

Table 2.8 **A snapshot of the innovation system**

Australia and selective countries, 2006

Mnemonic	*Description*	*AUST*	*Rank*	*Finland*	*UK*	*Can.*
GDPCAP	GDP PPP per capita ($'000)	30.9	13	31.2	30.5	34.3
GCI	GCI score 2006	5.29	19	5.76	5.54	5.37
I_INNOV	Overall innovation index	4.66	22	5.65	5.36	5.08
I_SCIQUAL	Quality of scientific research	5.3	13	5.7	6	5.5
I_FIRMRD	Company spending on R&D	4.0	23	5.5	4.7	4.4
I_COLLAB	Research collaboration between firms and unis	4.1	22	5.5	4.9	4.8
I_PROCURE	Govt procurement advanced technology	4.2	19	4.7	4.2	4.1
I_SCIENG	Availability of scientists & engineers	5.0	23	6.2	5.4	5.8
I_PATENTS	Utility patents per million pop	45.1	20	138.5	52.7	89.6
I_IP	Intellectual property protection	5.9	10	6.4	6.2	5.7
I_RCAPACITY	Capacity for own research cf acquiring from overseas	3.9	25	5.8	5.4	4.8
O_SPECIAL	Local availability of specialized research & training services	5.2	15	5.9	6.0	5.6
O_INFRA	Overall infrastructure quality	5.4	19	6.3	5.8	5.9
O_RIGHTS	Property rights	6.4	7	6.4	6.5	5.9
O_REDTAPE	Extent of bureaucratic red tape	2.5	6	1.2	2.3	2.2
O_TAX	Extent and effect of taxation	3.0	22	2.5	4.2	3.2
O_FSOPHIST	Financial market sophistication	6.1	6	6.0	6.8	6.1
O_LOANS	Ease of access to loans	4.8	13	5.3	5.5	4.1
O_VENTURE	Venture capital availability	4.8	13	5.4	5.2	4.5
O_EQUITY	Local equity market access	6.2	7	6.0	6.0	5.8
O_ABSORB	Firm-level technology absorption	5.6	16	6.0	5.5	5.5
O_READY	Technological readiness	5.5	16	6.5	5.8	5.8
O_TRAIN	Extent of firm training	5.1	18	5.6	5.3	5.0
O_EDUCQ	Quality of the educational system	5.1	10	6.0	4.5	5.0
O_BOARD	Efficacy of corporate boards	5.8	3	5.8	6.0	5.5
O_CREDIT	Credit rating	5.9	9	4.2	4.1	3.2
O_TERT	Tertiary enrolment rate	72	10	90	60	57
O_MQUAL	Quality of maths & science educ.	4.9	17	6.1	4.7	5.1
O_TRADE	Prevalence of trade barriers	5.5	11	6.2	5.3	5.0
O_ICT	Govt prioritization of ICT	4.8	23	5.6	5.6	5.1
O_PRODSOPH	Production process sophistication	5.2	20	6.1	5.6	5.3
O_MARKET	Quality of marketing	5.8	10	5.7	6.6	5.9
O_BUYER	Buyer sophistication	5.7	7	5.7	6.0	5.6

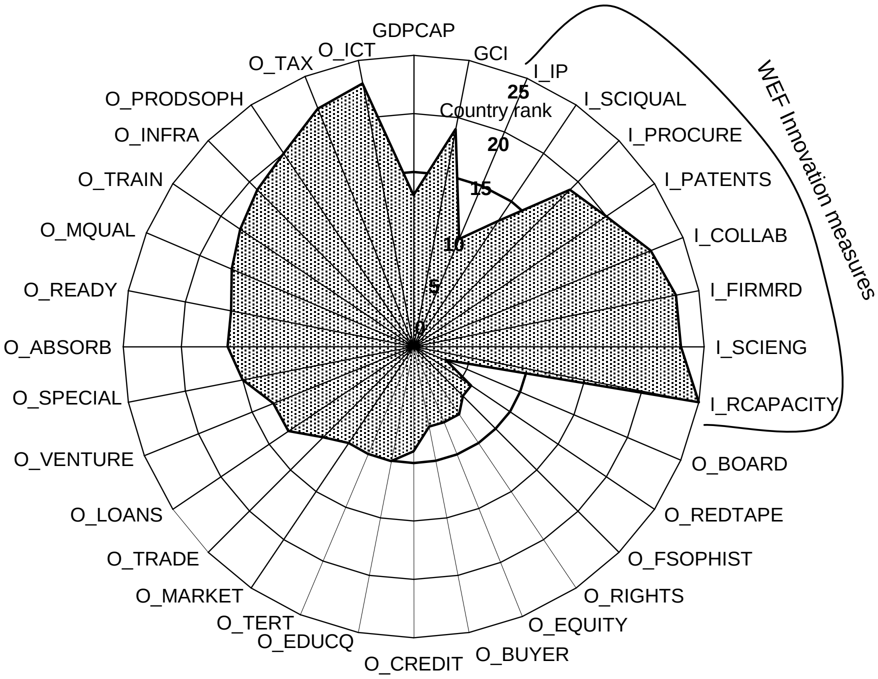
a With the exception of patents, GDP, the credit rating and the tertiary enrolment rate, all other measures are based on business survey data or are a hybrid of objective and subjective evidence (the GCI and I_INNOV measures). The GCI is the aggregate measure of competitiveness, and I_INNOV the aggregate measure of innovation performance. In subjective variables, performance is on a scale from 1 (bad) to 7 (good), with the exception of red tape where the order runs the opposite way. All I_ variables are those making up the composite innovation index. The rank shown is that of Australia among those countries with GDP per capita exceeding $20 000 (excluding Luxembourg). There are 30 countries in this group.

Source: World Economic Forum (2006).

The WEF itself has produced an ‘innovation’ indicator based on eight underlying measures (shown as I_INNOV in the table with the contributing components preceded by an I_). This suggests Australia is a relatively weak performer (20[th] globally) compared with other advanced economies, but it gives considerable weight to patents and technological R&D, rather than other aspects of the innovation system. Once other aspects that are likely to be important for an innovation system are considered (those indicators preceded by an O_ in table 2.8), Australia shows considerable strengths in many areas (corporate governance, regulatory compliance, recognition of property rights, buyer sophistication, finance and education). But some perceived weaknesses are also apparent in areas such as taxation, firm training and the capacity for business absorption of ideas from others — and these show up clearly in figure 2.10.

Figure 2.10 **Australia’s performance in the innovation system**

An international perspective[a]

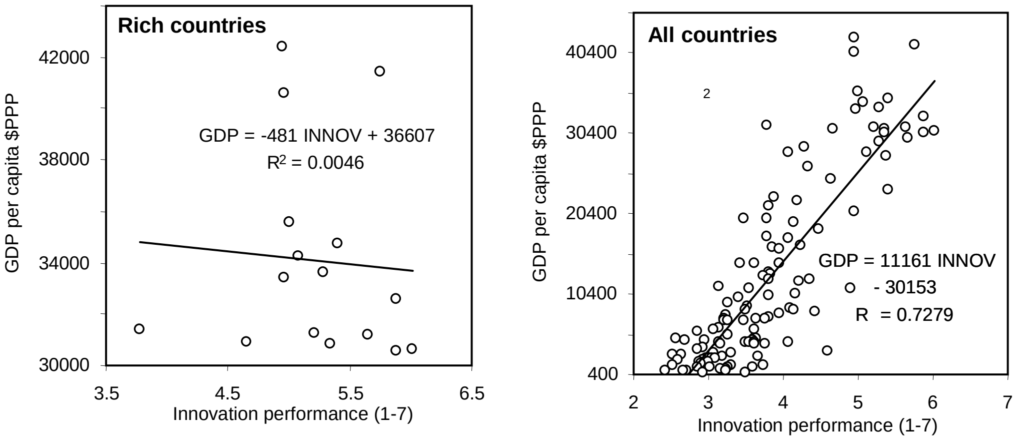


[a] The rank shown is that of Australia among those countries with GDP per capita exceeding $20 000 (excluding Luxembourg). The meaning of the mnemonics is shown in the table above.

Data source: World Economic Forum (2006).

A limitation in the indicators is their weak empirical association with economic prosperity in *rich* countries For example, the WEF Innovation indicator (I_IINOV) has a reasonably strong association with GDP per capita across all 125 countries for which the data were available. But among rich countries, the WEF innovation summary indicator has no explanatory power and no statistical significance (figure 2.11). The only surprising pattern was that higher current innovation indexes are associated with poorer past growth (box 2.4).

Figure 2.11 **In rich countries, simple innovation indicators explain little**[a]



a Rich countries are those with GDP per capita exceeding $30 000 (PPP basis 2005), excluding Luxembourg. The measure of innovation is the WEF's composite index. It encompasses a relatively narrow range of factors, giving emphasis to technological and research capabilities and ignoring broader aspects of the innovation system. Figure 2.10 above draws on a much broader range of indicators that indicate the health of an innovation system. The innovation indicator is not statistically significant among rich countries.

Data source: World Economic Forum (2006).

To address this limitation, the Commission considered several other approaches. One approach was to examine the bilateral association between each of the variables in table 2.8 and prosperity in the richest countries. 19 variables were found to be statistically significantly associated with GDP per capita. Then Australia's ranking on each of the indicators was considered against the extent to which these indicators mattered for prosperity (figure 2.12). It was found that Australia tended to have a higher ranking for those indictors that were most influential in their association with prosperity. If nothing else, this finding suggests some of the problems of giving equal weight to constituent indicators when their potential importance for prosperity is likely to vary.

Since the relationships underlying figure 2.12 only relate to the correlation between single variables and income, the question is whether it is possible to get a more textured view about the collective aspects of a broad innovation system that might be influential in shaping national per capita incomes. Since it is obviously important to distinguish richer countries from poorer ones, the Commission's analysis focused on two groups of countries only — those incomes above $20 000 and above $30 000 per person respectively.

Box 2.4 **What about growth?**

It would be desirable to examine the ratio between an innovation indicator in a given year and subsequent longer term *growth* in GDP (say over a period 10 to 15 years later). Unfortunately, the data are not available for the 1990s to test this, though such tests should be undertaken as future data become available.

However, it is possible to test the relationship between the present innovation index and past economic growth. For rich countries,[23] it is found that those with stronger past economic growth have, statistically significant, lower present innovation indexes than those with past weaker economic growth. This holds for growth from 2000 to 2005 and for a longer period (1992 to 2005).

There are several possible interpretations of this pattern.

- One is that innovation capabilities are diminished by past growth (a 'complacency' effect), rather than there being reinforced by past innovation performance, as some hypothesise.
- A second is that the measured innovation index is a good proxy for past innovation indexes. In rich countries, governance, educational, financial and IP institutions tend to move over decades or longer, rather than year by year. In that instance, the 2006 indicators for the innovation index may provide a rough proxy for the innovation index in 2000. In that case, the *measured* innovation index is actually inimical to growth — a surprising result.
- A third possibility is that any subjective survey bias in the innovation indexes is negatively correlated with past growth. This may reflect that fact that past low (high) growth often results in future catch-up (slowdown), so that the surveyed company executives tend to give higher innovation scores to countries they expect to grow in the future.
- Finally, it could simply be spurious.

Either way, the causal links between measures of innovation capability and growth are likely to be more complicated than usually claimed.

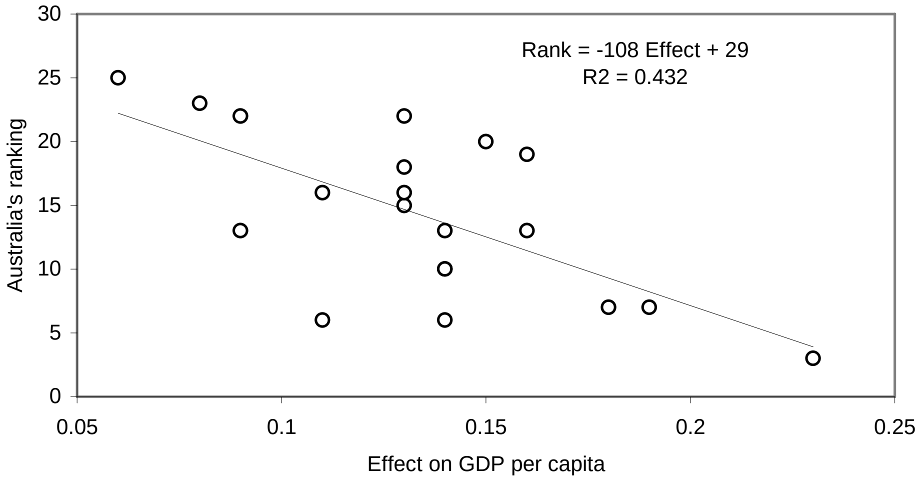
No stable adequate model could be found. In many cases, the models were characterised by counterintuitive results (such as a negative coefficients on scientific quality, IP rights, and aspects of the financial system), and signs and magnitudes were highly sensitive to variable addition and deletion. Using a range of general to specific econometric reduction processes, no econometrically/economically sensible model was found, other than those that collapsed to a simple bivariate relationship. This may reflect the subjective nature of many of the indicators, the high correlation between many of the explanators, the

[23] The same group of rich countries as described in figure 2.11.

use of cross-sectional rather than panel data analysis, the complex nature of innovation systems, and spurious causation.

Figure 2.12 **Australia ranks best on the performance indicators that globally are most influential in shaping income per capita**

WEF indicators 2006



[a] Each of the indicators in table 2.8 was regressed against log GDP per capita for countries with incomes above $20 000 per capita in PPP terms (excluding Luxembourg, which was always an outlier in the analysis). Then Australia's relative ranking was derived for the variables that were statistically significant and these rankings were correlated with the effects of each of the variables on log GDP per capita. It should not be assumed that the elasticities are causal. Checking this will require more robust statistical methods that rely on panel data derived from future data sets.

Data source: Commission analysis and World Economic Forum (2006).

Either way, the evidence on the data available to the Commission suggests that even quite extensive sets of innovation indicators fail to provide strong explanatory power about the relative performance of rich countries. Countries can be equally prosperous with quite different settings in their innovation systems, once they have achieved some acceptable threshold in the relevant indicators (for example, most rich countries had good education systems). If nothing else, this should suggest a sceptical regard for statements asserting the obviousness of changes to an innovation system required to produce additional wealth. There are likely to be many, context-dependent, trajectories to continued economic prosperity and conversely many traps for the unwary in pursuing superficial approaches to enhancing innovativeness.

3 Rationales for public support

Key points

- Public support of science and innovation should be based on clear and credible rationales. These also help in designing appropriate support mechanisms and, where empirical evidence on impacts is absent or uncertain, enable policymakers to better judge whether particular forms of public support are likely to produce net benefits.
- There are two strong rationales for public funding support of science and innovation. The first reason is that governments exercise many functions, and need to fund R&D to discharge those functions effectively.
- The second is spillovers from innovation that cannot be captured by the innovator and that cannot be realised without support. The spillovers may arise through high quality human capital development, the development of basic knowledge capabilities and diffusion of new ideas among firms and others. They arise from research undertaken in universities, businesses and public sector research agencies.
- Spillovers provide a strong *a priori* rationale for public support. But it is important to note that:
  - not all research in universities and public sector agencies create significant spillovers, especially if research is mediocre or research is poorly managed;
  - not all spillovers matter for policy;
  - some apparent spillovers are illusory; and
  - the areas where public support for commercially-oriented R&D is likely to produce the biggest spillovers depend on the methods used to ‘absorb’ knowledge generated by others, the costs of absorption and the nature of the R&D being absorbed.
- Spillovers not only provide a rationale for public support, but pinpoint other policies that are important in increasing the effectiveness of an innovation system. These include reducing the costs of absorption (such as skill upgrading) and facilitating research cooperation.
- Other reasons for public support with some validity are:
  - intangible factors, such as national identity, which relates mostly to scientific research in universities and public sector research agencies; and
  - the asymmetric tax treatment of highly risky investments, which mainly relate to R&D undertaken in small or newly created businesses.
- Problems in capital markets that could affect the availability of finance to risky or uncertain investments in small firms and start-up companies may provide a rationale, but come with strong provisos and significant uncertainty as to their true relevance.
- Some cited reasons for supporting the system, such as indivisibilities, business myopia, and the aspiration to achieve a transformation of Australia’s industry away from its present structure have weak validity. In many instances, they would entail completely different support arrangements than those currently observed.

3.1 Introduction

This report focuses on the impacts of public support for science and innovation, the impediments to the operation of the innovation system and the frameworks for assessing where and how public funding should be allocated and overseen.

A fundamental starting point for all of these tasks is the assessment of rationales for government intervention. This chapter explains why rationales are an important first step in deciding whether to support an activity (section 3.2). Since public support for science and innovation primarily takes the form of funds or tax concessions for R&D, a wide range of rationales for public support of R&D is then explored, with the major categories of rationale shown in figure 3.1. But at various points, the chapter briefly considers the (strongly based) arguments that public policy also has a broader role to play in improving the functioning of the innovation system. Many of these broader concerns are taken up in subsequent chapters.

A useful principle for judging the importance of rationales for public support is the likely implications were no public support to be provided. In most forms of current support, this amounts to assessing how much R&D would be carried out without public support and whether any forgone R&D would have been welfare enhancing or not.

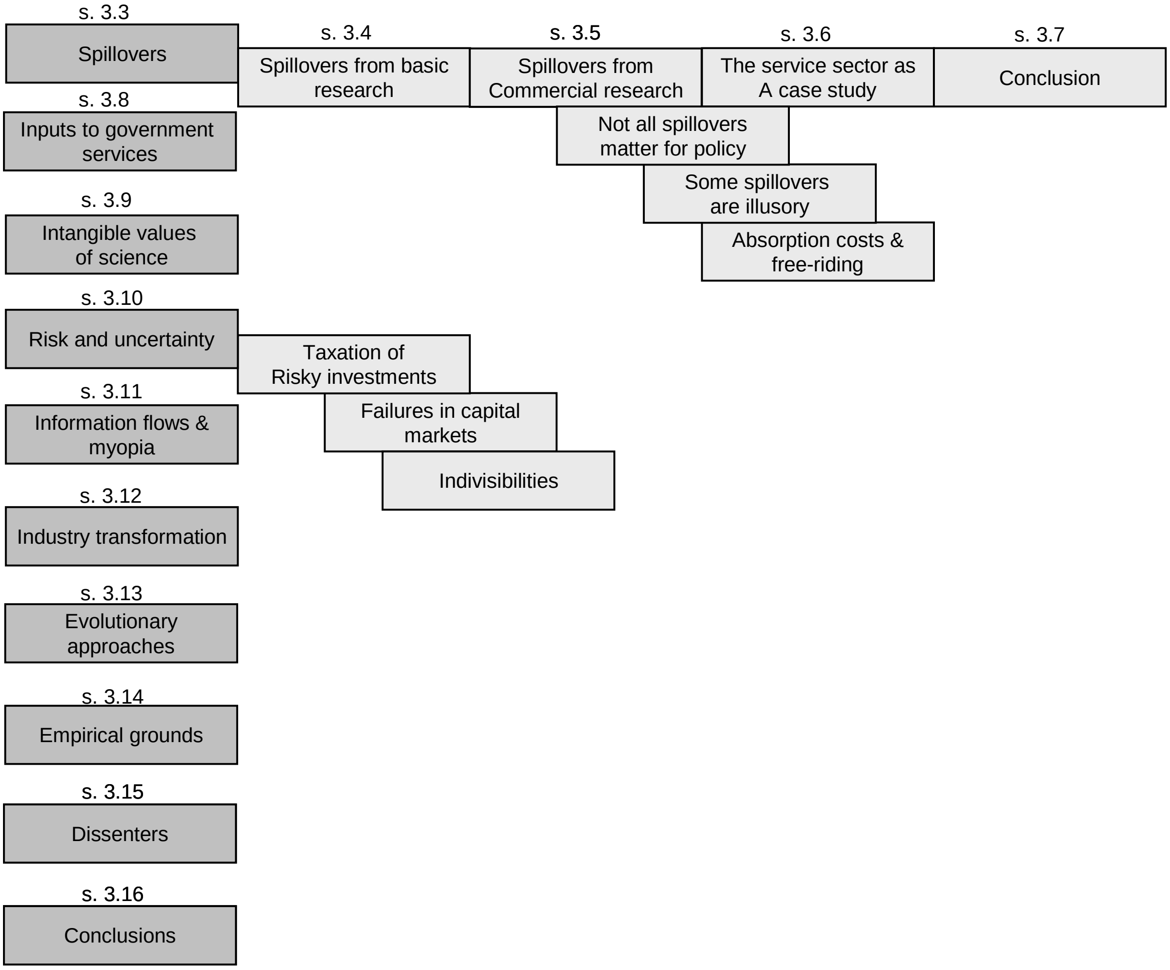
3.2 Why do rationales matter?

Public support of science and innovation should be based on clear and credible rationales. Such rationales identify areas where government actions are likely to provide net national benefits. They weaken claims for interventions based on other grounds, such as the demands of interest groups. Rationales usually describe a mechanism underpinning the need for an intervention (such as specific problems in markets that lead to less than optimal investments in R&D), not just a desired objective (such as productivity growth or reduction of poverty).

Describing rationales precisely has several major advantages.

It enables policymakers to test whether the problems that justify intervention exist and how widespread and enduring they are. For example, if private venture finance is not adequate for commercialising innovation by R&D start-up companies, is that for all types and phases of commercialisation, all sizes of start-up companies and all types of management structures?

Figure 3.1 A ‘map’ of the chapter



The specific form of a rationale shapes the design and evaluation of programs. Where the rationale is under-investment in R&D due to the incapacity of firms to capture a sufficient share of the total gains from R&D, the commensurate measures might be creating research consortia that internalise the gains, as in Rural Research and Development Corporations, or where that is not practical, subsidy arrangements. In this case, an evaluation strategy would focus on whether more R&D was performed and whether the benefits were diffused. If the rationale for a measure is failure in capital markets (section 3.10), then loans or equity arrangements that provide a full return to the government may be warranted, rather than pure subsidies. Such a program is self evaluating, since if it does not produce an adequate return, it cannot be true that capital markets have really failed at all.

Assessing the credibility of specific rationales allows policymakers and evaluators to better judge whether particular forms of public support are likely to produce net benefits, especially where empirical evidence on program impacts is uncertain. Chapter 4 reviews evidence about the aggregate impacts of public support and concludes that public support is likely to generate benefits for Australians in excess of budget spending. However, the Australian Government alone provided science and innovation support through at least 75 specific measures totalling $5.4 billion in 2004-05 (appendix B). While evaluations of specific measures provide some evidence of their impacts, it is often the case that these impacts are difficult to quantify in rigorous cost-benefit terms. Assessing the rationales for specific measures provides another basis for judgment about whether such measures are likely to have big impacts or not, which can then feed into decisions about where to allocate public support in the best way.

Rationales are a necessary feature of sensible public support, but are not sufficient. Policies that are, in principle, justified by appropriate rationales may, nevertheless be difficult to implement efficiently. There may be high administration and transactions costs, unintended impacts, capture by private interests, poor design and a range of other problems. Moreover, analysis of rationales sheds little light on another critical question — how much support is required. The rationales identified in this chapter could be consistent with public support of $2 billion or $10 billion.

The dual importance of rationales and design principles is why this report has a large emphasis not just on establishing that a convincing and robust rationale must exist (the basis for this chapter), but also in avoiding some of the pitfalls of past practices through improved program design (the theme of chapter 10).

3.3 Knowledge spillovers — the conventional rationale

It is often argued that R&D investments provide knowledge that beneficially and cheaply ‘spills’ over beyond the investor (Arrow 1962). The existence of such ‘spillovers’ provides the most frequently cited economic argument for government interventions.

Spillovers arise because knowledge can have some distinctive characteristics.

First, researchers often cannot appropriate the full returns from new knowledge, so that at the margin they do not invest in new knowledge. This may occur:

i. if firms and others cannot sufficiently exclude others from observing and using new knowledge generated by innovation (*non-excludability*) — spillovers may reduce incentives for developing new knowledge. Secrecy of, or complexity in, knowledge may give its generators some capacity to appropriate the returns, but usually not for long. Knowledge is therefore said to have only partial excludability; or

ii. if the value of a single fragment of knowledge is significantly increased when it is openly shared and combined with other fragments *and* it is difficult to negotiate prices for mutual exchange of knowledge. Individual investments in knowledge contribute to a body of knowledge at the industry, country or global level that is collectively useful, even when the parts that contributed to it are not very useful to their individual generators (Hall 2004). A physical analogy may be a jigsaw puzzle. The intangibility of knowledge, the scale of knowledge sets and the complexity of contracts for market exchange between parties, suggest that firms may often be unable to arrange coalitions among each other to jointly internalise the benefits of collective knowledge (though this does not rule out the conduct of some open basic science by firms).

Second, the generation of new knowledge may have high ex ante fixed costs, but the ex post incremental costs of diffusion are often relatively low (Stephen 1996). This trait of knowledge increases the likelihood that spillovers are large and also provides the justification for public support to meet the fixed costs of research, which is then diffused at marginal costs to many users. Such incremental costs are particularly low when:

iii. knowledge can be codified, transparently embodied in a product/process, or otherwise readily copied;[1] *and*

iv. there is an economical capacity to understand and employ it. More efficient ways of processing and sharing information through ICT have probably increased the capacity for cheap knowledge flows of these kinds.[2]

One way of addressing some spillovers is to assign property rights to intellectual property (IP), through patents, trademarks and copyright. However, property rights deal with (i) and not (ii), (iii) or (iv). Nor can they be readily assigned to some forms of knowledge due to the transactions costs of IP regimes (which, among other factors, are embodied in the difficulties in verifying ownership and the costs associated with enforcement). Even where rights can be assigned, they may still reveal useful information to rivals. They reveal that certain outcomes are technologically possible — aeroplanes or synthetic fibres, for example. Moreover, they must disclose the scientific mechanisms underlying the innovation, hence the

[1] This contributes to the prospects of (ii) above.

[2] It is commonly argued that knowledge exhibits *non-rivalry* in consumption. This arises when use by one party does not reduce the potential for its simultaneous use by another. While this is true for pure public goods, it is less clear that this holds strictly for knowledge. As Boldrin and Levine (2002) have argued, knowledge is only economically useful when it is embodied in people, machines or goods, which *are* rivalrous in consumption. In this case, considering the incremental cost of usefully embodying knowledge (diffusion) is probably a more useful way of understanding how spillovers might arise.

proliferations of ‘me-toos’ in the pharmaceutical industry. More generally, Levin et al. (1987) found that patent disclosure was the single most common way that competitors found out about rivals’ technologies. Similarly, copyright may protect given pieces of content, but they do not stop creative mimicry that selects very similar themes.

In any case, there is a tradeoff between IP protection, which creates incentives to create new knowledge, and the costs of monopoly, which is why the statutory provisions of protection are limited.

Spillovers still appear to be associated with R&D, even when an IP regime is in place. (The relevance of spillovers to public policy is contested by some — for example, Kealey 1996 and IPA sub. DR139. Some of these counterarguments are considered in sections 3.4 to 3.6 below and some broader objections to public funding in section 3.15.)

It is useful to consider arguments based on spillovers for two types of knowledge:

- basic research (primarily undertaken in universities);
- commercially valuable applied research activities, usually undertaken in business, but also sometimes in universities and public sector research agencies. This kind of research is the immediate driver of business-based innovation and has been the most rapidly growing part of Australian GERD.

Research that has broader, non-commercial, uses is discussed in a wider context as part of section 3.8.

3.4 Spillovers from basic research

Basic research, including knowledge about experimental methods and new instrumentation,[3] has some of the properties of knowledge described above. In particular, basic research has the property that its value is higher when it is aggregated into a collective stock of knowledge (condition (ii)). It is common for the most important papers in basic science to involve many institutions, often across nations, attesting to the cooperative and global nature of the open science system. For example, of the top 20 cited papers in science (recorded in the ISI index) from

[3] It is sometimes claimed that experimental methods and instrumentation derived from basic research are ‘not necessarily part of the knowledge system of science’ (Martin et al. 1996), and that therefore this economically valuable aspect of basic science constitutes a *separate* basis for public support. However, in most cases, the requirement for openness and replication of scientific experimental results also requires disclosure of information about such methods and equipment. Accordingly, we treat this knowledge as part of the knowledge system of science.

2003–2005, 17 involved multiple institutions (an average of 9 institutions per multi-institution paper), and 6 involved institutions across national boundaries.[4]

In this open system, new ideas come from many sources. For example, a slowly developed understanding of insect vision undertaken in several countries (including Australia) over the last 40 years, involving biology, mathematics and physics, preceded applied developments in long-distance light-guide transmission (communications) and in machine vision used in low flying aircraft and other unmanned robots (Horridge 2002).[5] But interestingly, the idea of considering applications in flying aircraft was influenced by the experience of one of the key researchers in applied aerospace research after the Second World War. This example illustrates that the benefits of the open science system are magnified by links across countries and disciplines, and between applied and basic research.[6]

It is not likely that arrangements that were strictly funded within the private sector could successfully achieve such agglomeration benefits given the diverse nature and scale of knowledge, though private companies are often partners in the open system. For instance, private companies were partners with public entities in 3 of the 20 top science papers discussed above. In the United States, it has been noted that relatively few industrial R&D performers expend any amount on basic research (only 10–12 per cent of firms), but that when they cooperated with federal laboratories more than 70 per cent of the collaborative research was of a basic nature (Rogers and Bozeman 1997).[7] This suggests the complementary role of the open system.

The knowledge gathered from basic science can often be readily codified (condition (iii)), which underlies the potential for geographically-separated researchers to undertake joint research, as well as its more general diffusion. Within universities, there are established institutional conventions that attempt to aid the cheaper diffusion of basic science by encouraging its codification, ranking its quality (Gans sub. 10) and increasing its assimilation through conferences, reviews, text books

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4 These data were obtained by examining the top 20 papers identified by ISI (at http://in-cites.com/hotpapers/shp/1-50.html) and classifying them by numbers of institutional affiliations.

5 These developments led to the Australia science prize for two Australian scientists (Allan Snyder and Mandyam Srinivasan).

6 Gans (sub. 10) outlines these interdependencies and sees science as an institutional form for their efficient production. He also argues that spillovers are *not* a valid basis for public support. But that is because he categorises spillovers as part of the faulty linear view that basic science knowledge leaks to applied science. If spillovers are considered more broadly as knowledge flows that can occur between any part of the system, then their relevance is retained — hence our continued use of the term.

7 And in these basic projects, the industry partner undertook basic research themselves in around 40 per cent of cases.

and other means. Given these conditions, public funding and the adoption of institutional arrangements that facilitate its global sharing may be the best way of maximising its collective value.

Non-excludability and ease of use may be less important

The spillover benefits of basic research do not require non-excludability or ease of use (conditions (i) and (iv)) to be met, as sometimes argued (for example, Romer 1992). Were public support not to be provided, the institutions that facilitate codification and open exchange would be weaker. But firms could often still exclude others from using or learning from their complex basic research through deliberate strategies, such as secrecy.

In other cases, even when there is 'leakage' of the science, there are frequently significant costs of absorbing complex knowledge by others that would partly protect the gains from research (a point emphasised by Davidson 2006 and Kealey 1996, 1998). After all, it is often claimed that even in the presence of the current institutions for spreading knowledge, absorption costs by users create barriers to the use of basic knowledge:

> Individuals need to develop substantial skills and to expend considerable resources to understand codified knowledge. It is a labour intensive process, involving extensive trial and error, effort and learning. Moreover, among individuals and organisations there are wide variations in the ability to make sense of the codified knowledge available to them. The ability to understand codified knowledge requires organisations to maintain a substantial and often expensive research capability. (Martin et al. 1996)

That said, the observation that secrecy or absorption costs help protect the gains from research does not mean that appropriability is complete. Secrecy is rarely absolute: it simply costs too much to ensure. And absorbing knowledge is far from free — as in the caricature given in some economic analysis — but it is often likely to be much less than re-inventing the science. A scientific team may work away on a problem and after $10 million dollars of spending, develop a complex new set of ideas that are far from easy to interpret and understand. But a properly trained scientist in the field and acquainted with the broad literature is likely to be much more able to quickly comprehend this result than generating it afresh. Their efforts may cost, say $100 000 a year, a fraction of the investment needed to generate the original knowledge. Accordingly, the existence of 'significant' absorption costs need not preclude problems in appropriability for the generators of new complex knowledge. The question then is when does this matters? No generalisation is possible.

Basic science is part of an innovation system, but only a part contributor to technological change

It is sometimes claimed that basic science is the key ultimate source of critical and novel applications that could never be anticipated by commercial labs pursuing strategic basic research. This can be true. For example, polymerase chain reaction, a key technique for DNA research underlying the biotechnology revolution, depends on Taq polymerase, an enzyme from *Thermus aquaticus*, an organism that was first isolated from a hot spring in Yellowstone National Park as part of basic research (Brock 1997). There are many other examples of new technologies that had their origins in basic science, but that could not have been foreseen in a commercial context.

But while there are often particular applications of pure basic science, the idea that basic science is generally the driver of fundamental new technologies is now generally seen as problematic:

- It is not an empirically sound generalisation. The dichotomy between basic and applied science is a loose one. Basic research can sometimes have explicit prospective applications — what has been called 'use-inspired' basic research to differentiate it from fundamental research that does not anticipate applications (Stokes 1997 and Gans sub. 10). Indeed, much of productive basic science discussed above under the rubric of basic science is use-inspired. Stokes provides many examples of use-inspired basic research including Pasteur's research in microbiology. Private firms, at least in the United States and the United Kingdom, do undertake basic research of this type (though they do little in Australia).
- Basic science may be triggered by preceding advances in applied science. The arrow does not necessarily just move from basic to applied science (the 'linear view'). Kealey (1996, p. 9) provides some vivid historical examples, including the discovery of carbon dioxide by Joseph Black,[8] an applied scientist, which led, through subsequent academic work by Lavoisier, to major theoretical advances in chemistry.
- Basic science may be useful sometimes because it does *not* lead to applications. Particular basic research can reveal unprofitable ideas that should not be investigated in an applied setting.

[8] Really the re-discovery of carbon-dioxide, since Van Helmont had discovered it initially about a century earlier (Jacobson 2002).

Basic science can directly trigger novel applications, but the broader perspective outlined earlier suggests that its value lies in its role as just one part of an dynamic interdependent system. In this sense, basic science is like an animal within an ecosystem or a component of a complicated machine, rather than as the ultimate origin of invention.

In summary

The most important rationale for public support of scientific research rests on the fact that this creates an institutional form for the conduct of science that maximises agglomeration benefits, cumulative knowledge generation and variety. These institutional arrangements also allow the development of globally recognised qualifications, educational processes and professional networks that develop highly specialised human capital. Hiring new graduates and tapping into such networks is recognised by innovating firms as an important source of new expertise and knowledge for generating business innovation.

The important question then is whether private agents would have the right incentives to develop an optimal system for undertaking scientific research. The thesis of this chapter, as outlined above, is that they would not. That does not mean that firms do not sometimes do basic science, but that they would not do enough. But theoretical spillovers need not materialise as actual ones — their elicitation will often involve careful policy design.

But such research need not always generate spillovers

While basic research has a form that encourages spillovers, it does not guarantee that such spillovers will always be realised. There are three major criteria (which are taken up again in subsequent chapters) that are relevant to realising spillovers from basic research.

First, the governance arrangements for basic research should be of high quality. The risk otherwise is that even if the research is potentially of high quality, it may not be funded efficiently, or complementary inputs (such as ICT, laboratory and field work expenses) may not be adequately provided.

Second, knowledge diffusion mechanisms need to be efficient. The reason that basic research is different from the kinds of research that are often undertaken within firms is that it exists in a system in which the exchange of research ideas is actively encouraged through publication, conferences, sabbaticals and other mechanisms. However, any weaknesses in these systems, including gaps in the way that knowledge may be disseminated to businesses, can erode the spillover returns, even if their potential exists.

Third, high spillovers require research of reasonably good quality. Peer review provides a major quality sorting mechanism for basic science, but not all research funding is subject to its disciplines and even peer review funding approaches have flaws. Consequently, some mediocre research will be conducted. Low quality research is unlikely to be published in influential journals or diffused widely, if at all, and is unlikely to generate substantial spillover returns. For every dollar of public funding allocated to projects of the lowest quality, the economic loss could be around \$1.20 to \$1.30 — the original dollar of funding, plus around 20 to 30 cents, associated with the economic costs from raising public finance.

Moreover, the poorest choices within the publicly supported basic research system are likely to be more costly than publicly supported ones in the business sector, especially where the latter support is made through tax concessions rather than grants. Businesses generally face strong commercial incentives to choose valuable research.[9] The most common risk is that publicly funded research projects are funded that would not otherwise have occurred. These are transfers not economic losses. For every dollar of public funding allocated to these business projects, the economic loss is around 20 to 30 cents, representing the efficiency costs from raising public finance. The marked contrast between the costs of the worst choices in the business versus the private arenas does not necessarily mean that public funding should be shifted to private R&D or that public funding of the basic system should be reduced. That will depend on the expected marginal payoffs, which are empirical rather than theoretical issues.

Summing up

Prima facie, there are grounds for anticipating spillovers from basic research and the risk of underinvestment in the absence of some public funding. However, there are still many questions about which specific research activities should be supported, the ways in which this might be done, their ownership, location, governance arrangements and the total quantum of funding that cannot be addressed merely by establishing a rationale for some support. In some cases, it may be that the practical issues involved in implementing policy make some interventions undesirable, though there were prima facie grounds for doing something. This is why the existence of a rationale is a necessary, but not sufficient condition.

[9] There have been some historical exceptions, such as later phases of the Syndicated R&D program of the mid-1990s, where tax loss companies with lower quality projects were inadvertently adversely selected by the program (Lattimore 1996).

3.5 Spillovers from commercially-oriented research

In the second type of research, commercially useful applied research, there is also a strong case that spillovers exist and that public support is warranted. This is because the conditions underlying spillovers set out in section 3.3 also apply to commercially driven research.

Firms’ research results often involve tangible outcomes in goods and services that can be emulated by competitors or by other firms. Employees are the footloose carriers of ideas. At the margin, this implies that firms will under-invest in research activities. Moreover, while the capacity for codification and useability (conditions (iii) and (iv)) above are often seen as mainly applying to basic science, in fact there are market mechanisms for both to occur in a business context. There are intermediaries that seek to codify firms’ spillovers and to diffuse them efficiently, such as technical consultants. Institutional arrangements, such as trade conferences and trade journals, also increase the diffusion of such ideas. Patents provide detailed disclosure of knowledge.

However, just as it is important to question whether all research in the basic science system generate spillovers that warrant public support, it is equally important to probe the nature of business R&D and to consider possible variations in spillover intensities. This can help determine where public policy might best be used to support business R&D. In the business case, the issues that adversely affect which sorts of research might be funded are more complex than those outlined above for basic research. They rest on three main contentions:

- not all spillovers matter for policy;
- some apparent spillovers are illusory; and
- the extent to which public support is justified depends on the methods used to ‘absorb’ knowledge generated by others, the costs of absorption and the nature of the R&D being absorbed.

These issues are examined in the next section.

Not all spillovers justify government intervention

Spillovers only matter if public supports stimulates additional R&D

Sometimes policymakers and others argue that spillovers per se need to be compensated to ensure efficient innovation. However, *if* the private returns are above the required rate, then the investment will proceed regardless of the magnitude of any spillovers. In such inframarginal projects, subsidies would have no effect on whether the investment is made, and no matter how big spillovers were, there would be no case for public support.

Thus, spillovers are only a relevant rationale for public support when subsidies change the private decision about whether to proceed with an investment.

Firms can develop more sophisticated inter-firm relations to internalise spillovers

In abstract terms, the 'firm' is an organisational form that economises on certain transactions costs associated with contracts (Coase 1937; Williamson and Winters 1993), but that nevertheless has many other explicit and implicit contracts with external parties that are often close to those that exist internally. Once seen this way, the boundaries of firms are often ill defined and fluid, with firms having the capacity to forge complex symbiotic relationships with other firms through consortia, supplier and customer relations and loose networks. This suggests that firms may have greater opportunities for appropriating the benefits of spillovers than the usual firm-centric view of R&D incentives suggests.

This is shown in real world situations over a long time span.

- In the industrial revolution, firms in the iron industry formed a loose network that freely exchanged technical information with competitors about the construction details and performance of their new blast furnaces and typically did not patent new methods as they developed them (Allen 1983).
- Likewise, in Cornwall, dissatisfaction with technological progress under Watt's extended patent-based monopoly on the steam engine, led to the creation of a loose collaboration and open sharing (including a widely available publication of technical results) that helped spur best practice use of steam technologies and better engineering in Cornish mines (Nuvolari 2001).
- Similar, loose networks are currently commonplace in software (West and Gallagher 2006).
- Patent pools, in which collaborating firms communally enjoy access to patents if they provide their own IP, have been used extensively, such as by US steel makers (Morison, 1966) and European GSM telephone manufacturers (Bekkers et al. 2002).
- In Australia, the Australian Mineral Industry Research Association (AMIRA) International, is an industry association that manages collaborative research for its members in the global minerals industry. By taking a partnership approach to research and development, which is managed by AMIRA, members gain better access to leading edge technology. Information is distributed via a web page,

with password protected access to the detailed technical results of research projects for sponsors. Some projects are co-funded by public research agencies.

- Some rural research funding pools in Australia are based on voluntary contributions (though these come with the sweetener of additional R&D subsidies from the Australian Government — chapter 10).
- In Australia, around one in seven large innovating firms (those employing 100 or more persons) engaged in joint R&D with other firms during 2003 (ABS 2006a). This form of collaboration was considerably lower in smaller firms (about 6 and 7 per cent in small and medium sized innovating firms).

Such strategies represent efforts by firms to facilitate spillovers, typically without the need for public support. As noted in section 3.4, these strategies are often not feasible for basic science, but they are much more applicable to reasonably narrow, but mutually advantageous commercially focused research.

The potential for such arrangements can also mean that it may be more effective for public policy directed at increasing spillovers to reduce some transaction costs between firms, rather than supporting R&D per se. The legal structures that allow mandatory R&D levies within certain rural industries in Australia are an example. There may be other ways in which public policy can reduce obstacles to, or otherwise facilitate, the formation of such cooperative arrangements.

The policy drawback is that the member firms will often need to apply a variety of policing efforts to ensure widespread cooperation (such as the reciprocity arrangements in patent pools), which can sometimes have implications for competition policy. However, since this is not a form of anti-competitive behaviour, they are not usually constrained by competition regulations.

Some apparent spillovers may be illusory

Sometimes looking at spillovers in isolation misses other ways in which innovating firms can make adequate returns to justify their investments.

Spillovers are partly internalised through the labour market for technical personnel

Movements of people carrying knowledge are likely to be a major source of information exchange between firms and other organisations. This is explicitly recognised within the public research system through mechanisms that encourage sabbaticals and collaborative arrangements.

However, businesses generally try to constrain the spread of trade secrets through this route, encapsulated by the quip from the Intel general consul: 'Don't let your employees do to you what you did to your former boss'.[10]

But Møen (2001), among others, has questioned whether such information exchanges necessarily constitute spillovers. To the extent that research has a training element, then technical personnel may pay for its accumulating benefits through lower starting wages with the original firm (and are subsequently rewarded by higher wages when more experienced). Using matched employee-employer data for the Norwegian machinery and equipment industries, Møen found a steeper experience-earnings profile in research intensive firms relative to other businesses, which is consistent with this hypothesis. Various alternative explanations for this pattern were tested and rejected.

But there are several important provisos:

- even in the firms studied by Møen, the results suggest some internalisation of spillovers by businesses through lower wages, but do not rule out the existence of some residual spillovers;
- in other cases of firm innovation, this wage mechanism may not be present; and
- universities and public sector research agencies have quite different internal labour markets from firms and have different objectives for undertaking R&D. Accordingly, Møen's findings should be seen as relevant only to spillovers from business R&D.

Nevertheless, Møen's results weaken the intuitive assumption that finding a potential route for spillovers means that they are therefore significant.

Firms may encourage the diffusion of their intellectual property if they can make money from associated activities

Firms may be able to extract the benefits from an innovation in unexpected ways even if they receive no compensation for the free or cheap use of their IP by others. In this case, incentives for innovation are not dampened even at the margin. The apparently 'spilled' knowledge is like a loss leader.

It is common in the ITC sector for firms to seek small or sometimes zero returns for the distribution of their IP in the form of software, but to seek to make their returns through advisory services where bigger revenues are available, or in better versions of software that can be sold (West and Gallagher 2006). Open source software

[10] Cited in Møen (2001).

(where the code is published and where there is a process of continued improvement from a multitude of users) can expand the market for associated services or fuel other innovation within the hosting firm sufficiently to warrant the divulgence of knowledge. In fact, in these products, free transmission of IP is not resisted by innovators, but used as a strategy for maximising competitiveness and future revenue.

Absorption costs and free-riding

As in the case of basic science, firms and other agencies must often make some investments in an absorptive capability to gain the benefits of others' commercially useful knowledge. This reduces the prospects for free-riding on the global science and innovation system. But the extent to which the presence of absorption costs are relevant for public science and innovation policy depends on the context. Appendix D sets out a taxonomy of the relevant circumstances as a guide to policy. The arguments underlying these are complex, and so are not repeated here. The general conclusions are discussed below.

Where innovative firms are engaged in competitive rivalry, each will undertake R&D to absorb each others' ideas, develop new innovations and to gain a temporary edge — thus pushing the knowledge frontier further out in a virtuous cycle. These circumstances are more likely in innovative oligopolistic industries, where firms are undertaking more radical business innovations. Public support may potentially intensify such cycles of innovation, but there are already strong incentives operating through market forces.

Where absorption of external knowledge is based on R&D that exploits non-R&D strategies (such as hiring experts) or that does not produce its own global spillovers, the grounds for public support are often weak. Absorptive strategies aimed at relatively cheap imitation of widely available technologies, while commercially useful, are likely to proceed without that support.

On the other hand, the costs of absorbing the equivalent foreign R&D could sometimes be high, but once available domestically may not be costly to copy. Leading domestic firms are then effectively forced to undertake more costly larger-scale R&D to absorb and partly re-create foreign stocks of knowledge. But if other domestic firms can cheaply absorb the knowledge created by these leaders, then the leaders have weaker than optimal incentives to undertake R&D and subsidies are potentially justified. Again, these spillovers are more likely to arise if the novelty of the innovation is greater and there are a wide group of other domestic firms than can exploit the knowledge generated within Australia by the technological leaders.

The same situation can apply if there is a need for innovation that is highly specific to Australian circumstances and the investments of leading firms can, as above, be cheaply imitated by rivals.

The importance of absorption further undermines simple international comparisons of R&D intensities. Pure free-riding is not possible, but clearly there are huge knowledge transfers across borders and a multitude of strategies to enhance these flows. It is more sensible to diagnose the capacity of the innovation system to allow efficient information flows from abroad and between the parts of the domestic system, than to consider a single metric that represents a particular narrow way of achieving this end. Public policy strategies that promote trade openness, investment in human capital at all levels, the free movement of (especially highly skilled) people across borders, the development of excellent ICT infrastructure, and appropriate standards are important methods for reducing the costs of absorption. They are likely to widen the types of investments that can be successfully used to promote absorption.

3.6 The paradoxical role of the service sector

The service sector is the most rapidly growing segment of the Australian economy (PC 2003b, McLachlan et al. 2002). The innovation dynamism of this sector (Potts sub. 18) provides a challenge to the conventional thinking about the role of public policy and spillovers. Spillovers appear to be ubiquitous in many parts of the service sector, though the innovative activities that lead to them do not necessarily involve R&D as usually defined. In these industries, many, but certainly not all, of the innovations visibly affect organisational structures,[11] business processes[12] and customer products.[13] By their nature, the broad ideas underlying these innovations are easily understood and reproduced in ways that are far less ambiguous than for knowledge flows in any other part of the economy.

However, these apparently ubiquitous spillovers in the service sector do not provide as strong a case for direct public subsidies for innovation as might initially be thought. This reflects that the patterns of innovation in this sector illustrate the points made about spillovers in the previous section.

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[11] Such as outsourcing arrangements and alliances.

[12] For example, billing methods, customer self service, human capital management and training procedures, database use and construction, spam and tele-marketing.

[13] For instance, bundling, new access points and speed of services.

In order to explore this, it is important to note the heterogeneity of the service sector — both split by the type of service activity and, particularly, the size of the firms concerned.

For small firms (in for example, retailing, restaurants and cafes, and personal services), many service sector innovations arguably reflect the routine, incremental experimentation that is merely part of the business of being a successful service supplier. The marginal effects of subsidies intended to elicit additional innovation are likely to be small in these firms.

For that part of the service sector dominated by large players or characterised by economies of scale, it is likely that many of the benefits of innovation can be internalised because:

- the specific realisation of the ideas often involve more appropriable technologies, such as proprietary software or complex, rapidly changing algorithms;[14]
- of their logistical capacity — realising the gains from the innovation requires efficient coordination of different functions and parts of the business; and
- of the need for co-specialised assets (Jaffe 1996), such as the ability to finance and undertake large scale complimentary investments to put the innovations into practice. For example, in the finance industry, changes to billing arrangements or customer information systems require large associated IT expenditures. New service bundling arrangements often require changes in the management of these services within the firm and substantial marketing costs.

This still holds even in cases where the broad innovative ideas are not expensive to create — such as the idea of self service, new billing methods or a distinctive bundle of services. The point is that their detailed realisation does involve large resource requirements, so that ‘free-riding’ is not an easily realisable goal, notwithstanding the likely pervasive nature and significant size of knowledge spillovers.

In responding to the draft report, the Department of Industry, Technology and Resources noted the potential importance of spillovers associated with interdependent innovation by service sector firms:

[14] Internet search engines provide an illustration. The idea of *having* an internet search engine is easily observed and able to be copied, as are general methods like web-crawling or popularity-based indexing, whose basic ideas are published. But the specific algorithms used to deliver efficient searches is not, either through secrecy, speed of development, or patenting. For example, in 2003, *Google* was successful in its patent application on its search engine algorithm.

> … spillovers from improved technology, process and business practice innovation are likely to be significantly higher than originally thought, particularly the benefits from much service industry innovation which cannot accrue by being implemented by one firm alone. The nature of the innovation requires increased inter-firm collaboration and convergence of systems from several suppliers. (DITR sub. DR185, p. 9)

Such interconnectedness is important in some areas of the service sector, such as in the case of software development discussed earlier or in widespread vertical and horizontal business relationships across many firms (for example, IT hardware manufacturers and operating system developers). But while interconnectedness may provide a mechanism for the transfers of knowledge spillovers, it does not necessarily require government support to encourage them. These relationships and information flows may be encouraged by individual firms since the gains from expanding the market for everyone exceed the losses from sharing. The critical observation is that knowledge spillovers only matter much for policy if they can be easily absorbed by others without large costly complementary investments and would not be forthcoming in the absence of public support.

For all of these reasons, most policy analysts contend that spillovers in the service sector do not affect the amount of innovation to a degree that would warrant *direct* public support for these activities. Even were support to be warranted in principle, it is highly unlikely an appropriate policy instrument could be feasibly designed because it is so hard to determine the boundaries of innovation in service sector firms.

Of course, while this applies generally, it may not apply to particular R&D projects or to research undertaken in universities or public research agencies that might have generic benefits for service sector agencies (for example, developments in e-health).

Moreover, there are stronger rationales for policy actions in the information economy, comprising content (written material, film and sound) and distribution networks (the Internet, broadcasting, telecommunications). This part of the service sector plays a central role in the creation and diffusion of knowledge. This is directly relevant to innovation, broadly defined, since media creation is a significant form of innovation in its own right, with large economic impacts. This approach takes the focus away from R&D to broader determinants of innovation (as noted by Scott-Kemmis sub. DR183).

- It places a spotlight on the design of copyright laws, which influence the creation and efficient diffusion of information, especially in a world in which electronic transmission of ideas has effectively reduced the marginal cost of dissemination to zero.

- It suggests the importance of infrastructure complementary to the electronic transmission of ideas, such as high bandwidth services and efficient postal services, both of which are regulated.
- It also emphasises the importance of avoiding regulations that frustrate the introduction of new services.[15]

Emerging policies for this segment of the service sector also recognise that another rationale for public support based on spillovers is not directed at their creation, but at lowering the cost of their absorption, especially for codified knowledge that is generated as part of publicly funded research. For scientific creation there are specific concerns about access to the results of publicly funded research, which is taken up in chapter 5.

Government is also a large buyer of services. In that role, Government can affect innovation in the service sector by not giving preferment, but by being a sophisticated, knowledgeable and demanding customer, as such demanding customers are a significant source of national economic advantage (Porter 1990).

More generally across the service sector, governments play a critical role in determining the framework conditions for business. These are likely to be more effective at stimulating business innovation than any direct forms of support. As discussed further in chapter 5 and raised by participants (DITR sub. DR185), a central government role involves removing the unnecessary regulatory burdens posed by government itself that can frustrate entry and exit, entrepreneurship, and innovation broadly. This role also includes building human capital and a broad research capability, where these are not likely to be developed by private agents. As observed by the Centre of Excellence for Creative Industries and Innovation (sub. 20); the Australian Academy of the Humanities (sub. 64) and CHASS (2006; sub. 52 and sub. DR171), this capability is not isolated to the natural sciences and engineering, but also includes the social sciences and the humanities. Education and research in these disciplines can have direct impacts on innovation in many parts of the service sector (for example, media, education services, tourism, finance, marketing and health services) and may have more subtle broad influences on creativity and innovation (Mueller 2006). Options pricing in finance and diagnosis related groups in hospitals (box 1.5 in chapter 1) provide examples.

[15] Several studies have examined the adverse impacts of regulation on new services (Prieger 2001, Hausman 1997). For example, regulatory arrangements that delayed the introduction of just one service — voicemail — in the US imposed annual costs of US$1.2 billion (Hausman 1997). The PC (2000) analysed some of the effects of Australian broadcasting arrangements on the development of new services.

Finally, as noted later, government is itself active as a supplier in some of the most knowledge-intensive parts of the service sector — such as healthcare and education services. This knowledge intensity is witnessed by the complexity of ICT solutions in all of these areas, and the adoption of new models of service delivery (such as Job Network). While it exercises these functions, government must provide public support for R&D and innovation generally in these parts of the service sector (section 3.8).

In summary, the case for business R&D or innovation subsidies per se appears weak for the bulk (though not all) of the *private* service sector on both conceptual and practical grounds. Public policy focused on general business framework conditions is likely to be a much more powerful instrument for stimulating innovation in business service (and other) industries.

3.7 The bottom line on spillovers as a rationale

The existence of spillovers that, at the margin, reduce the private incentives for research has been seen by economists as the major rationale for government support. The Commission has frequently cited this as the prime basis for public support (IC 1995; PC 2003a) as has the OECD, the World Bank and many Treasury departments. Chapter 4 examines the empirical evidence for their existence and magnitude.

The rationale, however, should not be regarded uncritically as the basis for subsidies to research activities. Apparent spillovers may be captured in surprising ways or may not adversely affect incentives to innovate by as much as formerly thought. The strongest case for public support based on spillovers occurs:

- for basic research in science, especially where most governance and funding mechanisms concentrate on the highest quality and most efficient diffusion practices; and
- where businesses are engaged in novel R&D activities induced by support that either spill over cheaply to others or that trigger cycles of innovation by rivals. The spillover benefits will be greatest when there are many potential domestic beneficiaries (generic technologies, or many potential users of the technology because of industry structures).

Spillovers not only provide a rationale for public support, but pinpoint other policies that are important in increasing the effectiveness of the innovation system. These include measures that reduce the costs of absorption (such as skill upgrading); that facilitate research cooperation; and that provide new mechanisms for the legal distribution of knowledge in a digital world (for example, copyright and journal publishing models).

3.8 R&D as an input into government activities

Most considerations of the rationale for public support of R&D start and stop with the alleged characteristics of new knowledge and the spillovers that arise from these traits. In fact, the spillover attributes of R&D are often largely irrelevant to the issue of whether funding is warranted for a significant portion of R&D receiving public support. A major reason for public support of R&D is that it is directly useful to many directly exercised functions of government. Governments need to invest in research to improve their goods and services or to better discharge their functions, just as in the private sector. Research is a valuable input into:

- defence technology (for example, DSTO's functions);
- alleviation of social and public health problems that are the responsibility of government (for example, crime reduction involving research into forensic science; social and psychiatric determinants of crime);
- the design of efficient and effective social services, such as in care of the disabled, management of public hospitals, child welfare case management, and systems of welfare payments for the unemployed;
- provision of higher quality education services (with substantial internal government research capabilities and significant research grants provided to numerous academics, consultants and institutions, such as the Australian Council for Educational Research);
- economic policy, regulatory decision and law making (for example, the economic research function of the Reserve Bank of Australia and Treasury);
- foreign, defence and terrorism policy advice (for example, as undertaken or contracted out by the Office of National Assessments; the Australian Strategic Policy Institute; the National Security Science and Technology Unit; and the National Institute of Forensic Science);
- broad environmental problems (for example, resolution of salinity problems, weed and pest controls, and climate modelling).

Many of Australia's National Research Priorities (chapter 9) fall clearly into research activities complementary to government functions. Many of the large data collections funded by government — often with complex associated specialist research — are primarily aimed at areas under the control of government. The data collection and specialist research activity of the Australian Bureau of Statistics is an example.

The examples above are applied and strategic 'use-oriented' basic science (including the social sciences and humanities). But governments also have an interest in funding basic science and research institutions, like universities, because they build up problem solving capabilities, provide a vehicle for absorbing research at the frontier[16] and supply training that can be useful to the performance of government functions.[17]

The absence of public support would mean considerable under-provision of knowledge and inefficient supply of government goods, services and functions that are dependent on this knowledge. The problem of under-provision would occur even if those undertaking the R&D could exclude others from observing and using the research knowledge cheaply (excludability), which is one of the requirements for a pure public good. This is likely to be the case, for example, in:

- much of the research undertaken by DSTO, where enforceable secrecy provisions apply; or
- areas where substantial investments in human capital, software and equipment may be needed to absorb, test and interpret results, such as some climate research.

In many instances, however, it is also likely that the *useful* component of knowledge from applied research itself is only weakly excludable, and the knowledge itself then assumes many of the characteristics of a public good. This provides further grounds for public support of such applied research. For example, the actual research that determines the best biological control for a given pest/weed can be technical and not necessarily easily transferred except to other biologists in that field. But the knowledge relevant to the particular application it generates is only weakly excludable because it often takes a simple form — what the biological control is, where to find it and how to release it. This knowledge is hard to appropriate by the researcher. So worthwhile projects would remain unfunded (or under-funded) if they were left to private provision. Moreover, the low marginal

16 And one of the quid pro quos of getting excellent scientists to interpret emerging results from the literature is to give them rewards that they value. This is often not money. As Kealey (1996, p. 229) notes, 'Good scientists have to be bribed with considerable liberty'.

17 Kealey (1996, p. 264), an opponent of public funding of science, argues that business has an interest in funding basic science in universities because of the capabilities that they provide for business innovation. But once it is recognised that governments must innovate because they also provide productive outputs, governments would also have an interest in funding university research on grounds identical to that of business.

cost of copying the knowledge and applying it suggests that it is optimal to encourage its adoption through zero pricing — as with public goods.

The major concern about public support of R&D that is an input to government services is where government exercises a responsibility that would properly belong in the private sector.[18] Where this occurs the appropriate reform is to transfer responsibilities to the private sector, and until then, not to make the quality of public provision worse by reducing public support for the R&D.

Government R&D support will depend on other policy settings

While there are grounds for support of R&D that is an input to the functions performed by government, these justifications need to be constantly assessed as the role of government and the economic environment change. For example, given concerns over global warming there is a strong rationale for publicly funded research into technologies that lower CO_2 emissions or that lock up existing atmospheric CO_2. However, the argument for *public* support of this research would weaken (but not vanish) were taxes on global CO_2 emissions to become a feasible policy option. Taxing would provide stronger incentives for more private funding of the research by emitters.

But does government have to *do* the R&D?

While the complementary role of research to government services provides a strong rationale for funding that research, it leaves open several major governance issues. It does not automatically require that the research be undertaken by the public sector or even within Australia. In some cases, it may be desirable to have private and public agencies compete for applied research projects. The appropriate choices for institutional location and organisation of applied research will ultimately depend on synergies with other research activities, the advantages of Australian capabilities, and relative cost efficiencies.

The other major issue is the control and management of the research agenda and funding among the many arms of government. In some instances, such as DSTO, it is efficient for funding to be provided through an intermediary public sector agency that has principal responsibility for the provision of the service in question (such as

[18] In fact, many of the functions exercised by government are public goods for which there are strong government grounds for provision. For example, defence, the legal framework, foreign policy and the resolution of broad environmental problems would usually be regarded as public goods. In these cases, even if R&D is not a public good, it plays a complimentary role because it is an input into a good or service that is itself a public good.

the Australian Defence Organisation). In some other areas, no single agency may be responsible, or it may be difficult for the responsible department to contract potentially politically damaging research, even if it is ultimately in the public interest. Salinity, for example, affects tourism, environment, industry, agriculture and regional employment, which are the responsibility of multiple government departments across many Australian jurisdictions, so that it can be more efficient for funds to go directly to research agencies (as in the majority of funding to CSIRO). So the complementarity between supply of a service and research by an arm of government does not necessarily imply that the two activities need to be funded and controlled exclusively by that arm.

These issues are taken up in more detail later in this report.

3.9 Intangible values: a cultured and worthwhile society

Generally, the value of public support for the science and innovation system is cast in cost-benefit terms, reflecting its productivity effects or the specific measurable environmental or social problems it can solve cost effectively. These are often seen as the major criteria for assessing the extent and nature of public investments in the system.

The net benefits to society from support of science and innovation also include intangible benefits, though these are sometimes overlooked. The World Bank (2001) has explicitly adopted a broad framework that recognises these intangibles when assessing, for example, the role of higher education.

In this context it is important to pose the question of the role of public support for science and innovation in a 'good' society. The value of re-casting it in this way is that it considers aspects of the system that are still valuable, but that might otherwise be neglected (Marginson 2001). As the Nobel prize winning physicist, Richard Feynman, quipped 'Physics is like sex: sure, it may give some practical results, but that's not why we do it.'[19]

From this broader perspective, there are three *separate* intangible grounds on which public support of science and innovation might be justified:

- as a cultural statement of the kind of society we have created for ourselves;
- to increase national prestige; and
- to meet moral obligations.

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[19] http://en.wikiquote.org/wiki/Richard_Feynman.

Identity

The important role of the scientific mode of thinking about the world is one of the defining aspects of our society. This mode values the application of rationality and evidence when considering issues — whether social, political, economic or in the natural world. It can be seen as promoting social self-knowledge and reinforcing an important part of our cultural identity, such as pleasure from knowing more about Australia's unique environment or the appreciation of the role of Australian science in world breakthroughs, such as the recently successful development of a vaccine for cervical cancer. The Queensland Government (2005, p. 31), for example, argued that valuing science was both economically useful, but also important in this wider sense:

> A vital culture is one that embraces a sense of discovery, creativity and imagination at the same time as basic human values of compassion and respect. Our future depends on valuing the status of knowledge and a curiosity about new ideas.

Prestige

Science and innovation can also increase national prestige. The race by the United States and the then USSR to get the first person in space after the second world war is an indication that national prestige can be a non-trivial reason for support (Dick 2005; CSIRO sub. 50).

These arguments for support can sometimes be conceived as a special form of public good, because the value people get from these aspects of science could not be appropriated by the originators of new knowledge and because any individual's benefits do not come at the expense of others. For example, suppose that a voluntary subscription service were proposed to fund the Parkes radio-telescope, which played a major role in space exploration and research. There would be a risk of under-subscription because many people would be still able to gain pleasure and a sense of national pride from its major scientific achievements, without having to subscribe (the standard 'free-rider' problem). However, the existence of prestige value should be substantiated, not merely asserted.

A moral obligation

Finally, public support could be seen as an obligation by a rich country to make a significant contribution to the stock of world knowledge, which also affects national prestige. CSIRO (sub. DR184, p. 6) for example, commented:

> There is also an international dimension to this issue as Australia's national prestige and international influence require a commitment to address global issues at a level

commensurate with our stage of economic development to show that we are not free riding on overseas research.

Whether this is a convincing rationale depends on whether such knowledge production is a more cost-effective way of meeting such global obligations than other possible solutions. But it is, at least, a defensible rationale.

Quite apart from the general contribution to the global common pool of knowledge, publicly funded science and innovation can also have an application to foreign aid, as in agricultural or medical research undertaken for applications in developing countries. An important question, however, would be whether research that is provided as effective foreign aid actually has the desired applied impacts. This issue is considered in chapter 4.

The three rationales have to be critically assessed in actual funding decisions

There are many policy questions about how arguments based on identity, prestige and moral obligations can be translated into decisions about the quantum and allocation of science and innovation funding.

- If scientific curiosity is the trait to be valued, then what does this suggest about the breadth, governance and variety of research to be supported? CHASS (sub. DR171) for example, suggested that the value of curiosity was best stimulated by allowing research funding to go to creative people across a wide range of fields, rather than to well anticipated outcomes.
- To what extent are the views of the general public to be taken into account? If people are more interested in astronomy, health and the environment, does this suggest preferential funding for these disciplines over other fields?
- What measures should be used for gauging prestige — large publicly successful scientific projects, medical breakthroughs, Nobel or other international prizes, and excellence generally? Who decides what is prestigious?
- To what extent should scientists be expected to engage generally with the public about the meaning and value of their work, and should the system generally encourage public science understanding?

Whatever methods are used to answer these questions, the decisions about public support for science and innovation based on these intangibles may often need to be made in a different way and with a different discourse from that used for support undertaken on more utilitarian grounds.

Inevitably and appropriately, decisions would ultimately require value judgments, and therefore be made through the political process. It would also be appropriate to at least consider whether it was likely that *large* publicly funded projects really were likely to benefit Australia's prestige, national identity or meet any moral obligation in the public eye. As the IPA (sub. DR139, p. 2.) note there is a risk that '… any white elephant project can be said to provide 'national prestige'.'

The values of cultural identity, national pride and moral obligations — while hard to quantify — have validity as a basis for public support of science *when they reflect the public's preferences*, not just those of the funder or funded.

3.10 Risk, uncertainty and capital markets

It is commonly argued that there are major market failures in the provision of finance for risky R&D projects. This section sets out the mechanisms for these failures and outlines some of the evidence used to indicate their existence. It also raises questions about whether all of the apparent failures are real or, instead, represent reasonable market responses to unavoidable and costly phenomena, such as information asymmetries.

Tax treatment of risky investments

The strongest grounds for concerns about capital markets stem from the actions of government itself — through regulatory and taxation arrangements. Of these, the treatment of tax losses in many income tax systems may be an important source of distortion for risky investments, of which R&D is a particularly risky class. In most corporate tax systems, including Australia's, tax losses are treated asymmetrically. Profits are taxed now, while losses must be carried forward and thus lose value through discounting — often appreciably so. In effect, under the current system, governments generally share 30 per cent of the gains of risky investments if they yield positive returns, but bear considerably less than 30 per cent of the losses if they do not.

The literature on the effects of corporate tax asymmetry is highly complex and assumption dependent, but generally suggests that for entities ultimately having positive cash flows, the asymmetry reduces incentives for risky irreversible investments (Heaton 1987; Myers and Majid 1986; Auerbach 1986). For example, Heaton concluded:

> The unwillingness of the government to share equally in firms' gains and losses for tax purposes … leads to a bias against high risk projects that may result in underinvestment in these projects. In addition, if the institutional framework of debt markets is such that

high risk projects have more difficulty obtaining debt, then this disincentive to invest in high risk projects is exacerbated. If the government wishes to offset the disincentive to invest in very risky projects in which risk is measured by the variance of outcomes, it may need additional incentives such as the research and development tax credit.

The asymmetry appears to affect two groups of firms particularly — entry by new firms, and firms that cannot flexibly adapt their sources of finance (Faig and Shum 1997). Small, young, R&D-intensive firms may, therefore, be particularly affected.

The asymmetric treatment of losses is not a rationale for R&D policy per se, for there are many classes of investment that are potentially affected. However, there are several theoretical and pragmatic considerations that suggest that a broad approach is not warranted and that the asymmetry does provide a rationale for dealing with its effects for (certain kinds of) R&D assets alone.

Why is asymmetry a rationale for special treatment of R&D alone?

It is not possible to remedy the broad effects of the asymmetric treatment of losses in the current tax system by allowing immediate deductions for all tax losses without the risk of widespread rorting. The R&D Syndication program demonstrated the risks of this in the 1990s.

One practical remedy with fewer risks to general revenue is to quarantine immediate deductions for tax losses for risky innovative investments alone, as is currently done for the losses of small firms (box 3.1). The main issue, even within a quarantined arrangement for exchanging tax losses, is whether the rationale for privileged tax treatment is limited to some firms or investments. There are several relevant dimensions to these boundaries — the size of the firm (or its losses) and the type of risky investment.

Size

The existing R&D Tax Offset program is available to firms with R&D between $20 000 and $1 million and with group turnover below $5 million. Clearly many R&D performing firms with tax losses will exceed these thresholds and will be unable to make use of the Tax Offset provisions.[20]

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[20] While now dated, the BIE survey of Tax Registrants undertaken in the 1990s provides some indication of the extent to which R&D-performing firms with tax losses would be eligible for Tax Offsets. At that time, just over one half of R&D-performing tax loss firms would have been eligible (on an inflation adjusted basis) for Tax Offsets, but given the small size of their R&D values, the effective value of their R&D tax losses were only around 10 per cent of total effective R&D tax losses.

On the other hand, the absence of any conditions may lead to strategic exploitation of the provisions through the manufacture of tax losses. Moreover, larger firms have generally more scope for diversifying their activities so that they can offset losses in one area against another, and arguably may be more able to restructure their business or choose financing rules that reduce the biases of tax asymmetry (Faig and Shum 1997).

Box 3.1 **The R&D Tax Offset**

The Tax Offset component of the R&D Tax Concession allows small firms to obtain the full benefit of their tax concession claim, regardless of whether they are in profit or not. For example, a firm spending $100 000 on R&D eligible for the 125 per cent deduction will be given a tax benefit of:

Tax_rate × *(1+concession_rate)* × *R&D* = 0.3 × 1.25 × $100 000 = $37 500

Had it had to wait five years to realise the gain, then with a discount rate of 10 per cent, the value of the realised deduction would have been $23 284 or 38 per cent less. In this example, the tax offset is combined with a concessional treatment of R&D (which relies on another rationale), but were the concessionary component to be removed, there would still be *a priori* grounds to preserve the tax offset for the non-concessional component.

The type of risky investment

There are non-R&D investments associated with early commercialisation of R&D that remain highly risky (as well as other investments quite unconnected with R&D, such as new business ventures in new industries). Accordingly, it is difficult to know how the lines should be drawn in counteracting the impacts of tax asymmetry.

It may be argued that the level of risk associated with R&D investments is particularly high relative to other projects, and that the ability for the firms that undertake it to diversify or fund it in tax effective ways are more limited than many other risky projects (like infrastructure developments). It is possible that this argument may be extended to early commercialisation costs too. In the latter case, it is probably not appropriate to provide tax offsets given risks of abuse, but it *may* provide a (tentative) rationale for subsidies to eligible early commercialisation projects or venture capital provision that meets appropriate risk criteria. Of course, governments already support the early stages of commercialisation and the venture capital market. Thus, even if this rationale were accepted, it may not have a significant impact on the current policy landscape.

The IPA (sub. DR139, p. 2) argues that the rationale based on tax asymmetries is not an appropriate basis for public support because it reflects a government failure. However, the underlying presumption of this argument is that such government failures can be fixed readily. That is not clear in this instance. Neutral taxes involve many practical difficulties and would be subject to many risks that a prudent government would wish to avoid. Consequently, once the practical difficulties of dealing with non-neutral tax treatment are considered, compensating measures for the most affected class of assets may be appropriate grounds for public support of business R&D.

‘Failures’ in capital markets

Quite apart from possible regulatory, taxation and institutional problems in capital markets, it is often claimed that there are major market failures that affect the efficiency of debt or equity provision for risky R&D projects (Stiglitz 2002; Hall 2002; DITR sub. 93). As we show later, it is not clear that these really are failures, but it is worthwhile setting out the arguments and the evidence for them.

The problems are grouped into three categories.

First, it is often argued (starting with the seminal work of Arrow 1962) that the high risks entailed by research activities and, in some cases, the absence of knowledge by their financiers or performers of the underlying probability distribution of project returns (uncertainty) means that socially worthwhile projects will be left unfinanced.

Second, a similar argument is that there can be asymmetric information about the quality of a research project that can frustrate financing — the researcher ‘knows’ it is worthwhile, but the potential backers do not know, and cannot trust the researcher. This is akin to the ‘lemons’ problems associated with the sale of second-hand cars and can mean that good projects will not be financed.

Third, recent theoretical elaborations of these, essentially information-related, problems suggest that there can be other sources of financing constraints, associated with principal-agent problems within the firm and difficulties in signalling to markets the value of intangible assets, such as R&D human capital (Hall 2002).

Sometimes the statements by risky firms that they face barriers to finance are seen as adequate substantiation that capital markets are failing. Certainly, innovative firms cite greater difficulties in obtaining finance or face higher costs of finance (table 3.1).

Another strand of evidence, supported by numerous international studies (Hall 2002), is that firms' R&D is 'excessively' responsive to retained earnings. These results suggest that firms must have some unexploited R&D opportunities that provide adequate rates of return to the firm, but that could not attract external finance, or that were not profitable using costly external finance. Either way, this excess responsiveness suggests a gap between internal and external costs of finance. However, there are sizeable econometric and measurement problems affecting these estimates. Such excess sensitivity was not found by the Commission in its analysis of business data from the ABS Innovation Survey (appendix R).

Table 3.1 **Perceived problems accessing finance**

2003, Australian firms, by employment size[a]

Share of firms facing obstacle:	*Small*	*Medium*	*Large*	*Total*
	5-19 persons	*20-99 persons*	*100+ persons*	
	%	%	%	%
Innovating firms				
Cost or availability of finance	19.3	20	15.1	19.2
Excessive economic risk perceived by financiers	4.7	11.5	6.5	6.7
Excessive economic risk perceived by the business	23.7	25.3	28.2	24.4
Non-innovating firms				
Cost or availability of finance	9.9	9.1	6.2	9.7
Excessive economic risk perceived by financiers	4.1	3.9	1.9	4.0
Excessive economic risk perceived by the business	8.3	10.4	8.1	8.7

a It should be emphasised that the data relate to innovating firms, which is a far wider group than firms that undertake R&D. So patterns found for R&D performers may be different from those for innovators.

Source: ABS (2006a).

A further indicator of the potential for market failure would be if the risk-adjusted portfolios of venture capital firms *systematically* earned higher returns than the market, since it could be expected that entry would occur to compete away the premium.[21] This is supported by some evidence that US venture capital firms as a group earn higher rates of return, despite significant entry into the venture capital industry (Hall 2002, pp. 26–7).

There is evidence that capital constraints may be more significant for small firms and start-ups than for large firms. Big firms have reasonable avenues to access finance for risky projects, internally through their capacity for diversifying risk or

21 A rival explanation for premia could be the presence of tax or regulatory problems.

through conventional equity markets. While some small highly innovative firms access venture finance, this financial form is relevant only to a small proportion of small innovative firms. The distinctive difference in financing sources for different sizes of innovating firms is the greater reliance by smaller firms (employing 5–19 persons) on debt finance[22] and their reduced capacity for accessing internal financing. Debt will typically be less 'patient' than other financing sources and exposes the borrower to default risk.

On the other hand, the *difference* in the proportion of firms nominating the cost of finance (or its availability) between innovating and non-innovating groups was about the same across firm size (table 3.1). This is not consistent with deeper problems for the smallest firms. This may reflect that the ABS data relate to innovation broadly, and not to R&D.

In summary, there is evidence that certain types of risky projects, usually undertaken by start-ups and small firms, find it more difficult to access finance than other projects. The fundamental question is whether these difficulties reflect imperfections in markets or the real costs that financial intermediaries face when dealing with small risky firms.

Do difficulties in accessing finance represent market 'failures' in capital markets?

A major limitation of some descriptions of 'market failure' problems based on information asymmetries, other transactions costs and general uncertainty is the definition of the appropriate counterfactual. If the counterfactual is a market with no information gaps, then the existence of information asymmetries and its consequences are indeed 'failures'. But if the counterfactual is one in which transactions costs are viewed as real features of the market, like other costs, gaps in finance do not necessarily constitute a failure (Zerbe and McCurdy 2000; Demsetz 2002). These costs may be like other transaction or production costs, such as transport costs. Few would argue that there are efficiency grounds for governments to act as freight intermediaries or to subsidise freight costs because some trades do not take place in the presence of transport costs.

From this perspective, a gap between internal and external costs of finance need not signal a 'market' failure, but reflect the role of the firm as an economiser of transactions costs that are higher outside the firm. Inside the firm, principal-agent problems associated with information asymmetries are much less. Managers know more about the merits of various projects and whether their internal advocates may

22 33 per cent of small firms, compared with 9 per cent for medium and large firms (ABS 2006a, p. 71).

be exaggerating their benefits and prospects, and these managers have a wide range of carrots and sticks, not available to outsiders, for penalising poor internal disclosure.

A rationale for action would have to be based on a privileged capacity for government to:

- use its own judgments to economise on transactions or information costs for firms who need to access external finance because they do not have recourse to retained earnings; or
- apply coercion, subsidies or guarantees, which do not reduce these costs, but that result in improved welfare outcomes.

Of the two, the first is implausible. It is hard to imagine circumstances when government has a capacity superior to private agents for processing and collecting information about the prospects of R&D projects.

In the second case, there are *theoretical* instances when governments can improve finance outcomes and overall welfare through simple measures, such as interest rate subsidies, without overcoming information asymmetries.[23] However, some theoretical studies suggest taxes on credit not subsidies (de Meza and Webb 1987); others find that the apparent benefits of government policies are offset by strategic responses by intermediaries. The results are strongly dependent on model assumptions, and, in all models, financial intermediaries are characterised as relatively unsophisticated.

This belies the actual characteristics of financial intermediaries and ignores the dynamic capacity for such intermediaries and their clients to develop their own solutions to information asymmetries, adverse selection and other agency problems. For example, warranties, collateralisation, development of specialised expertise in judging risky R&D ventures, and giving up managerial control to financiers have been developed as mechanisms to solve or reduce the problems posed by asymmetric information in goods and finance markets. Finance markets are continually adapting to develop new approaches for dealing with asymmetric information, whether it be R&D or other risky investments. Indeed, in models of risky finance, Lacker (1994) was unable to find circumstances where government intervention in loans markets was superior to new forms of financial intermediation. Government interventions in capital markets risk impeding the development of innovative private initiatives.

[23] For example, Ordover and Weiss (1981), Mankiw (1986), and Minelli and Modica (2006).

A further concern for policy interventions in highly risky activities, like R&D, is that governments face political penalties for bearing risk. Wallsten (1997) examined the financing arrangements of the Small Business Innovation Research program and found that it had low additionality, almost completely crowding out private finance. He conjectured that the low additionality reflected the political need for commercial success, which prompted fund managers to select the most promising projects, which would have received private funding anyway.

An alternative problem is that governments may be less able to credibly commit to early exit strategies from financing a firm's project because it may be seen, politically, as failing to provide sustained support. This is important because the existence of highly uncertain, but potentially highly profitable, R&D projects suggests an options approach to financing projects compared with the usual static financing approaches. Under an options approach, the financier puts forward finance for a project to commence, with the option of discontinuing finance if the technology looks unpromising later. But failure to exit at the right time eliminates the virtue of the options approach.

Overall, a broad reading of the literature suggests limited scope for governments to use policy instruments to improve welfare outcomes from any financing gaps. As Parker (2002, p. 28) concluded:

> While credit rationing is impossible to reject on theoretical grounds, human ingenuity at devising rich and specialised contracts can be expected to reduce the scope for its emergence; and its empirical relevance appears to be rather limited at best. In view of the … fragility of policy analysis based on credit rationing models, this is probably just as well.

These concerns about capital market imperfections suggest significant caution in giving public support on this basis. It suggests any policy measures should have sunset clauses and periodic evaluation. They should not be premised on the unrealistic potential for government to wield superior information, in which case they will have to demonstrate that other arrangements, such as subsidies, will yield positive welfare outcomes. The ultimate test of whether capital market failures are present is fortunately transparent (if they are evaluated). Government should observe long-run gains from such financing that are higher than other private investments. If these fail to materialise, the rationale is an empty one.

It is important to distinguish policies that might use capital markets as a mechanism for public support from policies that are intended to overcome deficiencies in capital markets themselves. For example, stock-option grants, a form of equity finance (chapter 10), aim to support truly additional R&D projects with high spillovers, not to overcome capital market problems.

Indivisibilities

A project may have to be very large to be profitable, and its scale may be beyond the capacity for private financing. Examples might be pharmaceutical development, major aerospace projects, space and defence technologies and nuclear fusion development. This might be seen as more severe in a small country. However, the argument provides a poor foundation for government intervention as many businesses — or consortia of businesses — have been able to undertake very large R&D investments, without government assistance. As noted by Boldrin and Levine (2005) in a US context:

> The famous big movies “The Titanic” and the “Lord of the Rings” cost $200 million each in 1997 USD; DiMasi et al. [1991] estimate the average cost of bringing a new drug to market at $231 million 1987 USD, including clinical trials (which are a public good). Hence, privately financed ideas have an indivisibility that is, at most, 1/10,000 of US GDP. … Finally… we are all familiar with the “Genoma Project” and the fact that, because its indivisibility was [apparently] so large, it had to be financed by the public purse. Still, we are also all aware that, in spite of the public project to be already underway and, hence, in spite of the fact that the most of the (de)coding of the human genoma was going to be in the public domain, a relatively little private entrepreneur was able to pay for that large indivisibility, recover it, and make a non negligible profit by competing against the public enterprise. (pp. 56–7)

Cooperative arrangements between firms, on many occasions across national boundaries, can resolve the costs of development for very large projects. For example, this is often used in aerospace development or, for small biotechnology companies, by taking a drug to market through licensing to a large global pharmaceutical company. Many of the large projects cited as examples of indivisibilities are really financed by governments for public good and prestige reasons (such as the Manhattan project, development of the European fighter and the Apollo program).

Empirically, the rationale is revealed to be largely irrelevant to public support decision making. Most Australian public sector research and almost all university research is directed at relatively small-scale projects. Exceptions are large expenditures associated with certain infrastructures — nuclear technologies (ANSTO), the Synchrotron and telescopes. But their justification is not some indivisibility. Rather, they represent a shared resource for basic research with spillover benefits and capability building (or, in ANSTO’s case, a complementary isotopes manufacturing capacity).

3.11 Tackling myopia and information deficiencies

The issues that potentially reduce the efficiency of financial markets are part of a broader class of potential difficulties affecting information exchange between principals and agents (Stiglitz 2002). In particular, it is sometimes claimed that smaller firms lack good internal resources for assessing the usefulness of external information. They will therefore tend to place a discount on the uncertain value of information services offered by intermediaries (such as advice on technology and commercialisation). This may eliminate exchanges that are, absent such asymmetries, worthwhile to small firms' capacities for innovation.

This argument suffers the same pitfalls that beset assertions of market failure in capital markets, but with one possible exception. Public sector agencies — universities, public sector research agencies, standards bodies, and regulators — often act as providers of information services, because, by the nature of their tasks, they have privileged access to certain information (for example, a particular technology that has been developed in a university). Yet these agencies are often not subject to the competitive pressures of private services and, therefore, may not have the same incentives to develop measures that reduce the impacts of information asymmetries. This may provide a rationale for at least being open to policy proposals that might lessen the impact of information asymmetries between publicly-owned bodies and private ones. For example, these might include:

- developing contingent fee arrangements on IP, whereby IP is transferred on the basis that it is free unless subsequently used in a successfully commercialised project. This is effectively a stock-option grant, but with the grant being in the form of initially free IP; and
- encouraging more effective commercialisation arms in universities and units within public sector research agencies, or developing intermediaries between such institutions and businesses.

Information policies may also have a role as mechanisms for providing subsidies that might be better than cash grants. For example, giving away IP in some circumstances may be preferred to a subsidy for R&D because the IP is more likely to stimulate truly additional R&D and to generate spillovers than general grant or R&D concession schemes.

But such information policies are not rationales for public support of innovation, but rather intended to overcome deficiencies in government agencies or acting as a possible instrument for dealing with spillovers. They may be useful policy instruments, but they are not rationales for assistance to innovation per se (IPA sub. DR139, p. 2).

A more contentious class of information problems occurs *within* firms. It is sometimes argued that businesses, especially small ones, are myopic or fail to act on information that is cheaply available and of benefit to their enterprises. There is considerable evidence that R&D is often privately profitable for firms, but some firms do not undertake much R&D or access technologies that are important for innovation. There are several grounds for questioning whether this provides a basis for public support for R&D and technology/commercialisation extension services.

First, it is hard to know where myopia is present and where not, because there are other equally hard to observe factors that can explain why firms might not undertake R&D when it appears to be privately profitable. For example, in these cases, low R&D might be testimony to high transactions costs or the absence of complementary assets in the firms concerned.

Second, firms are continuously learning and so are constantly reducing information problems as they emerge. Competition is a dynamic process that discourages myopia or other information deficiencies. Poorly performing firms have incentives, through low profits, to improve or fail. And many private sector intermediaries — like banks and consultancies — have strong incentives to provide information that reduces deficiencies in the key aspects of firms' management.

It is likely that the most appropriate policy response to apparent business information failures of these kinds is to ensure that competitive processes and institutions are functioning adequately (such as ensuring the removal of excessively costly regulatory entry and exit barriers, the introduction of strong competition policies, appropriate bankruptcy provisions, reducing inappropriate impediments to specialised intermediaries, and improvements in the quality of education systems).

To the extent that information problems remain, it is more likely that they lie at the periphery of the key strategic concerns of business managers.[24] Innovation, however, is central to firms' strategic concerns. The grounds for using myopia as a rationale for public funding support for innovation are weak.

3.12 Successful firms and transformed industries

The rhetoric and objectives for some industry R&D programs are *not* cast in terms of the realisation of outcomes related to valid rationales, like spillovers or specific capital market failures. They often emphasise business goals.

[24] For example, it is sometimes claimed that firms neglect options for improved energy efficiency.

For example, the Australian Government's premier business R&D support measure, the R&D Tax Concession, aims to make 'eligible companies more internationally competitive' (AusIndustry and the Australian Tax Office 2006). There is a requirement in the *Industry Research and Development Act 1986* (section 39D) that the project be 'for the benefit of the Australian economy', but the interpretation of this is not in an explicit spillover sense, but that the profits or gains *directly* accruing to Australian residents from the exploitation of the innovation be sufficient.

In contrast, perhaps indicating its more recent vintage, the objectives for *Commercial Ready*, a suite of grant programs for small and medium enterprises specify a national benefit test that is clearly and appropriately related to the spillover rationale:

> …customers for *Commercial Ready* funding must carry out their activities in a way that provides some identifiable benefits beyond those that can be captured by the customer. In order for your application to be competitive, you must demonstrate that you will conduct the project, and/or exploit its outcomes, in ways that will benefit Australia… Successful projects can benefit Australia in many ways, including: improved national productivity and contribution to economic growth; diffusion of knowledge, skills and know-how to other parts of the Australian economy; increased collaboration between Australian businesses and/or research institutions, or generation of societal, environmental or community benefits. (AusIndustry 2005)

Other innovation programs or science and innovation statements may refer to the standard rationales for public support, such as national productivity improvement, but they also cast government innovation policy in terms of industry policies that create jobs (IR&D Board 2005, p. 18); meet specific competitive threats from low wage economies like China (for example, Queensland Government 2005, p. 5); or that transform industry so that it may better compete in an increasingly knowledge-based global economy (Western Australian Technology and Industry Advisory Committee 2002).

Taken literally, these rationales provide weak grounds for public funding support of R&D.

Competitiveness is an appropriate goal for firms, since it will determine their long-run profits. But international firm competitiveness, as conventionally defined, is a difficult goal for governments, if for no other reason than that flexible exchange rates act as an equilibrating mechanism to ensure that enough firms are always 'competitive'. If Australian firms are highly productive, then the exchange rate required to achieve competitiveness is higher; if they are low in productivity, the exchange rate associated with that competitiveness is lower. (It may be that the literal goal of 'competitive' firms is intended to be interpreted figuratively as policies that promote multifactor productivity. This is a sound policy goal, but the statement is open to misinterpretation.)

Technological change has a twofold effect on job creation. The fact that a new industry or set of innovative firms may record strong employment growth is often offset by displacement in other industries. Overall, the empirical evidence suggests that no systematic long-run relationship is present between job creation and technological change (Cahuc and Zylberberg 2004, p. 583ff; Layard et al. 1991, p. 5). The strongest evidence for this is that unemployment rates do not exhibit long-run trends, despite ongoing technological change and accumulating knowledge. Aggregate unemployment and jobs growth are more broadly macroeconomic phenomena, rather than the consequences of industry policy.

The rapid growth and development of China as a powerful industrial country has been beneficial for Australians. It has increased global productivity and improved the sales level and prices of our natural endowments. It has meant reduced prices of manufactured imports for Australian consumers and industry users.

It also generates structural changes within Australian industry that have reduced the relative importance of the manufacturing sector. This is why some consider that it is necessary to develop public innovation policies that transform and improve the economic prominence of that sector.

The argument has several limitations:

- Given our smaller and more specialised manufacturing base, it is likely that the future economywide effects of such structural change will be smaller than in the past.
- Resources cannot be allocated everywhere. The mining sector appears likely to play an enduring role in Australia’s continued growth (Henry 2006). Australia’s resource endowments are diverse and, contrary to some characterisations, the sector is innovative and further as the economically exploitable reserves are depleted, resources will have to shift to other sectors.
- It assumes that government needs to orchestrate industry transformation with specific industry policies. In fact, resources are highly mobile and industries are always adapting to external and internal pressures, unless thwarted by policy or by market failures. Despite its real output growth, the role of manufacturing in Australia has declined in *relative* importance over the last forty years from one in every four dollars in GDP to around one in eight. At the same time, national income per person has risen dramatically (PC 2003b). Within manufacturing, relative price changes and comparative advantage have led to restructuring towards more capital and knowledge-intensive activities. Innovation activity is a

central part of that story, but private innovators have strong incentives to transform their firms. In other words, the imperative for transformation exists, but its details are driven largely by private sector incentives, backed by broad and flexible capabilities developed by governments, and occasional strategic opportunities (for example, CSIRO's investigation of titanium processing).

- The realistic scope for industry-specific innovation policies of the kind envisaged to transform Australia's industry structures appears weak. The transformative goals of past policies do not appear to have achieved their original aspirations. Moreover, the definition of innovation usually adopted when referring to transformation tends to place excessive weight on technological innovation, downplaying the arguably more important role of wider routes to doing things better. As noted previously, the most clearly transformed sector in Australia is the services sector, where technological innovation has played a relatively attenuated role in contrast to adoption and non-technological innovation.
- To conceptualise decreased prices for manufactures as a significant economic threat that requires transformative policies to promote alternative manufacturing capabilities is to return to the intellectual underpinnings of protectionism, which had the same objective. In the past, policies that have resisted structural change, such as tariff and quota policies, have been damaging to Australia's economic fortunes. Dr Ken Henry (2006), Secretary of the Australian Treasury notes:

  > …despite the fact that the Australian economy is now operating at close to full capacity, with relatively few idle resources, many people think that industry policy should be doing something in response to higher terms of trade. The first test that should be applied to any proposal in this area is the following: Does the proposal seek to resist the change in resource allocation implied by the higher terms of trade, or is it empathetic with that change? Proposals that resist the changes … should themselves be resisted. My reasoning is straight forward: Let's just suppose for the moment that we wanted to prevent the consequences of an increase in the terms of trade to which I have referred. What would be the best policy means of achieving such an objective? The answer is an across the board additional tariff on all imports at a flat rate of about 25 per cent. Now that would be absurd. But the point is this: absurd as it is, anything else would be worse. (p. 11)

Arguably, the best policy response to structural pressures that will assume unknown forms is the encouragement of a high quality broad-based innovation system as part of a highly flexible economy, well functioning labour markets with high quality labour endowments, and excellent and adaptive institutions. Innovation policy is a central part of a flexible capability, but arguably does not need to be directed to goals of transforming particular segments of (manufacturing) industry.

3.13 Evolutionary theories and the 'innovation system' approach

Evolutionary approaches originated from Schumpeter's theories, but were developed in their modern form by Winter and Nelson (1982). Evolutionary economics apply some of the ideas of evolutionary biology to the study of innovation. In this theory, heterogeneous and boundedly rational firms and other agents use constantly adapted, experimental processes in competitive contests. Entrepreneurs play an important role in evolutionary economics as a major source of innovation. Successful processes are discovered and then imitated through competitive processes. Firms that do not adapt fail. The nature and speed of competition is influenced by the innovation system (chapter 1).

The most important policy relevant features of the approach are:

- the value of variety, since this increases the likelihood that useful, novel processes will be discovered, and reduces the risk that an economy selects a poor technology pathway. Novelty is expressed not just in a technological form, but in new business models and processes, emerging industries, different business relationships, new markets and adoption of new technologies (Hine sub. DR126; Scott-Kemmis sub. DR183). The conventional economic approach would conceptualise the learning benefits of variety and experimentation as 'spillovers', suggesting that the two approaches are perhaps not as distinct as sometimes suggested. On many occasions, the practical problems for policy is not whether there is a case for eliciting the gains from experimentation, but in dealing with the practical side effects, such as potential corruption of competitive processes and additionality;
- a consideration of the whole system (in the same way that understanding evolutionary processes needs to consider how species interact as part of a whole ecology). Potts (sub. 19, p. 1) and Scott-Kemmis (sub. DR183) appropriately emphasise the systemic insights offered by the evolutionary approach;
- an interest in the effectiveness of diffusion of ideas among firms (Cutler sub. 43, p. 2); and
- the importance of innovation systems that support entrepreneurial invention and competition. A significant focus of more recent development of evolutionary economics is analysis of innovation systems that assist rapid innovation. The central concerns are poorly developed linkages, inappropriate standards, poor regulations, inadequate infrastructure, network failures, and high exit and entry costs that reduce competitive pressures.

The evolutionary approach has useful insights into innovative behaviour in firms, and into the obstacles that may arise in the innovation system. The approach also recognises that science plays a role in the innovation system as an important source of knowledge and human capital that firms can draw upon in pursuing their innovations (and in which the interactions go both ways).

However, unlike some of the orthodox market failure arguments for public interventions, the evolutionary approach does not establish a welfare benchmark against which to gauge appropriate government policy. As Fagerberg (2002) notes:

> … from an evolutionary perspective there is no such thing as an 'optimal' rate of growth. Hence it is left to politics to decide whether or not the economic system is performing in a satisfactory way. If it needs to be invigorated there are two main mechanisms that follow from evolutionary reasoning. The first would be to attempt to increase the economic system's ability to generate new variety. For instance, rather than subsidizing R&D in well established firms in traditional sectors, one might put the resources into new types of activities or actors, not necessarily with the expectation that these would do extremely well, but because the entire system (including the traditional sectors) might benefit from such increased diversity. The second would be to focus on the economic system's capacity to absorb innovations. (p. 42)

Potts (sub. 19) argues that while there is no objective policy benchmark in evolutionary economics, there nevertheless is some basis for public policy evaluation. An innovation system is 'healthy' (ie 'good') if it '… maintains the complexity of the economic order by maintaining the flow of new ideas, the possibilities for adoption of new ideas and the retention of existing ideas.'

This is why the evolutionary approach places an emphasis on experimentation, variety, competitive approaches and continual change. However, complexity is not a compelling public policy end in itself, but rather only of policy interest to the extent that it improves the prospects for better living standards broadly defined.[25] Once this is the ultimate objective, the apparent difference in the goals of conventional economists and evolutionary economists largely evaporate (even if the tools they employ are overlapping rather than common).

The relevant question then is the empirical connections between the key system attributes and that goal. The Commission investigates these in this report, to the extent possible in such complex systems. A significant part of this report (chapters 5 to 12) attempts to explore some of the key attributes, such as the potential regulatory, institutional failures, linkage issues, human capital adequacy and governance questions that could increase or decrease the effectiveness of Australia's

[25] In many cases, those policy analysts who use evolutionary economics intend it as a way of achieving this broadly defined national benefit. This objective, for example, appears to be the orientation of DCITA (sub. DR180).

innovation system. Other approaches — based on drawing lessons from economic history, detailed case studies and more elaborate models of economic growth (such as those developed by Lipsey et al. 2005 in relation to general purpose technologies) — are also useful, though this report cannot address all of these given the breadth of its task. Generally, however, the key policy recommendations based on these frameworks for innovation (for example, Lipsey 2001) are, often qualitatively similar to the Commission.

3.14 Empirical rationales for support

The previous sections have considered theoretical reasons for public funding support, and these are usually the only factors discussed when seeking a rationale. However, in many arenas of decision making, including scientific discovery itself, emerging empirical findings, rather than theory, are the basis for real world applications. For example, many pharmaceutical treatments arise through the observed consequences of compounds developed for other purposes. Penicillin is the classic example. More recent examples include Bupropion (*Zyban*) which was used as an anti-depressant, but was observed to reduce the craving for smoking; and sildenafil citrate (*Viagra*), which was originally a rationally selected molecule for the treatment of angina. Bio-prospecting — the search for new compounds in living things that may have medical applications — is a systematic application of this empirical approach.

Empirical approaches have advantages when theory is insufficiently developed. The expansion and elaboration of industrial organisation theory and models of general purpose technologies in economics has made it less clear to policymakers when, and in what form, public support should be provided to businesses (though less so for public research agencies or universities). This is because firms are seen as complex strategic entities with incomplete information, whose behaviours are shaped by their (varying and evolving) technologies and by the actions of firms, industries and public agencies around them. It is possible in these contexts to get over-investment in R&D through patent races and duplication in one set of circumstances, yet re-invoke the conventional story of under-provision in another.

Given these theoretical uncertainties about the rationales for public support of business innovation, there are grounds to be at least open to empirical evidence that may help guide policy. Evidence about the impacts of innovation policy on the economy (chapter 4 and appendices G, H, I and M) may help do this.

3.15 There are some dissenters

The Commission's view that there are strong rationales for government funding of R&D is not the only view. Several opposing perspectives have been put forward that question whether significant, or sometimes any, government funding of science (especially of basic science) is justified. The IPA argued that:

> An apparently strong economic argument exists to support the public funding of science. The standard analysis, however, rests on a series of assumptions. Each of these assumptions will be examined in turn and each will be shown to be defective. Furthermore the standard analysis abstracts from 'real world' issues that have considerable impact on actual policy conclusions. In many instances effective government funding of science would require the government to have information or foresight that others do not, and cannot have. Finally, the standard analysis ignores industrial organisation questions that also undermine the usual policy conclusions. In sum, the standard economic analysis that suggests a substantial role for government in funding science is flawed. (sub. 30)

The IPA (sub. DR139) reiterated this view in a follow-up submission to this study and in a paper by Davidson (2006). This perspective has also been advanced by Martino (1992), Butos and McQuade (2006) and, as described in box 3.2, most forcefully and polemically by Kealey (1996, 1998). Some of the arguments are theoretical: it is claimed that poor results from public funding can be expected, given the incentives and average efficiency of governments compared with businesses and philanthropists. This sceptical literature also observes that governments are not neutral agents, but must respond to the lobbying and political pressures they face, distorting their decisions. Existing players acknowledge this. For example, CSIRO commented:

> Political and other practical considerations are part of the environment within which research organisations and other players in the national innovation system operate … The variety of stakeholder perspectives and expectations that feed into the political processes that result in decisions about research funding do not always have a strong economic (or even rational) base, but governments cannot ignore them. (sub. DR184, p. 3).

In CSIRO's case it meant that sometimes they funded more of a project themselves than would be desirable on public benefit grounds to avoid the risks of complaints of unresponsiveness by industry users.

Box 3.2 **A controversial alternative view: *science* is valuable, but *public* funding of science is harmful**

Some see science as an important element of innovation, but argue that public funding of science is adverse for economic growth. Kealey (1996, 1998) has provided the most detailed attack on publicly funded science. Kealey's thesis is based on several perspectives. He claims that public science involves:

Displacement: He argues that private companies would fund and undertake much of the valuable R&D currently supported by governments if public funding were not forthcoming. The most important of the significant, non-commercial science would be undertaken by philanthropically funded non-profit agencies and by private universities. (Amateurs would also undertake good science for pleasure.) This displacement is sometimes referred to as 'crowding out' of private funding by public funding. Indeed, he makes the observation that frontier basic science is *already* done by private companies and openly published by them, undermining the conjecture that private firms have no incentives to participate in an open scientific system.

Misdirection: Kealey suggests that much of publicly funded (basic) science is fun, but not valuable, or it may be pushed into commercial white elephants selected by bureaucrats, wasting valuable capabilities. Moreover, because public science has to be funded through taxes it has damaging incentive effects throughout the economy, so that the waste extends outside the activities of scientists and the organisations that employ them. As a consequence, he claims that public funding does not just displace private funding, but actually diminishes aggregate R&D spending, with adverse effects on economic growth and the innovativeness of a country.

Maladministration: Kealey provides detailed study of the political forces behind the formation of the public science system in the United Kingdom and the United States (pp. 139ff), suggesting that while cloaked in the public interest, the leading advocates and bureaucrats were often motivated by personal and private interests that frustrated more sensible allocations of resources. He notes, for instance, that the newly founded publicly funded UK Medical Research Committee, attempted (unsuccessfully) to forbid the establishment of competing funders, such as the charitably based Cancer Research Campaign (p. 175). Kealey suggests that, out of jealousy of a rival organisation, the MRC created a schism between basic science and clinical science that was to frustrate early 20th century medical science in the United Kingdom.

Incorrect causality: Kealey questions the hypothesis that basic science leads to technological developments and economic growth — attributed to Francis Bacon originally and given fresh vigour by Vannevar Bush in post world war two United States. He argues that this 'linear view' invariably places the cart before the horse. In many cases technology begets new technologies directly, and technology often raises interesting problems for basic science rather than the other way round. Project Hindsight by the US Department of Defence found that of the 700 research events that led to the development of weapons systems, only two had arisen from basic science

(Continued next page)

Box 3.2 **(continued)**

(Kealey p. 163). Project TRACES (published the National Science Foundation) found the missing link to basic research, but ironically to research that was undertaken 50 years before, when it was mainly privately funded in the United States.

The key question about all of these potentially major deficits of publicly funded science is not whether there are vivid examples available — Kealey clearly provides many of them — but whether their presence is sufficiently systemic to matter when there are positive influences that go the other way. This is why consideration of the validity and interpretation of Kealey's more general empirical results is warranted.

There are also many methodological and factual questions about Kealey's arguments. For example:

- Some of the facets identified by Kealey, such as the bi-directional nature of links between basic science and technology does not undermine public funding per se (Nelson 1997). The linear model is rejected as much by those who make a case for funding (for example, David 1997).
- Kealey does not take account of the need for government to stimulate research capabilities for its own productive activities and roles.
- Kealey appears to be selective in his use of case study evidence. He emphasises those cases where industry funded basic research proved valuable to business innovation, and to cite 'white elephant' examples of public funding (a valuable corrective to romantic views of government funding and to mistaken characterisations of business research funding). However, he neglects cases in which publicly funded basic civilian science has contributed to fundamental advances that are complementary to business innovation (Llewellyn Smith 1997).
- Kealey notes the importance for firm innovation of understanding the scientific literature, but most of this would (currently) be publicly funded and therefore complementary to business innovation. This stylised fact appears to be inconsistent with Kealey's argument about the low value of public science (David 1997). On the other hand, the degree to which it is or not depends on whether, absent public support, businesses (or charitable foundations) would engage in sufficient open research of a fundamental basic nature to replace that which was lost — raising again the empirical issue of crowding out.
- It can also be maintained, without inconsistency, that the private sector is the most active agent in national innovation without giving up the view that some public funding of science is justified.
- There are questions about whether some of the causal links alleged by Kealey between public science and economic stagnation are soundly based. For example, the problems in Britain during the Wilson years probably reflect much more than the science policy to which it is primarily attributed.

Ultimately, however, Kealey and others critical of public science on similar grounds have provided a useful, if one-sided, alternative hypothesis against which the mainstream view of its benefits should be appraised and clarified.

But the political realities can be interpreted in three alternative ways. In the most pessimistic interpretation, they might suggest the difficulty in public funding at all (the Kealey and IPA view). Alternatively, they could be seen as just a friction in the system, whose costs have to be factored into expectations and cost-benefit calculations. Or, most optimistically, they could be seen as a factor to be circumvented (or at least reduced) by more careful design of governance rules and institutions.

The pessimistic perspective is as much an empirical as a theoretical objection to public funding of science. The dissenters argue that it can be *empirically* shown that the returns from public science are low and that there is large crowding out of private research by public science. For instance, in the case of Australia, Kealey (1998, p. 906) argues that the changing public private shares of R&D have revealed crowding out and that 'Clearly the public funding of civil R&D in Australia has represented a waste of money'. These empirical issues are taken up in chapter 4 and appendix M.

3.16 Bottom lines

There are a plethora of rationales given for public funding support of science and innovation, but only a few have relevance. The most important, in order of relevance, are:

- the need for government to use research and innovation for those activities in which it has a central role (such as reducing environmental degradation);
- spillovers from innovation that cannot be captured by the innovator and that cannot be realised without support. The spillovers may arise through high quality human capital development, the development of basic knowledge capabilities, and diffusion of new ideas among firms and others. They arise from research undertaken in universities, businesses and public sector research agencies;
- intangible factors, such as national identity, moral obligations and national prestige, may also potentially justify some public support, subject to some substantiation for any large projects that the supported activities are likely to have these benefits. They relate mostly to scientific research in universities and public sector research agencies; and
- the asymmetric tax treatment of highly risky investments, which mainly relate to R&D undertaken in businesses.

Problems in capital markets that could affect the availability of finance to risky or uncertain investments in small firms and start-up companies may sometimes provide a rationale, but this rationale is accompanied by strong provisos and significant uncertainty as to its true relevance.

Some commonly cited reasons for supporting the system, such as indivisibilities, business myopia, and the aspiration to achieve a transformation of Australia’s industry away from its present structure have weak validity. In many instances, they would entail completely different support arrangements than those currently observed in their name.

Rationales for public support are based on implicit models of the behaviour of agents. With the advent of more complex models, it is harder to make clear rules about when support should be given or not, especially for business innovation. This suggests that it is important to be open to empirical evidence that may reveal unexpectedly effective (or ineffective) policy initiatives.

There are also strong potential grounds for public policy interventions to improve the functioning of the innovation system, but that generally do not take the form of public funding support for R&D or associated activities. For example, they may involve ensuring efficient education and regulatory systems. These are considered in other chapters in this report.

FINDING 3.1

The need for government to fund research to discharge its own functions and the existence of benefits from innovative activity that cannot be captured by the innovator provide strong rationales for the provision of public funding support for science and innovation. But some commonly given reasons are not soundly based.

4 Impacts

Key points

- Economywide productivity is linked with advances in R&D. Evidence for this linkage within Australia includes:
  - aggregate time series studies;
  - panel data analysis across Australian States;
  - cross-country results;
  - models of innovation; and
  - case studies.
- It is not possible, given a host of measurement and methodological issues, to provide accurate estimates of the social rate of return on R&D for Australia.
- The relevant issue for public policy is the magnitude of benefits from *public support* for science and innovation, not from science and innovation in general.
- Existing information suggests that government spending on R&D effectively increases national R&D and does not, to any substantial extent, substitute for privately funded R&D. This is important because significant crowding out would reduce the potential for positive net impacts from public funding support.
- The Commission judges the benefits are likely to be high for R&D in universities and public sector research agencies, due to their orientation to public good research and their role in development of high quality human capital for the Australian economy.
  - This is backed by case studies and some econometric evidence, though the latter has not been sufficiently replicated to be reliable.
  - Other indirect indicators of academic quality suggest that Australian scientists are performing as well as in other advanced economies.
- Business programs are likely to have had smaller absolute impacts than publicly conducted R&D. This reflects crowding out of privately financed R&D, the relatively (and appropriately) small scale of public funding support and the emphasis on support given to particular declining manufacturing sectors.
- The Commission judges that publicly supported science and innovation have produced important social and environmental benefits. It is difficult to enumerate these benefits, but research appears to have:
  - increased national preparedness and reduced risks in some areas; and
  - been widely adopted in a range of settings (public health, risk abatement in the environment and social and educational policy).
- Uncertainties over the marginal returns to publicly supported R&D imply that it is not possible to use the quantitative information in this chapter to calibrate aggregate funding levels.

4.1 Introduction

Australian governments direct significant public resources to science and innovation (chapter 2). A key question posed by the terms of reference for this study is what Australians get from this spending. These impacts are not just the gains that end up in gross domestic product or other more tractable measures of the economy, but also broader social and environmental benefits to Australians.

This chapter brings together evidence on these impacts — from research undertaken by the Commission, as well as from the many useful studies undertaken in Australia, and to the extent that they may be applicable, from overseas. The impacts are explored from many perspectives because no single method is flawless. Some of this material is technical in character — especially section 4.4.

The chapter is structured as follows. Section 4.2 briefly describes the potential nature of impacts that should be assessed, of which the most important goal is to investigate the effects on Australians' wellbeing. It also explains briefly why it is necessary to use several methods when gauging impacts.

Section 4.3 assesses the extent to which broad public support makes a difference to the actual amount of R&D that is conducted (*additionality*). This issue stems from the fact that government support may, directly or indirectly, substitute for R&D that would otherwise be financed by others (*crowding out*). Additionality is important because beneficial impacts can only be generated by truly additional innovation, while the taxation distortions imposed by financing the transfers still produces costs.

Section 4.4 considers the orthodox economic impacts of public support, applying a variety of quantitative approaches and drawing on evidence from overseas studies. Section 4.5 supplements this evidence with case study analysis. More detailed analysis is in appendices E to K and T.

While innovation in the market sector is the greatest source of national productivity growth, and a major indirect or direct target of public support, a key goal of public support is innovation outside the commercial sphere. The chapter uses several approaches to assess the environmental (section 4.6) and social impacts (section 4.7) of public support.

In many cases, it is only possible to derive indicators of the impacts of public support, such as its effects on patent counts and bibliometric measures and the goal, present in some industry programs, of growing highly successful Australian firms. While these have to be interpreted carefully, these may still provide useful information about the performance of the system and its potential impacts. These are briefly discussed in section 4.8 and specific aspects of these indicators are the subjects of appendices J, K, and T.

Section 4.9 draws some brief conclusions about the impacts of public support for R&D.

4.2 What is meant by 'impacts'?

In common usage, 'impacts' is a term that means effects of any kind. However, in this chapter a more narrow meaning is used, consistent with the framework in chapter 8. Impacts (or 'outcomes') are conceptualised as effects that are beneficial to Australians. The impacts could be:

- specific beneficial economic outcomes (such as new products or services, faster adoption of overseas technologies, the formation of rapidly growing high-wage industries, reduced costs, and increased consumer surplus). A summary measure of impacts will be their effect on aggregate productivity, if that is properly measured;
- beneficial social and environmental outcomes, some of which may only partly be visible in markets, such as reduced dry-land salinity or improved public health outcomes; and
- other intangibles (chapter 3), such as national prestige, contributions to the global common knowledge pool, implicit aid to developing countries and the development of capabilities that have future option values, even if they are not immediately useful (for example, a capacity to understand whether or when nuclear energy is a viable option for Australia).

Higher level impact measures have several desirable properties.

First, they should indicate the extent of the benefit, not just whether a particular beneficial objective was achieved. For example, in the case of a research program aimed at developing a vaccine for cervical cancer, it is preferable to know not just whether the project was successful, but whether that success translated to big or small benefits (such as, what is the likely effect of the uptake of the vaccine on reduced cervical cancer rates and the consequent improvement in wellbeing and reduction in health and other costs).

Second, if possible, measures should be commensurate across projects, so that the aggregate benefits of a suite of projects can be assessed. This is why measures of value expressed in dollars are useful.

Third, measures should take account of the indirect effects of projects or programs. Even a ‘failed’ project often builds up human capital, indicates unprofitable research directions and adds to knowledge that may be useful in the future in many other ways. These indirect effects are just one manifestation of the non-linear nature of the innovation process.

However, it is often not possible to devise impact measures with these desirable traits, or in some instances any impact measures at all. In many cases, outputs are used as proxies for likely impacts. Some examples are high quality human capital, patents, academic papers and their citations (which reveals how widely the underlying knowledge may be diffused and gives an idea of their quality). Research outputs are mainly inputs into broader innovation processes and whether they produce outcomes depends on their character and the context in which they become available. There are many lower quality academic papers and lapsing patents, whose ultimate effects on Australians’ wellbeing are likely to be weak. Nevertheless, while the existence of outputs from public support is not sufficient to be assured of a subsequent outcome or impact, an output of some kind is at least necessary for that objective. Accordingly, carefully interpreted outputs can sometimes be useful as proxy indicators of ultimate outcomes.

Moreover, it may be useful to measure outputs (and sometimes inputs) as well as outcomes because this can better indicate what kinds of policies are effective in generating outcomes/impacts. For example, a study of national multifactor productivity growth might show a high ultimate impact from the conduct of R&D, but it is also useful to know whether any separable effects stem from good quality human capital and problem solving capabilities, the diffusion of codified knowledge or particular areas of research. Gans’ analysis (sub. 10, pp. 12ff) of Australia’s innovation capacity proceeds along these lines (albeit looking at Australian patents granted by the US Patent and Trademark Office per capita, which is an output measure rather than an outcome measure).

Another important facet of the impacts of public support is their distribution among Australians. This can be particularly pertinent to programs or projects that have low additionality or where the gains mainly come in the form of higher private returns, since these imply large transfers to relatively few shareholders. As noted by Baumol (2002, pp. 143ff), the usual assumption that non-distortionary lump sum taxes can address this is improbable. However, while distribution is a relevant issue, it can only realistically be assessed on a program by program basis.

Where information is available, this chapter explores the above aspects of impact. In some cases, as in the human capital effects of the science and innovation system, the discussion is elsewhere in this report (chapter 6 and appendix L).

The distinction between economic and social/environmental effects

The terms of reference for this study requests that the Commission separately consider economic, social and environmental impacts. This chapter accordingly divides impacts into these three types. In doing so, the chapter implicitly adopts the conventional, though not rigorous, view of economic benefits as those that are apparent in markets (and typically represented in official national accounts measures).

However, in fact, from an economic perspective, people's wellbeing is not just determined by goods and services that are counted in GDP. Since most people value peace of mind, good health and sustainable environments, these are also relevant to economic wellbeing, properly defined. They are also, in theory, measurable, since it may be possible to discover the tradeoffs people are willing to make between market-produced goods and others, such as biodiversity and reduced crime. Many social and environmental impacts are, in any event, also standard economic benefits. For example, improved environments can increase productivity (for instance, reduced salinity raises crop yields), as can investments in animal and human health.

Where possible, the Commission draws attention to quantifiable measures of social and environmental benefits — whether in the market system or not. Nevertheless, in many instances, eliciting accurately people's aggregate preferences about such non-market goods is often difficult (and some people consider the preference-based approach to valuing such non-market goods is flawed in any case). Given these difficulties, assessment of the social and environmental impacts of R&D often use qualitative as well as quantitative approaches, and invariably involve more subjectivity (sections 4.6 and 4.7).

4.3 How much additional R&D does public support elicit?

Australian Governments commit around $6 billion in funding or related support for science and innovation, mostly as funding for R&D. A key question is the extent to which this funding translates to R&D that would not otherwise have occurred (defined in appendix M). This is central to the concerns of this chapter since only genuinely additional R&D can even potentially have impacts that can be ascribed to government actions. The IPA (sub. 30 and sub. DR139) highlight this as a potential drawback of public support, as have critics of public science generally, like Kealey (1996).

When considering the question of additionality, it is important to distinguish three types of publicly supported R&D — that mediated through tax measures; competitive grants to businesses; and through spending in PSRAs and universities. In many discussions of this issue, the three modes are conflated, with the risk of misdiagnosis of the true effects.

The Commission has examined the existing large theoretical and empirical literature on additionality (appendix M). Three broad conclusions can be drawn from the Commission's analysis.

Public support for business R&D that lowers the price of R&D

First, policy measures that generally lower the price of business R&D, such as tax measures, have been intensively analysed, though only recently has analysis attempted to differentiate empirically the degree of additionality associated with different designs of schemes. The evidence suggests that it is likely that every dollar of public support generates somewhat less than a dollar of new business R&D because it substitutes for R&D that businesses would otherwise undertake. This may well rise above one dollar for well designed incremental schemes. Additionality rates of less than one can still produce sizeable net benefits, as explained in appendix M.

Competitive R&D grants for business

Second, it is possible that additionality could be high for competitive grants to business because of the nature of the target firms and projects. But poor program design risks lower additionality than tax concessions because of selection biases in the application and merit award processes for grants. These biases can favour firms with projects that have strong commercial viability and that would probably still be financed in the absence of the grants.

The alternative risk is that flaws in the selection processes (reflecting the difficulties in technical assessments by grant committees of the quality of R&D) result in choices of projects with high additionality, but little likelihood of commercial or spillover gains. Consequently, outcomes from competitive grant programs depend on the nature of grant selection processes.

The existing international evidence favours reasonable additionality of grant programs. But recent analysis of Australia's R&D Start Program — the predecessor to *Commercial Ready* — suggests a substantive risk of poor additionality for this program (chapter 10 and appendix M).

Public R&D funding for PSRAs and higher education

Finally, there appears to be little crowding out between government funded R&D support for its own R&D activities in PSRAs and higher education institutions, and R&D performed and financed by business (appendix M). The commonly reported findings of crowding out by public funding cited by some (for example, the IPA sub. 30) are based on either *all* public funding (which includes public funding of business R&D) or are biased by the inclusion of results for the United States, where public funding of defence R&D does appear to crowd out private sector defence R&D. Such R&D is of little relative importance in Australia.

While the judgment of little crowding out in an Australian context may be true at the aggregate level, individual publicly funded projects with research applications that are likely to be used by relatively narrow groups of industry members may well crowd out private R&D investments. This may affect some industry-centred research activities by CSIRO and RRDCs and is discussed further in the appendix on case studies of R&D support (appendix I).

The other question is whether there are complementarities between aggregate publicly supported R&D in non-business entities and that in business. In theory, increases in R&D in one can actually stimulate, rather than crowd out, R&D in the other. There does not, however, appear to be robust evidence of this. Of course, complementarities may take many years to materialise, so their usual absence in empirical analysis should not be regarded as definitive evidence against their existence. (It is unlikely that long-run crowding out is greater than short-run crowding out, so the same bias is probably not present for this issue).

The overall finding of no crowding out (or for that matter, complementarities) from public support of R&D in non-business settings is particularly important because of the emphasis of public funding support on R&D in universities and PSRAs (chapter 2).

4.4 The macro and industry evidence on economic impacts

The economic impacts of R&D are often assessed by examining the effects on productivity of R&D stocks *as a whole*. A link then needs to be made between the size of these aggregate effects and the likely impacts from R&D stimulated by public support. (This is why additionality, discussed above, is so important, as well as determining what parts of the publicly supported R&D are relevant to the market sector.)

This section first sets out how productivity is measured, its link to economic growth and the role of R&D stimulated by public support compared with other factors. It then shows the results of a semi-parametric method that illustrates the potential impacts of publicly supported R&D. These results are then compared with econometric results based on Australian and overseas time series and panel data. The differences between spillover returns from business R&D and publicly conducted R&D in universities and public agencies is drawn out, since this distinction is critical to the assessment of the value of public investments in science.

Economic growth and multifactor productivity

Australians' *material* wellbeing is determined by the capacity to consume more, or better quality, goods and services. With some qualifications, which are ignored here,[1] the long-run determinant of that capacity is economic growth. A major goal in understanding economic growth is to attribute growth to its various sources. It is clear that an economy gets larger with capital accumulation and a bigger labour force. However, in all advanced countries, a substantial part of past per capita economic growth is due to factors other than labour or capital inputs. This residual source of growth is referred to as multifactor productivity (MFP) because its effect is to raise the productivity of capital and labour. From 1964-65 to 2004-05, around 65 per cent of economic growth per capita in Australia can be ascribed to MFP growth (appendix E). MFP rises due to better trained and educated labour; technological and non-technological innovation, of which R&D is just one contributor; regulatory reform; and reduced barriers to trade that increase competition and improve incentives.[2]

Where does R&D fit among these sources of MFP growth? It is important to distinguish questions about the impacts of R&D, or even innovation more broadly, from the impacts of *publicly supported* R&D (which is the focus of government publicly funded support of the science and innovation system — chapter 1 and chapter 2). The R&D relevant to this narrower issue is smaller than the total stock of R&D that influences innovation. To address the issue of how much smaller, it is useful to progressively decompose R&D into its relevant constituent parts (figure 4.1), extending the categorisation used in chapter 1.

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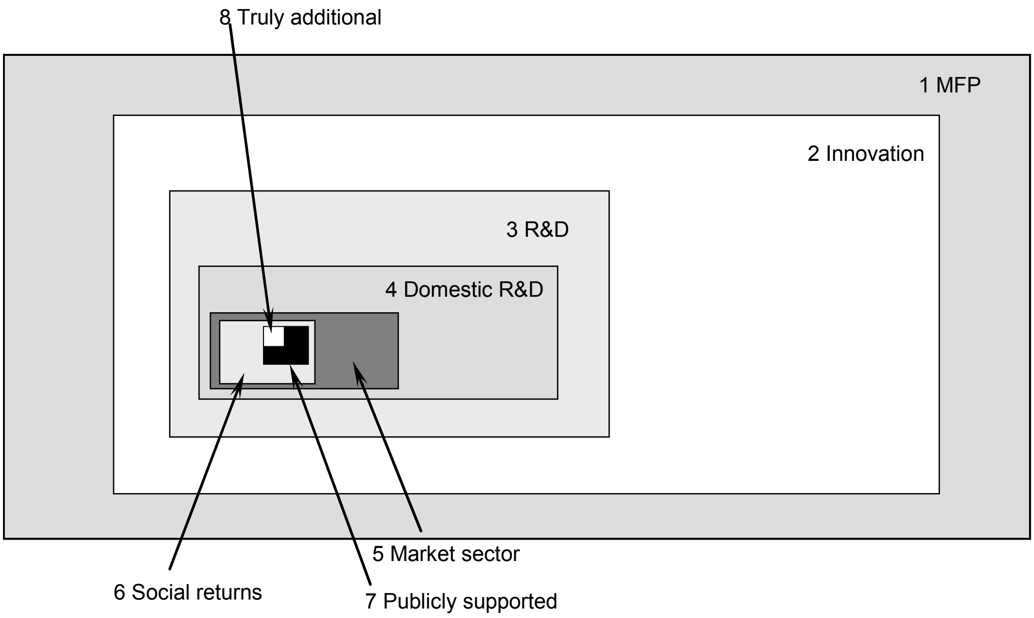
1 The terms of trade will affect the extent to which domestic production allows Australians to buy imports, and is ignored here. The IC (1997a, p. 26) has shown that, over the long run, declines in the terms of trade have had minor effects on per capita income.

2 It is now well recognised that MFP is not an appropriate measure of technological change, and in any case, suffers several other limitations (for example, Lipsey and Carlaw 2004). But it does provide a simple index of productivity that has empirical value in understanding some aspects of long-run economic prosperity.

Just as innovation is one source of MFP growth, R&D is just another contributor to innovation. As noted in chapter 1, innovation results from many sources, including new technological and non-technological developments; catch-up; and the imperative to learn that arises from the constant pressure of competitive processes. It is likely that much of the improvement in productivity in Australia (particularly in the burgeoning service sector) arises from non-technological knowledge generation and copying of ideas from abroad and between firms within Australia (2 in figure 4.1). Developments in ICT have probably increased the capacity for generation and diffusion of knowledge of this kind.

Figure 4.1 **What matters for market-sector multifactor productivity growth?**



R&D is most closely associated with technological development. But only part of technological development can be ascribed to domestic R&D. Foreign stocks of knowledge may be the most important long-run contributor to new technological developments, given Australia’s small size relative to other major generators of knowledge and the fact that knowledge is much more globally footloose than labour or physical capital (4 in figure 4.1). From a public policy perspective, the influence of foreign R&D stocks is only of interest to the extent that it has to be controlled for in estimating the impacts of domestic R&D; and to the extent that domestic R&D has to be undertaken to absorb its benefits.

And of domestic R&D, only a portion is relevant to developments that are likely to be included in MFP *in the market sector* (5 in figure 4.1). Domestic business R&D is important because it is aimed at improving market goods and services, but R&D

undertaken by higher education and public sector research institutions often have broader objectives, such as inputs into publicly provided policies, goods and services (chapter 3). These are valuable, but the test of their impacts has to look wider than the market sector. So only a portion of R&D stocks associated with HERD and GOVERD are likely to be relevant to measured MFP.

R&D is a cost that involves physical capital and specialised labour resources, so that it is already incorporated into labour and capital inputs. These inputs are weighted by their cost shares, assuming that inputs are paid their marginal returns (wages and rental prices of capital respectively). Accordingly, the private effects of (domestically conducted business) R&D on value added are already taken into account, and are not included in residual MFP growth. Any additional effects of R&D on MFP are therefore seen as picking up the social or spillover returns of R&D (6 in figure 4.1). These returns will contribute to innovation broadly, beyond the confines of firms that produce the knowledge in the first place.

Of domestic business R&D, a relatively small amount is supported by governments (7 in figure 4.1 and chapter 2).

Finally, as emphasised in chapter 3, part of public support for R&D is provided for activities that would have occurred anyway. The social benefits of these activities cannot, therefore, be ascribed to public support. Only the truly additional component is relevant (8 in figure 4.1).

Accordingly, while it is the case that innovation is the key driver of MFP, the relevant stock of domestic R&D underpinning MFP is likely to be small relative to other influences and the stock of publicly supported R&D even smaller.

To get an indication of the magnitude of the spillover benefits from both the total market-sector domestic stock of R&D and its publicly supported component, the Commission developed a semi-parametric method (appendix G).

At the default values used in this model, R&D stimulated by public support (whether in business or elsewhere) had a gross spillover rate of return of around 65 per cent. There is some uncertainty in this result, since the semi-parametric method relies on judgments about some important parameters. However, even when uncertainty about the parameters is taken into account, spillover rates of return are mostly above 35 per cent and below 100 per cent (figure G.1 in appendix G). Nevertheless, it cannot be certain that the true rates lie in this range. But much larger values would imply that the huge flows of knowledge from overseas and from non-technological forms of innovation were unrealistically small relative to the flows from domestic R&D (even after accounting for absorption issues — see chapter 3 and appendix D). And much smaller values would risk ignoring the important role of domestic R&D as a generator of knowledge flows and in absorbing foreign flows of knowledge.

However, even if the social rates of return to publicly supported R&D were to be in that range, the actual implications for long-run productivity growth are relatively modest compared with other factors. The appendix finds that around 5 per cent of conventional MFP change in the market sector from 1983-84 to 2002-03 can be attributed to R&D stimulated by public support, around 10 per cent to other market-sector-relevant R&D and the remaining 85 per cent to other factors (table G.5 in appendix G). The figures could be slightly higher or lower than this, but it is hard, given the logic of figure 4.1 to see this judgment qualitatively altered.

Of the 5 per cent of MFP change attributable to publicly supported R&D, a relatively small share can be ascribed to public support mediated through business R&D programs (as implied by table G.2 in appendix G). This reflects the (appropriately) small emphasis of public funding support for business R&D and the wastage associated with crowding out. The calculations in appendix G also ignore the potential implications of the considerable emphasis in public funding support of business R&D in a relatively few large firms facing significant future adjustment pressures, such as those in the automotive sector (chapter 10). This may reduce the gains, albeit probably modestly.

The observation that many other factors are important drivers of MFP does not diminish the significant absolute gains from public support of R&D relevant to the market sector (whether conducted in business or elsewhere). At a 65 per cent rate of return, the accumulated gross gains to market-sector GDP from R&D stimulated by public support over the roughly two decades from 1983-84 to 2002-03 are estimated to be around $54 billion in 2003-04 prices (table G.6 in appendix G). In 2004-05, the gains were around $6.5 billion (noting that this, in part, reflects the growth benefits of past supported R&D).

It might not be thought that this benefit is substantial given that governments invested around $6 billion on R&D in 2004-05 and have since increased spending (chapter 2). However, it should be recalled that these gains only relate to a part of that annual spending. About half of the spending of PSRAs and two-thirds of public support through higher education R&D is focused on non-market applications. This R&D has less relevance for the market sector and so does not show up in market-sector GDP. But it still produces gains in non-market goods and services, such as better health and a cleaner environment.

The results demonstrate that it is possible to reconcile high social rates of return on R&D with a modest relative contribution to growth of market-sector GDP. It is this modest relative contribution to MFP growth, against the background of the statistical noise in MFP models, that explains why econometric methods will generally find it hard to pin down the impacts of R&D on growth with any precision — the central finding of Shanks and Zheng (2006). The consequences of those difficulties are discussed next.

Past Australian aggregate studies

There are about a dozen empirical studies of the links between aggregate Australian productivity growth and R&D (tables 4.1 and 4.2). The R&D measures largely relate to business R&D or GERD, which have only partial relevance to the question of the effects of publicly conducted R&D. Apart from the State-based panel studies that have exploited geographic as well as time series variations in productivity, the studies have considered the extent to which measures of R&D have affected productivity growth over time.

Most of the studies have sought to consider the links between MFP and stocks of business R&D capital. The methods for constructing these and the theory that links R&D stocks to MFP is explained further in the companion Productivity Commission research study (Shanks and Zheng 2006, pp. 47–54; pp. 77–82).

Past Australian studies have had to use limited time series information (with the exception of studies that have used patents or panel data). The real position is worse than the apparent one. Studies have had to make up data for the many missing years when ABS surveys of R&D were intermittent. Two types of study were particularly affected by this problem:

- Earlier studies, because data were intermittent between 1968-69 and 1983-84. For example, Dowrick (1994) and the original Coe and Helpman study that it replicated, imputed more than half the data points on which their regressions were based.
- Studies based on quarterly data. Since, at best, only annual data are collected, these studies were forced to manufacture three out of four observations in years when annual data were available and 100 per cent when no annual data were available. In the case of Bodman (1998), nearly 85 per cent of observations on R&D stocks were imputed.

Of the national (not State and Territory panel) studies to date, the Commission's recent study by Shanks and Zheng (2006) have the least imputed data (about one in four). Large numbers of imputed data points undermine the precision of estimates from the regressions in a way that is not reflected in the standard errors of estimates (these are the statistical basis for assessing whether the estimated parameters of models are statistically significant or not). This should be borne in mind when interpreting results from these Australian studies, including those of the Commission.

Table 4.1 **Key features of prior Australian aggregate studies of the effect of R&D**

Study	*Dependent variable, period*	*Apparent Obs.*	*Real Obs.*	*Major data issues*	*Measure of domestic R&D*
Dowrick (1994)	Ln(MFP), 1971–90	20	9[a]	55% of the data were imputed	BERD R&D stock
Industry Commission (1995)	Ln(Y) & Ln(MFP), 1976–77 to 1989–90	14	9	36% imputed	GERD R&D stock
Rogers (1995)	Ln(MFP), 1972–1990	19	12	37% imputed	BERD R&D stock
Bodman (1998)	∆ln(Y), 1968 Q1 to 1996 Q4	116	18	84% imputed; All quarterly R&D data interpolated, data source and type uncertain[b]	R&D stock
Crosby (2000)	∆ln(Y/hrs) and ln(Y), 1901 to 1997	97	..	..	Patents
Williams, Draca and Smith (2003)	Ln(MFP) 1984–85 to 1999–00	96	96		BERD R&D stock
Burgio-Ficca (2004)	Ln(GSP) 1979–99	126	63	Interpolated of missing R&D series	HERD R&D stock
Chou (2003)	∆Ln(Y/hrs), growth accounting, 1960–2000	41	20	51% imputed; Data on researchers is extrapolated for 16 years prior to 1976 and linearly interpolated for various missing years from 1976 to 2000	Researchers to employers
Connolly et al. (2004)	Ln(Y/L), Qtly data 1971Q2 to 2004Q3	134	25	81% imputed; All qtly R&D data interpolated	BERD (Share of ICT & R&D in total capital stock)
Shanks and Zheng (2006)	Ln(MFP) & many other forms; 1968–69 to 2002–03	35	26	26% imputed	BERD R&D stock mainly, but other forms tried

[a] Dowrick used Coe and Helpman's R&D stock, which was based on data from 1976-77 to 1988-89, with all other data imputed from the relationship between R&D, real output and investment apparent for years when data were available. Coe and Helpman's stock calculations imputed 11 of the 20 annual observations (not 7 as suggested by Dowrick p. 30). The imputation method creates the risk of endogeneity in any regression. [b] Bodman (p. 59) indicates that the quarterly R&D data are from the OECD's *Main Science and Technology Indicators* database, without specifying whether BERD, GERD or some other R&D measure is being used. Moreover, the R&D data in this OECD publication are annual, not quarterly.

Table 4.2 **Key results of Australian aggregate studies**

Study	*Domestic R&D elasticity*	*Foreign R&D elasticity*	*Implied rate of return on domestic R&D*
	coefficient	coefficient	%
Dowrick (1994)	0.066	0.065	150
Industry Commission (1995)	0.119	0.086	149
Industry Commission (1995)	0.04	0.041	43
Rogers (1995)	often negative	0.04	<0
Bodman (1998)	0.13	None	>200[a]
Williams, Draca and Smith (2003)	0.056 (own state)[b]	0.039 (interstate)	173 in 1990; 116 in 1999
Burgio-Ficca (2004)	0.21 (non-HERD stock). For higher education, R&D elasticities were 0.262 (basic); -0.052 (strategic); 0.445 (applied) and 0.210 (experimental).	..	na
Crosby (2000)	na	None	na
	Increased patenting contributed to both labour productivity and output growth. Part of the decline in productivity in the 1970s might be attributable to declines in innovation (proxied by patenting applications) from the late 1960s. A one per cent increase in overseas resident patent applications in Australia reduces domestic long-run applications by 0.36 per cent.		
Chou (2003)	na	None	na
	42 per cent of Australian labour productivity growth attributed to rise in educational attainment, and 20 to 40 per cent to the increase in research intensity. Most of growth is associated with 'transitional dynamics'.		
Connolly et al. 2004	0.013[c]	None	150[c]
CIE (in sub. 70) [d]	0.0571	0.0172	170
Shanks and Zheng 2006	Depended on the form of the R&D variable	Varied among specifications	Average of around 50 per cent gross rate and 35 per cent net rate for the most statistically adequate models[e]

[a] There is some uncertainty over the R&D stock used by Bodman and its underlying depreciation rate. But under any range of assumptions, the rate of return will likely exceed 200 per cent. [b] Elasticity for states. [c] Elasticity with respect to combined ICT and R&D stocks. The spillover rate is based on an average R&D and ICT stock to total capital stock of about 20 (p. 15) and a depreciation rate of 10 per cent per annum. Accordingly, the rate of return was calculated as 100*0.013*20-2.4 = 23.6 per cent on a quarterly basis and around 150 per cent annually. [d] The CIE study details are not shown in table 4.1 since the associated paper does not list them. [e] Shanks and Zheng used a variety of model specifications that covered endogenous growth rate as well as conventional models. The spillover rates are inferred from the steady state properties of the most statistically and theoretically adequate models described below.

In addition to these economywide aggregate studies, there have been several Australian time series studies that have considered the returns to R&D at the aggregate industry level, or for certain types of R&D (rather than by funding source or sector of performance). Shanks and Zheng (2006), for example, considered returns to R&D in agriculture, manufacturing and other sectors. They found returns to R&D of 24 per cent for agriculture and 50 per cent for manufacturing. Very large rates of return were found for mining and wholesaling and retail trade, which the authors questioned as improbable.

Most recently, DCITA (2006) examined the possible magnitude of spillover returns in 12 industry groups from 1988 to 2002, splitting R&D into ICT and non-ICT R&D. They found evidence of spillovers for both, with higher spillover rates for ICT R&D. But the results were not robust to specification change and were not statistically significant.

Taken at face value, past Australian studies support the view that there are spillover returns to R&D. The returns are spillovers, not spillovers plus private returns, because the measurement of productivity already takes account of the private impacts of R&D (Shanks and Zheng 2006, p. 54). If it were assumed that the models were independent assessments of the data and were statistically and theoretically valid, then it would be appropriate to undertake meta analysis of the results. The resultant average of the rates of return of about 100 per cent (using a zero estimate for Rogers) is at the upper end of the spillover rates that are plausible for R&D obtained from the semi-parametric method described above.

However, some of the results represented in table 4.2 are based on statistically or theoretically inadequate models. For example, the conventional Coe and Helpman static model of R&D returns for Australia (on which Dowrick 1994 is based) misses out on some key variables. With more data, the model exhibits serious serial correlation that at best, indicates dynamic misspecification and at worst, the spurious regression problem. As demonstrated in appendix F, it is easy to find a highly significant positive relationship between trending variables such as MFP and R&D, with no underlying relationship being really present. The parameter results of this model are likely to be severely biased and are probably not useful. The implication of the model that rates of return are 150 per cent cannot be given weight.

The Commission has also been unable to replicate the findings of IC (1995) with new and extended data, and so, for present purposes, these results too cannot be given much weight now.

It is not possible to examine exhaustively the econometric properties of all of the various other models shown in table 4.2, but the other feature many share, at least in part, is their datasets. Where results use largely overlapping time series datasets, this means that they are not fully independent studies. Differences between studies with such overlapping data must therefore either reflect (a) different econometric specifications and/or (b) the effects of adding new observations and data revisions. The presence of differences due to (a) begs the question of which empirical specification is superior to the other,[3] while differences due to (b) raises the issue of parameter inconstancy, which is a sign of misspecification in its own right.

As a consequence of misspecification and non-independence, it is not appropriate to average across econometric results from the studies shown in table 4.2. At best, after excluding the clearly misspecified models, the remaining results should be seen as a very tentative indicator of what spillover rates might be.

In addition to the semi-parametric method discussed above, this study has chosen two other approaches to identify (spillover or excess) rates of return on R&D. First, the results of Shanks and Zheng (2006) provide a useful starting point for consideration of rates of return, because it uses the most up-to-date information, has the widest set of auxiliary variables and considers a broad spectrum of competing models. A second strategy is to develop some extension of those results. An initial issue in both cases is the criteria for using any model results.

What criteria identify 'adequate' models?

In both instances, it is important only to consider adequate models out of the large group of models that can be estimated.[4] Adequate models are characterised by:

- including in general specifications the economic variables theoretically related to MFP growth that are available and well constructed, thus reducing the risk of omitted variable bias; and
- excluding models that show signs of misspecification (such as integrated errors, serial correlation and unstable parameter coefficients).

A vexed question is whether models with 'incorrectly' signed, but statistically significant, R&D variables should be included within the set of comparison models. If it were possible that the focus variables — business or total R&D capital stocks in

[3] That is, 'encompasses' the other as in Hendry (1995).

[4] The CIE (for Standards Australia) (sub. 70 attachment) also used a meta approach based on the model findings of Shanks and Zheng (2006). However, they did not exclude statistically or theoretically inadequate models from the range of estimates suggested, though they were careful to caution against the simplistic use of the results. The study was backed by case study evidence as well. An extension was provided in sub. DR156 that applied the semi-parametric method of appendix G to standards.

this instance — could have negative signs, then it would be appropriate to include such models within the comparison set. However, given what is known a priori about the function of business R&D as a source of knowledge or as a vehicle for absorption of external knowledge that feeds into productivity growth, statistically significant negative coefficients must, at the national level, be taken as evidence of model misspecification.[5] (In the case of publicly conducted R&D stocks, however, this need not be true, as discussed in chapter 3, and no Bayesian criteria of this kind should be applied.) The more highly statistically significant and larger in absolute size is a negative coefficient, the less credible are the results.[6] Of course, zero or negative, but not statistically significant, elasticities on R&D are not a sign of misspecification and should not be omitted from comparisons. To do so would bias inferences and would amount to inevitably finding a significant positive effect for R&D.[7]

In this study, we exclude statistically significant negatively signed parameters on business R&D stocks from the comparison models shown in tables, but we consider whether the addition of control variables to a final preferred specification still results in statistically significant negative coefficients on R&D.[8] We also considered the extent to which models that have such negative coefficients statistically outperform the preferred model, and why that might be the case. In this sense, we still allow a model with a significant negative coefficient to be preferred if the evidence consistently points to this.

5 In some industries for some periods, it is plausible that significant negative coefficients would occur due to patent races and wasteful forms of R&D duplication, but that appears very unlikely at the national level. It is possible to get roughly zero parameters. This could, for example, be associated with large inframarginal spillovers that have been exhausted at the margin. But that is not likely to show up as statistically significant negative coefficients.

6 That said, it is also appropriate and useful, as in Shanks and Zheng (2006) and Rogers (1995), to document those models where negative, statistically *significant* elasticities are found for R&D because these indicate the possible sources of the likely misspecification and do not hide it as a problem. In addition, were this repeatedly to be found as the best model on all other grounds, it would require some reassessment of the role of R&D. Inconvenient results should not be hidden.

7 It is possible that selection biases of this kind have affected the international and domestic literature, inflating the estimates of R&D spillovers that are published. A major way in which this can occur is through publishing bias. Journals may not publish, nor authors submit, results that have negative results for R&D elasticities. As the Congressional Budget Office (2005) noted, ‘Time series studies are also sparse, probably because significant results are hard to come by’.

8 The problem with excluding models with negative parameter values is that it amounts to imposing inequality constraints using non-linear least squares, with consequences for inference (Seck 2005). Averaging across models in which inequality restrictions have been imposed will tend to give an upwardly biased perspective on rates of return as well as too narrow confidence bands. This needs to be taken into account.

The 'best' models of Shanks and Zheng (2006)

On the criteria set up above, there are seven admissible models (table 4.3). Of these, two have negative coefficients on the domestic R&D variable, one a zero coefficient and four, positive coefficients. So, more often than not, the results show some positive effect of domestic R&D capital stocks on MFP. However, the t statistics on domestic R&D rarely exceed two, which means that against stringent testing criteria, all the results bar T7.3(Y5) and T9.3(Y3), cannot be distinguished from zero (or for that matter from a similar positive coefficient).

Table 4.3 **Best models from Shanks and Zheng (2006)**

Models meeting criteria[a]

Model	*Domestic*	*t stat*	*Growth effect (%)*	*Gross spillover rate*	*Foreign*	*Form of LHS*	*Form of domestic R&D variable*
	parameter	ratio	%	%	parameter		
T7.3 (Y4)[b]	0	(0.00)	0.00	0.0	0.079	∆log (MFP)	log(K/Y)
T7.3 (Y5)[c]	0.018	(2.25)	0.17	26.8	0.014	∆log (MFP)	log (∆K/Y)
T9.3 (L1)[d]	0.019	(0.43)	0.18	60.8	0.042	log (MFP)	log (K)
T9.3 (Y3)[e]	0.027	(2.45)	0.26	86.4	0.153	∆log (MFP)	log (K/Y)
T10.2 (S3LP)[f]	0.025	(1.56)	0.24	80.0	0.054	∆log (LP)	log (K/(Y*hrs))
T10.2 (S4)[g]	-0.001	(0.25)	-0.01	-1.5	0.018	∆log (MFP)	log (∆K/Y)
T10.2 (S4LP)[h]	-0.005	(1.66)	-0.05	-7.5	0.028	∆log (LP)	log (∆K/(Y*hrs))

[a] The models are listed by table number (so that T7.3 is a model from table 7.3 in Shanks and Zheng, 2006) and by the model in that table (Y4 or Y5). All models use exhaustive control variables (described in Shanks and Zheng), though their parameters are not listed here. All models met statistical adequacy standards, through test procedures. The key variable of interest is the coefficient on the domestic R&D variable, though in Shanks and Zheng, it was also regarded as essential to include a foreign R&D variable, since foreign R&D is conceptually clearly important to Australian productivity growth. The t refers to the t statistic (in absolute value) for the domestic R&D variable. The growth effect is the deviation in the steady state growth of market-sector output associated with a 10 per cent permanent increase in the capital to output ratio relative to the base case. For example, in model Y5 the effect of raising capital by 10 per cent above base for ever is a 0.17 percentage points increase in the economic growth rate. The gross spillover return on domestic R&D capital is calculated by multiplying the domestic coefficient by the ratio of output to capital (which ranges from to 32 depending on the depreciation rate). Special features of the models, other than those associated with the definition of the left-hand side MFP measure or the right-hand side R&D capital variables (which are shown in the table), are listed in notes for each model. [b] Uses time shift dummy and finite distributed lags (FDL). [c] Uses 5 per cent depreciation rate and several time shift dummies. [d] Uses United States Patent and Trademark Office (USPTO) patents for weights for foreign stocks and includes a linear time trend. This is the only conventional MFP model of the group. [e] Also uses USPTO patents and includes three time shift dummies. [f] Uses intercept dummy, four time shift dummies and a two equation system approach. [g] Uses FDL, 5 per cent depreciation rate, intercept dummy, one time shift dummy and a two equation system approach. [h] Uses 5 per cent depreciation rate, intercept dummy, one time shift dummy and a two equation system approach.

Source: Shanks and Zheng (2006) and PC calculations.

On close analysis of the short-listed models, one (S4) has an implausible coefficient on the index of communication services industry capital that reduces the credibility of that model. Another (S4LP) fits[9] the data more poorly than S3LP, after penalising for the additional explanators in S3LP. Accordingly, the two models with negative coefficients for R&D capital (S4 and S4LP) have some features, other than those considered by our initial model selection criteria, that make these models somewhat less compelling than the others. Moreover, Y5, S4 and S4LP use an R&D specification of $\log(\Delta K/Y)$, which imposes strong restrictions on allowable rates of depreciation for R&D stocks to avoid taking logs of a negative number.[10] In that case, the weight of evidence shifts more towards positive rates of return.[11]

If the two most problematic models are excluded, the overall effects of long-run growth on increasing the R&D capital stock by 10 per cent range from effectively zero to around 0.25 percentage points a year and the associated gross spillover rates from around 0 to 85 per cent, with an average gross rate of around 50 per cent. The results are clearly imprecise — as could be expected — but the overall balance is nevertheless positive. None of the identified positive rates are implausibly large or small by the standards established by the semi-parametric analysis of appendix G.

New time series estimates by the Commission

The new approach involved estimating an error-correction model (ECM) of MFP. Such ECMs are now often used in empirical time series because it bridges the cointegration literature with realistic dynamics.[12] The economic interpretation is that there is some equilibrium relationship to which the economy returns when shocked away from it. This is consistent with the underlying hypothesis in the production function approach that there is a long-run relationship between levels in MFP and its various determinants, such as levels of R&D capital.

In the models estimated using this approach, it was difficult to find a statistically significant role for foreign capital stocks, and sometimes the coefficients were negative (though not significant). This was also a problem encountered by Shanks and Zheng (2006) for some types of models. While foreign stocks are theoretically important, it is not surprising that they might not be found to be significant when they are measured as smoothly changing stocks. In their measured form, they really act like trends and so will pick up any trending behaviour in other variables or

9 Using the Bayesian Information Criterion.

10 Depreciation rates must be 5 per cent or lower — which is below the usually accepted rates (Shanks and Zheng 2006).

11 Against that, the use of four time shift dummies, as in S3LP, might be really evidence of underlying parameter inconstancy in that model, so the shift in the weight of evidence is slight.

12 And has been used in other MFP models, such as the panel estimates of Guellec, D. and van Pottelsberghe de le Potterie (2001).

residuals. This is suggested by the fact that introducing a trend in the model makes the negatively signed foreign stock positive, but insignificant.[13] It is possible that the most important aspects of foreign R&D effects are being picked up by trade barriers (which tend to set up barriers to flows of knowledge as well as goods) and education. It does not appear that domestic R&D stocks — also a trending variable — is picking up the effects of foreign stocks (through absorption effects) because the domestic R&D elasticity actually rises if a foreign R&D stock is included in the model (table 4.4).

If the foreign stock is excluded from an ECM model, an adequate model of MFP was found (the *base* model):

$$\Delta \log MFP = \underset{(15.3)}{0.54}\, \Delta Cycle + \text{other } \Delta \text{ terms} - \underset{(6.4)}{0.692} (\log MFP_{-1} - \underset{(3.5)}{0.055} \log K_{-3} + \underset{(3.3)}{0.084} LERA_{-1}$$

$$- \underset{(5.6)}{0\ 175}\, LEDUCATION_{-1} - \underset{(5.5)}{4.07} + \underset{(3.5)}{0.003}\, TREND - \underset{(4.9)}{0.0244}\, DUM85)$$

$R^2 = 0.92$, 100SE = 0.542, DW = 2.81, tests for serial correlation, unit roots, cusum stability tests, reset misspecification were all adequate, estimation period is from 1971-72 to 2002-03.

All variables (bar the cycle variable) are in logs and subscripts indicate whether a variable is lagged. K is the domestic stock of business R&D capital (with a depreciation rate of 15 per cent). ΔCYCLE is a variable to control for business cycle effects and is measured as $\Delta(\{Y/HP(Y)\}-1)$, where Y is market-sector GDP and *HP*(Y) is the Hodrick-Prescott filtered value of Y. This differs from the cycle term used by Shanks and Zheng. DUM85 is an intercept shift for 1985 and other variables are as defined by Shanks and Zheng.

The use of lagged R&D stocks is important because of the risk of endogeneity bias. R&D investment decisions are affected by output growth as well as affecting output growth itself. Consequently, if there is some unobserved shock that increases output and MFP, then it will also increase contemporaneous R&D investment and the R&D capital stock. This can bias the coefficient on R&D. Lagging the R&D capital stock is likely to alleviate this concern, and is, in any case, probably a more realistic treatment of the response lags that are required for spillovers to emerge.[14]

The role played by the CYCLE variable is important. The business cycle has no long-run effect on MFP growth, but it can mask the effects of factors, like R&D,

[13] The long-run elasticity on the foreign stock is 0.069, which is consistent with the elasticities found by Shanks and Zheng in some of their best models, described in table 4.3.

[14] If it were thought that the contemporaneous R&D stock was the right variable for using in the model, then instrumental variables estimation would be required. We have not pursued that approach.

that make small long-run contributions and significantly affect the dynamic behaviour of the model.

The model compares favourably with the T(9.3) L1 model of Shanks and Zheng shown in table 4.3. The standard error of the estimate (over the same period) is about 30 per cent less for the new model compared with T(9.3) L1 and its better fit remains even after penalising the new model for its greater number of parameters. The gain is probably due to the dynamic specification of the new model.

The single most important problematic aspect of this regression is the high Durbin Watson statistic, which can suggest overfitting. Dropping the dummy shift removes this problem[15], but it also reduces the precision of the estimate of the R&D elasticity. An added foreign stock variable is positive, but not significant, so its inclusion in the model is rejected. The trend factor is a potentially questionable feature of the model, but it is the pattern that would be expected if hedonic price adjustment on physical capital stocks had overstated the economic value of the improvements made to those stocks. This is, at least, a tenable hypothesis. If the trend is dropped from the model, the coefficient on R&D is reduced, but not by much.

A concern in models with highly constructed variables, such as R&D capital stocks, is that the significance of the constructed variable is only picking up some other trend or time series behaviour of the variable, rather than its real economic information content. To test this, Box-Jenkins' methods were used to model the ARIMA characteristics of the domestic capital stock. Then an artificial variable with similar variance and the same ARIMA structure was created and used within the regression model as a substitute for the genuine domestic R&D variable. In repeated tests, such simulated artificial variables were not statistically significant in the model, which suggests that the significance of the R&D variable is not an artifice of its ARIMA characteristics. This further suggests in favour of the model results.

The interesting feature of the model is its long run, which is:

$$\log MFP = 0.055 \log K_{-2} + 0.084\ LERA + 0.175\ LEDUCATION - 4.07 - 0.003\ TREND - 0.0244\ DUM85$$

The long-run version of the model was estimated (in unrestricted form) and was found to be stationary, which provides evidence for a cointegrating long-run relationship even when the long term model is not nested within an ECM framework. The coefficients in the static model were very similar to those shown

[15] The Durbin Watson statistic becomes 2.2.

for the long run in the ECM form, providing further evidence for the adequacy of the model.

From an economic perspective, the long-run coefficients on education and openness agree with the findings of Shanks and Zheng and seem plausible. The model implies a long-run net rate of return on business R&D of 160 per cent. This is unrealistically high on the basis of the semi-parametric results in appendix G. However, the return is not accurately measured and could easily be half the rate shown.

It is also apparent that different specifications change the outcomes somewhat. The net rates of return are within the range 86 to 183 per cent when a variety of variable addition and deletion tests are undertaken (table 4.4).

Table 4.4 **Effects of variable additions/modifications on the long-run elasticities and rates of return[a]**

Addition or deletion	*Elasticity*	*Gross return*	*Net return*	*Dep*	*Y/K*[b]
		%	%	%	ratio
Base case	0.0552	178	163	15	32.3
Drop DUM85	0.0476	154	139	15	32.3
Drop Trend	0.0362	117	102	15	32.3
Drop DUM85 and Trend	0.0312	101	86	15	32.3
Add Foreign (lagged) (10% depreciation)	0.0579	187	172	15	32.3
Add Foreign (lagged) (15% depreciation)	0.0584	189	174	15	32.3
Add Foreign (lagged) (USPTO measure)[c]	0.0529	169	154	15	31.9
Change to Domestic_{-2}	0.0613	198	183	15	32.3
Change to Domestic_{-1}	0.059	191	176	15	32.3
Change to 10 per cent depreciation rate	0.0541	128	118	10	23.7
Average	0.0514	161	147	..	..

a The t statistics for the elasticity are not shown but fall when the specification shifts away from the base case, sometimes becoming not statistically significant at the conventional level. Other variable addition tests were undertaken, but are not shown. They also had no marked effects, but were intended to assess whether in moving from a general to specific model, any of the dropped variables in the sequence of reductions, should really be added back. These additions included the variables TIOPEN and CENTBRG that were used in Shanks and Zheng. **b** Y/K is the ratio of market-sector GDP to the relevant domestic R&D capital stock over the estimation period. **c** This uses USPTO patents for weights for foreign stocks. The Y/K ratio in this model is different from others due to the fact that the sample period over which the revised foreign stock is available is different.

Source: PC calculations.

Despite the overall stability of the model, parameters do, nevertheless, move over time, though within acceptable statistical bounds. As found in Shanks and Zheng, it appears that elasticities are steadily declining. This is consistent with the view that when R&D investment rates were much less, the marginal gains to productivity were more. These diminishing marginal effects might reflect large early catch-up gains from investing in R&D when a country is well behind the world's best technical frontier. Arguably, that gap has now closed somewhat, and with it, the marginal gains. As we discuss later, there is also some evidence of this phenomenon using international panel data. It is worth noting that even with a fixed elasticity, the implied spillover rates of return decline over time as the GDP to R&D ratio has fallen. With elasticities also trending slowly down, this implies more rapid reductions in spillover rates — though they remain high.

Obvious missing elements of the above specification are non-business R&D stocks — those from public sector research agencies and the higher education sector. Additions of these to the specification did not change results qualitatively on the business R&D stock, but it was not possible to get reliable results for these two important R&D stocks by themselves. The interpretation of why non-business R&D stocks is missing and the implications for policy are discussed below.

Overall, this new model appears to suggest strong returns to domestic business R&D, though these may be falling over time. Its major strengths are that it:

- passes standard tests of statistical adequacy;
- uses a dynamic specification and its long run appears stationary;
- considers a reasonable number of other factors that might explain MFP growth and tests the final model by retesting whether any omitted variables matter after all; and
- encompasses at least some of major alternative conventional models of MFP.

Its major deficits are the lack of statistical significance of a foreign R&D stock, the fact that, given other evidence, point estimates of the rates of return are unrealistically high, and evidence of overfitting. However, not too much weight should be attached to point estimates when the precision of the parameters is relatively low. As emphasised by DCITA (sub. DR180), econometric modelling of the various roots of economic growth is very complex. With statistical uncertainty, the results above could still be consistent with the credible bounds suggested in appendix G. Either way, the new model adds weight to the hypothesis that R&D produces significant returns to the economy through productivity increases that are not captured as rents by the firms undertaking R&D.

Panel data evidence for Australia

The Commission also used panel data for Australia to investigate possible rates of return (appendix H). The advantage of a panel dataset is that it can exploit two sources of variation in MFP growth rates — those that occur over time (as in the analysis discussed above) and that which occurs at any given time between Australian jurisdictions. The disadvantage of this approach is data scarcity. There are fewer observations on R&D, MFP, or for that matter some of the important control variables, so that the period of time considered is from 1990 to 2002 and more of the R&D data are interpolated than for the data set from Shanks and Zheng (2006).

The basic formulation used in this modelling (model 1 below) is similar to that used in the model above and includes similar controls for various factors other than domestic R&D stocks that might influence MFP. However, the panel data analysis also included a less restrictive model in which State Gross State Products are estimated directly, with capital and labour inputs included in the specifications. This allowed control for economies or diseconomies of scale (or better control for errors in national accounts relating to these measured inputs).

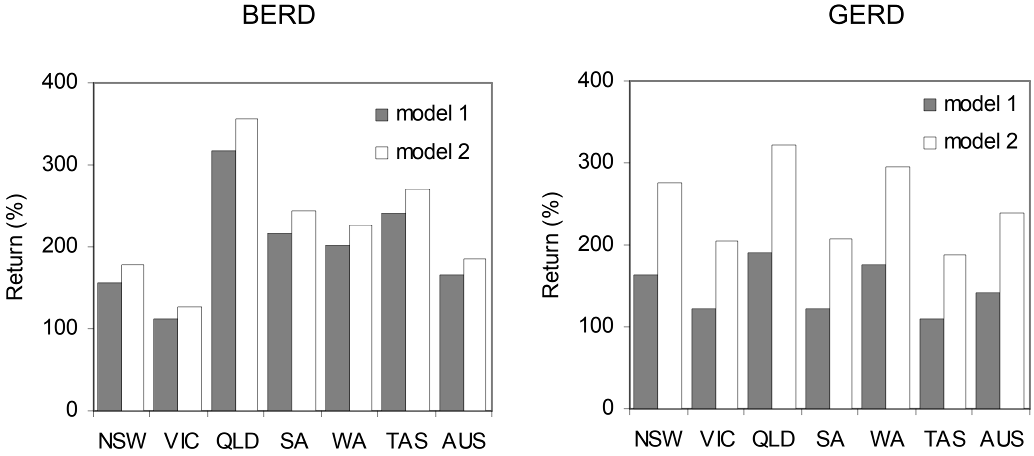
The implicit assumption in the panel data method used is that there are separate (fixed) effects for each State that account for statewide variations in their average MFP levels, but that the R&D elasticities are the same. There are still variations in their rates of return on R&D (figure 4.2) because rates of return are a function of elasticities and GSP to R&D ratios (which vary considerably). The estimation finds Australia-wide average gross rate of return is about 165 to 185 per cent for business R&D. This varied significantly by jurisdiction, though the precision of the models is too weak for this to be the basis for any policy action. The State differences could easily arise through misspecification biases or errors in variables.

The other major feature of the panel data estimation is that it suggested some impacts on economic growth from R&D undertaken in the public and higher education sectors. These were not significant at the disaggregated level, although point estimates were positive. But they showed up as positive and significant rates of return for an aggregate measure of R&D (GERD), which combined BERD, GOVERD and HERD. It could be that the major reason for this is simply that BERD is the biggest contributor to GERD. The Australian rate of return for the GERD stock was, averaged over the period, from 140 per cent (MFP model) to 240 per cent (GSP model), showing some of the sensitivity of the model specification.[16] The latter result appears to be implausibly high given the observations made earlier about the focus of non-business R&D and the time it takes for any market-relevant R&D in these parts of the innovation system to have commercial implications. But the results support positive impacts of some kind.

16 The rate of return in the latest year was between about 100 (MFP model) and 150 per cent (GSP model).

Figure 4.2 **Gross rates of return for Australian States**

Panel data estimates, BERD and GERD[a]



[a] Model 1 is based on estimation of an MFP equation while model 2 is based on estimation of a GSP equation. That included controls for labour and capital inputs. The model specification included controls for the foreign capital stock (which had a high elasticity, as theory suggests, but was not statistically significant); a measure of the business cycle; union membership rates and educational attainment. Rates of return are estimated by multiplying the elasticity by the average of the yearly GSP to R&D ratios.

Data source: Appendix H.

International evidence

The existing Australian studies available represent a small sample of the many international studies into the effects of R&D. International studies have several major advantages. The data are often of higher quality or is available for longer. The international dimension also makes it possible to extend the panel data approaches the Commission used within Australia to exploit cross-country variations.

However, some of the differences between countries may need to be considered. Australia is geographically remote from other developed countries, which affects the prospects for trade-intermediated knowledge flows (Tunny 2006; Jaumotte and Pain 2005). To the extent that there are complementarities between returns from domestic and foreign R&D flows, this might lower the impacts of domestic R&D on MFP. Panel data methods can, at least in principle, draw out differences in country-specific factors that affect R&D elasticities and spillover rates.

There have been many major reviews of the international literature[17] so that it is not appropriate to undertake another comprehensive review. The reviews cover empirical analysis at the firm, industry and macroeconomic level. All review papers find excess private returns as a general phenomenon. But since spillovers, by their nature, spread beyond firms and industries, the best level of aggregation for determining average R&D spillover rates is probably whole economies, and so results at this level are the focus of this section.

The overall conclusion of these reviews is that spillover rates are likely to be high, but that the results are imprecise. For example, the Congressional Budget Office of the United States (2005) observed that:

> In summary, the available empirical evidence supports the idea that spillovers exist at the macroeconomic level and that they probably cross national boundaries. Indeed, it would be hard to believe that spillovers did not exist, considering the characteristics of knowledge and R&D capital that resemble those of public goods. But the challenges of measuring and estimating the impact of spillovers are formidable. Hence, it is not surprising to find considerable variation in estimates of the size of spillover effects and in the significance of those estimates across studies.

The CBO's judgment for the US was that aggregate R&D stock elasticities were in the range of 0.02 to 0.05. These implied rates of return of around 20 to 30 per cent for the US. The elasticities are at the lower end of the ranges suggested by the international literature and the new model estimated by the Commission for this study, but very close to those found by the more extensive study by Shanks and Zheng (2006).[18]

Apart from the reviews, which all support the importance of spillovers to economic growth, some of the more contemporary panel studies on economywide own rates of return are worth highlighting because such studies use more data and better methods. These studies suggest strong linkages between productivity growth and therefore output growth and R&D (typically business or total). (The effects of public R&D is discussed below). Not all report spillover rates, with some instead just reporting the extent to which permanent increases in spending on R&D affects economic growth. Where spillover rates are reported, they tend, on average, to lie between 50 and 130 per cent. A recent panel data analysis by Gans and Hayes (Gans Sub. 10, pp. 23ff) found a high elasticity for Australian business R&D, implying a spillover rate of around 300 per cent (table 4.5).

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[17] Such as IC (1995); Congressional Budget Office (2005); Dowrick (2003); Commission of the European Communities (2005); Martin et al. (1996); and Scott et al. (2001).

[18] The rates of return implied for Australia by elasticities of between 0.02 and 0.05 are between 64 and 160 per cent because of Australia's higher ratio of output to R&D than the United States.

Table 4.5 Recent panel data international evidence on the effects of R&D

Study	*Study type*	*R&D elasticities*	*Summary measure/comments*
Coe and Helpman (1995)	Panel of 22 countries, 1971–1990, business R&D	0.247 for G7 countries and 0.107 for others	123% for G7 countries; 85% for the smaller countries.
van Pottelsberghe de le Potterie & Lichtenberg 2001	Panel of 13 countries, 1971–1990 business R&D	0.087 in G7 countries and 0.008 in small countries	68% in the G7 countries and 15% in the smaller countries
Lichtenberg & van Pottelsberghe de le Potterie 1996	Panel of 13 countries, business R&D	0.0 83 in G7 countries; 0.017 in small countries	51% in G7 countries; 63% in six small European
Frantzen 2000	Panel of OECD countries from 1961–1991; business sector R&D		About 60%
Luintel and Khan, (2003)	Panel of 10 OECD countries 1965–1999 Business & total R&D	Average around 0.27 for all R&D and 0.06 for business R&D	132% average for all R&D. Individual country results were: Ireland (453%), Denmark (183%), the US (175%), the UK (148%), the Netherlands (106%), Japan (100%), France (56.8%), Italy (4.9%) and Canada (-33.4%)
Guellec and van Pottelsberghe de le Potterie (2001)	Panel of 16 countries, 1980–1998; business & public R&D	Business R&D 0.132; Public R&D 0.171	The impact of business R&D on MFP is larger in countries where R&D intensity (the ratio of business R&D on business GDP) is higher.
Aiginger and Falk (2004)	Panel of 21 OECD countries, 1970–1999	Business R&D intensity 0.22	Measure is elasticity of R&D intensity with respect to long-run GDP per capita.
Bassinini and Scarpetta (2001)	Panel of 16 OECD countries, 1981–1998	GERD 0.14; BERD 0.13	Measure is elasticity of the R&D to output ratio with respect to GDP per capita growth. Implies a permanent 10% increase in GERD to output will raise GDP growth per capita by 1.4% per annum — a large return.
Luintel, K. and Khan, M. 2005a	Panel of 16 countries, 1980–2002; public, business & foreign R&D stocks	0.004 (UK) to 0.049 (Ireland) for business R&D	R&D elasticities are heterogeneous among OECD countries, so standard fixed effects models are probably invalid. Implies a business R&D spillover rate for Australia of about 40% (and a higher rate for public sector R&D)
Luintel and Khan, (2005b)	Panel of 19 countries, 1981–2000; Triadic patent stocks	0.048 (US) to 1.102 (Ireland) but patent stocks not R&D	Heterogeneity is important. Countries that already have an important R&D sector (such as the United States, Germany, Japan, the United Kingdom, Switzerland), the contribution of knowledge stocks to MFP appears very modest.
Gans and Hayes (2006) from sub. 10, pp. 23ff	Panel of 16 OECD countries from 1980–1998	0.11 Australia; 0.174 rest of OECD for business R&D stocks	Has significant foreign R&D effect. Introduces dummies for Australia to partly account for heterogeneity among the panel. Implied spillover rate of return for Australia is around 300%.

Many studies find (or implicitly impose) fixed elasticities of (usually business) R&D with respect to MFP, with the implication that there will be higher average spillover rates for Australia. This is because Australia has less R&D intensive industries (and therefore higher output to R&D ratios in aggregate) and the spillover rate is defined as the ratio of output to R&D stocks times the elasticity.

Against this, there are two contrasting findings. First, some studies have found that there are economies of scale in R&D, and that the larger G7 economies have higher elasticities, whose effect is to actually elevate overall spillover rates for these economies. This was more typical of the earlier panel data studies, such as Coe and Helpman (1995).

More recently, evidence has been mounting for the opposite hypothesis, which posits some exhaustion of the gains with the R&D size or sophistication of economies (as noted in this study and by Shanks and Zheng (2006) for time series evidence for Australia). For example, Griffith et al. (2000, 2004) suggest that the scope for technological catch-up plays an important role in determining the benefits of domestic R&D. Countries that lag more behind the global best practice frontier experience higher rates of return from R&D (figure 4.3, part A). Rates of return, however, are still high (around 40 per cent) for those at the frontier, such as the United States.

Similarly, Luintel and Khan (2005b) considered the extent to which ‘new-to-the-world’ knowledge stocks[19] affected productivity growth. They find that countries that have large stocks of such novel knowledge (such as the United States, Germany, Japan, the United Kingdom, Switzerland) derive relatively small marginal benefits in productivity from new additions to that stock (part B of figure 4.3). Productivity growth in Australia exhibits a higher than average responsiveness to additions to new knowledge of this kind (and has historically had a relatively low rate of production of these novel knowledge flows). These results are important in that they suggest a relationship between one type of innovation — that resulting in patents — and productivity. However, despite the sophistication of the model estimated by Luintel and Khan, it is likely that much of the effect picks up the correlation that patents have with some omitted factors that affect productivity.

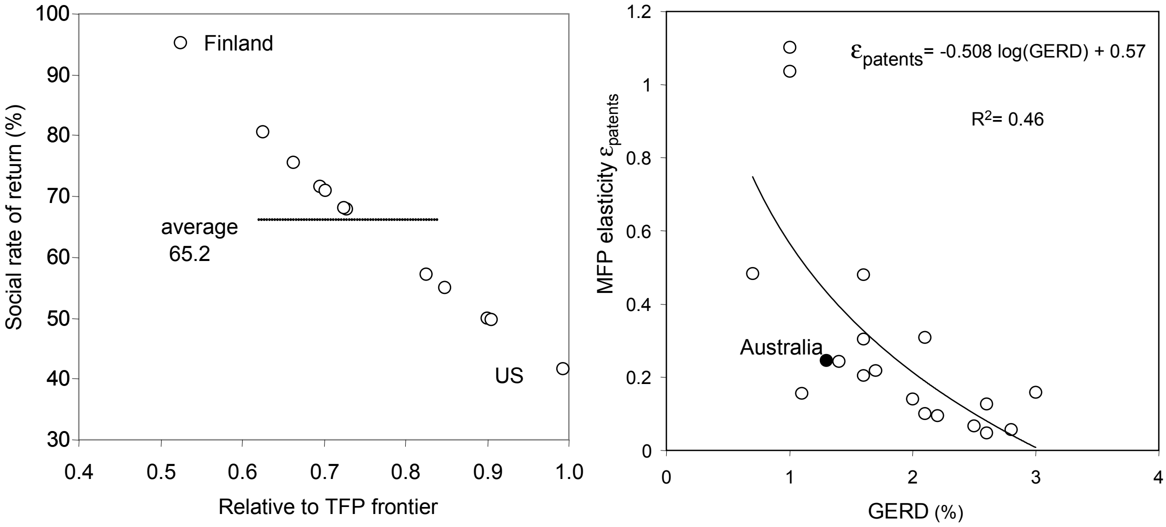
A broader perspective on the heterogeneity of responses of MFP to R&D among different countries took account of R&D stocks of different types (Luintel and Khan 2005a — shown later in figure 4.4). Such heterogeneity is much more intuitively appealing because it implies less dispersion in the associated spillover rates across countries than that automatically generated by fixed elasticities under imposed homogeneity.

[19] Such stocks were measured as the depreciation of flows of triadic patents taken out. This is the set of patents at the European Patent Office (EPO), the Japanese Patent Office (JPO) and the USPTO that share one or more priorities.

Figure 4.3 **R&D has different effects on MFP for different countries**

Panel results

Part A	**Part B**
Social rates of return to R&D depend on how far countries lag behind the best practice frontier	Productivity responsiveness to knowledge stocks is inversely related to R&D intensities
(Results from 12 countries, 1974–1990)[a]	(Panel of 19 countries, 1981–2000)[b]



[a] Spillover rates of return relate to manufacturing. Note that rates of return and the R&D elasticities shown in the other two sets of graphs are associated, but different concepts. [b] The spillover rates are the multiple of the elasticity and the ratio of GDP to the R&D stock, which vary considerably by country. Accordingly, the spillover rates are not proportional to the elasticities shown here. Australia (AUS) is shaded black.

Data source: Part A chart derived from Griffith et al. (2000, 2004); Part B chart derived from data presented by Luintel and Khan (2005b).

Australia is found to have a relatively low business R&D elasticity when the assumption of homogeneity is relaxed.[20] Taking into account Australia's very high GDP to R&D ratio in the business sector, this generates a more reasonable spillover rate for Australia (of around 40 per cent) than under homogeneity. The study also finds that the higher the stock of domestic R&D capital, the greater are the spillovers from foreign knowledge stocks, consistent with some value from domestic absorptive capacity (though this should not be taken to imply that this is the only way of transferring foreign knowledge — appendix D). This paper also makes important findings on the effects of public R&D on MFP, but these are discussed below.

[20] This varies from that found by Luintel and Khan's other study on patent knowledge sets (2005b), which also allows for heterogeneity. However, that model is concerned with only one kind of knowledge set, so the differences between the studies' findings may not be inconsistent.

International evidence on the returns to publicly supported R&D in universities and public research agencies

There are many international estimates of the returns to publicly supported non-business R&D (R&D conducted in public agencies and universities), though the weight of empirical evidence available depends on the level of analysis.

The least developed evidence relates to aggregate analysis of country growth or productivity using panel data. As noted earlier, panel studies are likely to provide a more reliable indicator of the aggregate effects of R&D expenditures because they can 'wash out' more of the noise present in individual time series studies, while better dealing with the endogeneity problems present in cross-sectional country data. Perhaps reflecting data deficiencies, most panel data studies incorporating separate public and private R&D effects are relatively recent. Given their importance, these are examined in detail.

Recent econometric studies using multi-country panel data

The earliest study adopting the panel data method is Park (1995), who analysed the change in GDP per capita in 10 OECD countries from 1970 to 1987. The paper found that public R&D, while being positive, lost any statistically significant effect on productivity growth when business R&D effects were also accounted for.

A more recent, innovative and widely cited paper is by Bassanini and Scarpetta (2001), who analysed the sources of GDP per capita growth in 21 OECD countries from 1981 to 1998. This paper was used as a prime input into the OECD's major analysis of the sources of growth among OECD countries. Limitations in data meant that several countries and variables had to be dropped in the model incorporating R&D. In this restricted model, the explanatory variables included population growth, public and private R&D spending to GDP, capital accumulation and the average years of schooling of the working age population. Most of the variables aimed at testing the effects of institutional and policy settings (for example, inflation, fiscal settings, state of financial intermediation) were not included in the R&D model because of data limitations. The variable measuring trade exposure was an exception. The model imposed the same R&D elasticities in the long run for all of the OECD countries, but allowed short run effects to vary.

The approach differs markedly from most other studies in the choice of the R&D variables. The study used contemporaneous R&D spending normalised by GDP instead of (the conventionally used) lagged R&D stocks. Lagged effects of R&D are allowed through the inclusion of a lagged dependent variable, but the coefficient on that variable will be largely determined by non-R&D variables (and is high in this model, p. 46). Consequently, the model effectively imposes a restriction that R&D spending has relatively rapid effects on growth.

The findings of the model are that business R&D to GDP has strong positive effects on economic growth (with an elasticity of 0.26 and a highly statistically significant t statistic of 26). But public R&D to GDP has a strongly *negative* effect on growth (with an elasticity of -0.37 and a highly statistically significant t statistic of about 9). The authors conjecture that this may reflect the potential crowding out effect of public R&D on business R&D, uncounted benefits of public R&D (such as better health) and long lag effects that are not well accommodated by the model. The latter self-criticism appears likely to be valid given the structure of lags imposed by the definition of R&D used. Dowrick (2003) also considered the treatment of lags as a problematic feature of the paper. Crowding out effects are less likely to be a convincing source of the finding since more direct evidence (appendix M) tends to reject significant crowding out effects for public civilian R&D (which is the dominant form of public spending).

There are also several worrying features of the results that should be considered. The t statistics are rather high given the known data and econometric problems besetting estimation of growth models. They certainly cannot be taken to indicate the degree of precision implied. Second, the R&D models suffer from omitted variable bias, since they exclude variables found to be useful in explaining economic growth in the more general models estimated by Bassanini and Scarpetta. Even in the cited results, there is evidence of this bias in that trade openness is only included in models not also including public R&D intensity. A related concern is the behaviour of other variables in the model as the specification is changed. For example, in the specification including public R&D, the population variable has a coefficient of -33.9 and human capital a coefficient of 1.76. In a model with just business R&D, the comparable coefficients are -16.4 and 0.82 — representing large changes in these variables. This suggests that multicollinearity may be present in the models in a way that reduces the policy usefulness of individual parameters. Finally, the lack of testing for the inclusion of foreign R&D is a concern, given its importance in many other studies.

Given these concerns, the paper cannot be taken as reliably identifying the effects of publicly conducted R&D, a view the authors also maintain.

Whereas the Bassanini and Scarpetta paper was aimed at developing a robust model of growth, a companion paper by colleagues Guellec and van Pottelsberghe de la Potterie (2001, 2004) aimed to elucidate the effects of R&D in particular. This study used panel data from 16 OECD countries to examine the impacts of business, foreign and government R&D stocks on MFP over the period 1980 to 1998.

By using MFP as the dependent variable, the paper already incorporates the influence of physical capital and labour. A deficiency in this approach, however, is that choosing this form effectively imposes constant returns to scale, which may not be realistic. While the paper includes several variables beside R&D (such as a German reunification dummy and cyclical effect) these control variables are not as varied as those of Bassanini and Scarpetta, making model comparison difficult. The model incorporates time dummies to allow change over time in intercepts and country fixed effects, but imposes fixed elasticities on the R&D stocks. As in the Commission's model it uses the error-correction form to allow deviations from a stable cointegrated long-run relationship between MFP and the various R&D stocks. The model employed a longer lag (three years) for public compared with business and foreign R&D to take account of the slower commercial diffusion rates for this knowledge. The effective lag is longer than this because the R&D stock at any time captures the effects of past R&D flows (depreciation rates are 15 per cent).

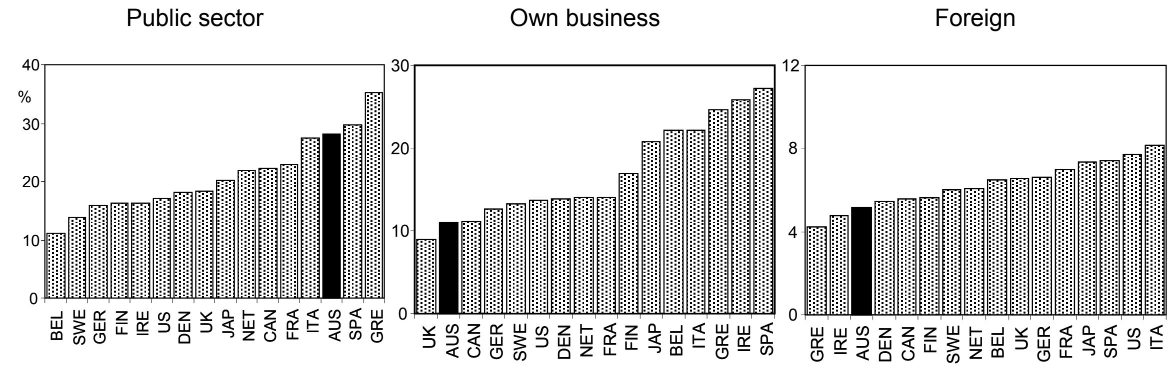
The paper found that the long-run elasticity of MFP with respect to public research (that performed in universities and public laboratories) was 0.17, somewhat higher than the estimate for business R&D. The authors thought that this premium reflected the concentration by public agencies on basic research, but the statistical problems present in any such study are almost certainly not sufficient to reach such a strong conclusion. The study found several other interesting features that illustrate some of the *potential* subtleties in the links between R&D and growth:

- The productivity effects of public research are higher in countries with higher business R&D intensities, which the authors attribute to better knowledge absorption capacities of the business sector.
- These effects are also higher in countries where the university share of public research is higher.
- The effects are lower — indeed negative — as the share of defence R&D spending increases in public R&D. This need not be seen adversely since it is likely to reflect the uncounted benefits of a defence capability (which is not valued in GDP).
- The impact of public research falls the more university research is funded by the business sector. The authors conjecture that this could reflect the displaced long-run returns from basic research, since basic research is less often the target of business funding of universities.
- The productivity effects of public research appear to be diminishing over time, which warns against using past estimates of impact effects as if they offer robust guidance to future policy. As emphasised throughout this report, the econometric indicators are simply not robust enough to reliably determine exact funding levels of public science.

The final paper in the trio of OECD panel data papers is that by Khan and Luintel (L&K 2005a, K&L 2006). They consider the impacts of business, foreign and government R&D stocks on MFP for 16 OECD countries from 1980 to 2002. The model estimated has a rich set of control variables.[21] As the authors note, models that focus mostly on R&D as the determinant of MFP growth risks omitted variable problems (p. 21). Unlike past models, their model allows coefficients for dependent variables to vary for each country (figure 4.4). They use a range of state-of-the-art estimation methods that better address endogeneity, inertia and variable measurement error than other approaches. The model met a wide range of diagnostic tests of potential misspecification.

Figure 4.4 **R&D has different effects on MFP for different countries**

Panel of 16 OECD countries, 1980-2002, R&D elasticities by type of R&D



a The spillover rates are the multiple of the long-run elasticity and the ratio of GDP to the R&D stock, which vary considerably by country. Accordingly, the spillover rates are not proportional to the long-run elasticities shown here. Australia (AUS) is shaded black. Country codes are the three letter shortening of the English names of OECD countries.

Data source: Derived from data presented by Luintel and Kahn (2005a) and Kahn and Luintel (2006).

This panel data analysis suggests significant variations in elasticities across countries, particularly for business and public sector R&D stocks. They found statistically significant long-run elasticities between MFP and public R&D (as well as to business and foreign R&D). The long-run public R&D elasticity varied between 0.11 and 0.298 depending on the country, with Australia at the high end at 0.28 (p. 26). The average was 0.21. As in the papers by Guellec and van Pottelsberghe de la Potterie, several interaction effects were present. Higher stocks of business R&D were associated with lower impacts from public R&D stocks and vice versa. However, public R&D reinforced the impacts of public infrastructure.

21 This includes control variables for human capital (years of schooling), stocks of public infrastructure, access to export and import markets, inward and outward FDI and an indicator that captures the effects of the business cycle.

There was no evidence of a diminishing impact on productivity growth as public R&D stocks increased in size (no diminishing returns to public R&D).

A major issue is why the findings about the effects of public R&D by Khan and Luintel (L&K 2005a, K&L 2006) and Guellec and van Pottelsberghe de la Potterie (2004) vary from that of Bassanini and Scarpetta (2001). Khan and Luintel provide at least some evidence on this point. They note (K&L 2006, pp. 17-18) that a misspecified model that excludes a range of relevant control variables and that does not allow heterogeneity among OECD countries replicates the findings of Bassanini and Scarpetta (2001), with public R&D stocks having a negative influence on MFP. They are therefore able to explain *how* misspecification causes a negative coefficient on public R&D, which builds the credibility of their model. The results presented by Khan and Luintel represent the best existing empirical analysis of the role of different types of R&D on economic growth.

Other evidence

Most evidence about the effects of publicly conducted R&D relates to the performance of parts of the economy, rather than to its overall growth. The most detailed is for the agricultural industry and shows compelling evidence of high positive returns to public R&D relevant to that sector. For example, the combined public returns for the 42 econometric studies examined by OTA (1986) and IC (1995) averaged 57 per cent (median 43 per cent) with the averages of the high and low levels of the ranges equal to 48 and 68 per cent respectively. There is also strong evidence of positive returns from public R&D for manufacturing industries, though there are not as many studies:

- Some early industry level econometric studies found only weak and inconsistent correlations between productivity growth and federally funded R&D (Terleckj, 1974 and Mansfield, 1980 for manufacturing). However, since these studies, better cross-country data sets have become more readily available and econometric methods have increased in their sophistication. The later studies typically found positive returns.
- Mansfield (1991) estimated the return to all US academic research using a sample of 76 American manufacturing firms. He concentrated on the impact of academic research undertaken within 15 years of the release of innovations. Surveys of firms revealed that 11 per cent of new products and 9 per cent of new processes had been significantly brought forward because of academic research. He also found that 2.1 per cent of sales of new products and 1.6 per cent of sales of new processes would not have been developed without the initial academic research having been done. He estimated the rate of return to academic research to be 28 per cent.

- In a follow up study Mansfield (1998) found that academic research was becoming increasingly important for industrial activities. He found that 15 per cent of new products and 11 per cent of new processes had been significantly brought forward and that innovations accounting for five per cent of total firm sales would not have been developed without the prior academic research having taken place. He estimated that the lag from academic research to commercialisation had fallen from seven to six years.
- Beise and Stahl (1999) conducted a similar study for Germany using a sample of 2300 manufacturing firms. They found that five per cent of new product sales would not have been developed without prior academic research.
- Cockburn and Henderson (2001) using their estimates and a review of other studies estimated a rate of return of greater than 30 per cent for publicly funded pharmaceutical research.

There is a large body of case study evidence measuring the returns to specific projects or portfolios of research, but this is reviewed in section 4.5.

The results described above represent a part of a larger corpus of evidence — summarised in a range of review papers — that collectively suggest positive returns to publicly conducted research. The reviews include Scott et al. (2001) (especially their review of NIST studies), Martin et al. (1996), Salter and Martin (2001), Dowrick (2003) and Econtech (2006). Garfield (2005) references a useful literature relating the links between the basic science revealed by journal publications and commercial applications.

What do all these numbers mean?

The Commission has considered many strands of econometric evidence about the effects of R&D on the market economy. It is important to categorise the evidence by the nature of the R&D.

A large body of evidence relates to business R&D stocks. This has only partial relevance to the question of public funding support for science and innovation. It is relevant to all R&D only to the extent that it provides empirical support for the existence of spillovers as a *mechanism* for diffusing benefits throughout the economy. But the empirical measures of spillover rates derived from this literature cannot be inferred to apply to publicly supported R&D projects in non-business sectors, though they are often cited as if they are relevant in this way — an observation emphasised by the IPA (sub. DR139 or Davidson, 2006).

The identified returns to business R&D have some policy relevance when considering public support for business R&D, but even here their usefulness is tempered. In the case of subsidy measures supporting business R&D that leave the choice of R&D projects to businesses — such as the R&D Tax Concession — the rates of return on any additional R&D may well approximate those suggested by the analysis above. But in competitive arrangements where R&D projects are selected on merit by committees, it is not clear what the relevant return may be. It may be better or worse. As noted in chapter 10, whether public support is worthwhile or not in either case depends not just on the rates of return on any business R&D stimulated by the support measures, but on the economic costs and inefficiencies of such support.

The evidence base for aggregate returns to non-business R&D (primarily GOVERD and HERD) is smaller than that for business R&D, though still significant. The econometric analysis undertaken by the Commission based on time series and State panel data failed to find statistically significant effects for these types of R&D.

This is not surprising. First, country-specific noise in the data is likely to make it harder to discover statistically significant effects in time series data, but common country effects increase the power of panel data analysis. This is why panel data estimates are generally preferred to single country time series analyses.

Second, there are often long lags before research in government or higher education institutions influence the market sector (Gans sub. 10, pp. 6–7). One estimate of the average lag is 20 years (Adams 1990). For example, drug therapies take very long periods from the initial research to successful commercial applications. But in other areas adoption rates may be quicker. Mansfield’s (1998) finding of an average six year lag for industrial commercialisation of academic ideas increases the prospects of finding some effects at least.

Third, large amounts of the research activities of government and particularly higher education institutions are also devoted to primarily non-market impacts relevant to the government sector (environment, education, social services etc) or to broader aspirations (culture and identity). In this case the true return rates are likely to be larger once the non-market and longer run market effects are taken into account.

There is, nevertheless, some international evidence concerning the returns from publicly conducted research. As shown in the previous section, the evidence is mixed when panel data studies of aggregate economic performance are considered. The IPA (sub. DR139), which was highly sceptical of the benefits of publicly funded research, drew attention to the poor returns from public R&D based on a single study, the OECD’s *Sources of Growth Study* (whose econometric results were derived from Bassanini and Scarpetta (2001), reviewed above). The IPA did not cite the more recent panel data evidence on positive public returns that differed from that study. As shown above, a more recent study (Luintel and Kahn 2005a, Khan and Luintel 2006) was able to develop an econometrically superior model that contradicted Bassanini and Scarpetta, while explaining how they would have got their results. While the robustness of Khan and Luintel's estimates will need to be tested with more extended panel data sets, the present evidence favours a positive return from publicly conducted R&D for Australia.

The overall consensus from the varying aggregate econometric evidence is that R&D stimulated by public funding support is likely to produce benefits for the economy. But as highlighted by Shanks and Zheng (2006) and every major international review of the effects of R&D, *it is impossible to give accurate estimates of these effects.*

The imprecision is not surprising. It reflects:

- the complex causal pathways through which R&D affects productivity growth;
- an excessively short span of data;
- the fact that some national benefits (which should strictly still be called 'economic' benefits) are not measured by MFP indexes;
- errors in data. The construction of capital stock estimates is particularly difficult. Choices of depreciation rates, initial growth rates used to form initial period R&D stocks, problems in interpolation of R&D data, and measurement issues associated with R&D survey data mean these errors could be large. For foreign R&D stocks, the problems are compounded by uncertainties over the correct weights to apply to R&D that originates from many different countries. Problems in the measurement of MFP are also appreciable;
- questions about the appropriate specification of models and the choice of estimation techniques;
- the potentially long lags from the conduct of R&D to ultimate benefits;
- by construction, any standard model of MFP with a stable elasticity for R&D implies that the marginal return to R&D is always positive, no matter how big the investment. This appears an unlikely real world feature. This feature suggests that apparently marginal returns suggested by the empirical analysis may also include some gains that are made at investment rates lower than current levels (inframarginal gains). This further reduces the capacity for econometric estimates to assist the determination of 'optimal' funding levels;
- difficulties in controlling for the other factors that also influence productivity; and

- a real risk that selection bias is present in the existing literature. The relative absence of negative and insignificant coefficients on R&D in the international literature on spillovers might be seen as evidence of robust positive returns. However, the many problems besetting the data and methodologies of this literature suggests that these notionally robust results are, at least in part, the outcome of either 'bottom drawer' effects ('don't submit papers with insignificant coefficients') or selection biases from editors and referees who find inconclusive results uninteresting.

In fact, finding apparent precision in results — such as those suggested by high t statistics in some empirical studies — conceals the imprecision stemming from these measurement and methodological concerns. Given the uncertainties outlined above, it is not possible to find accurate measures of the aggregate spillover returns to R&D.

Given the potential limitations of this aggregate econometric evidence, it is important to triangulate with other sources of evidence about the impacts of R&D, especially those stemming from publicly conducted R&D. As shown above, the bulk of the industry studies are favourable. The semi-parametric approach discussed above and in appendix G also takes account of the effects of public sector market-oriented research, also suggesting positive returns.

Case study and broader approaches are also useful in areas where publicly supported research has non-market impacts (in fulfilling environment, health or social objectives). These other strands of evidence are reviewed in the sections that follow.

4.5 What do quantitative case studies suggest about the impacts of public support?

Another approach to measuring returns from publicly funded research has been to undertake cost-benefit studies. The treatment here draws on detailed Australian evidence reviewed in appendix I, as well as some of the international experiences and particular observations made by participants in this study. The focus is on case studies of publicly supported research undertaken within public sector research agencies, rather than industry, because of the relative abundance of the former and their greater sophistication.[22]

[22] There are, however, some analyses of Australian research in manufacturing industry, such as that of the BIE (1993). Dowrick (2003) draws attention to some international studies. There have been several Australian program evaluations that also provide estimates of benefit-cost ratios for portfolios of research projects supported by particular industry programs — such as the

Cost-benefit studies have a number of advantages over the econometric methods discussed above. They focus on publicly supported R&D; provide lessons about the research investment decision processes; identify costs as well as benefits (and beneficiaries and losers); and provide insights into the mechanisms by which research produces benefits. They have been widely applied around the world and are increasingly attracting attention because of the insights they can offer for particular expenditure programs (for example, the Northern Territory Government sub. DR194), research fields (for instance, Hanney et al. 2004 in the field of musculoskeletal research), or technologies (DCITA sub. DR180). DCITA, in particular, point out the qualitative insights provided by the case study approach, citing a series of case studies spanning quite different applications in ICT that have social and economic benefits that could not be enumerated using aggregate methods.

The approach has disadvantages too compared with the macroeconometric approaches (chapter 8 and appendix I). Three should be highlighted. First, projects selected for case studies are often not randomly selected, so they can give a biased indicator of the overall returns. Second, it can be hard to determine the magnitude of any impacts because of the difficulties defining a counterfactual and the complexities of attributing outcomes to projects when outcomes are the result of joint research (and past failures). Third, the studies usually do not provide measures of the impacts of marginal projects, but give information about average benefits and costs. Average net benefits in any one study do not provide evidence about whether more public support should be provided, only about whether that particular project was worthwhile.

Cost-benefit studies of research projects were identified for a range of institutions, including the CSIRO, CRCs and RRDCs. These are bodies that specialise in mission-oriented strategic and applied R&D projects, with the goal of generating public good or commercially useful outcomes:

- A variety of CSIRO research areas were the subject of studies including: agricultural crop research; entomology; wool manufacturing technologies; automated mining equipment; industrial processing; advanced vehicle technologies; visual processing for road maintenance; pharmaceuticals; and animal health research. Portfolio reviews covered some social and environmentally oriented research agendas, such as preventative health and water management. The latter are also discussed in a later section from a more qualitative perspective.

Productivity Commission's evaluation of the PIIP program (2003a). However, these impute spillover rates from the general literature, rather than estimating them from specific information provided by firms and consequently do not provide independent information about the magnitude of benefits from publicly funded R&D.

- The latest CRC program evaluations (Allen Consulting 2005a and Insight Economics 2006) provided information on identified returns from a number of CRCs and compared the identified returns with the overall cost of the CRC program.
- RRDC programs covered agricultural and animal research. Detailed information was obtained for the grains research area.

There are few detailed Australian cost-benefit studies of university projects (except where they are part of CRCs). The virtual absence of university-based case studies is neither surprising nor problematic. Universities concentrate more on curiosity-driven research and applied social research, rather than on large mission-oriented research projects suited to analysis by cost-benefit methods. Existing university research evaluations have usually focused on the efficiency with which research outputs (mainly publications) are produced (appendix K). The ARC (sub. 73, pp. 20ff) describe some instances of very successful university research and has commissioned analysis of the collective market-sector benefits of research funded by the ARC (described later under social impacts), but the latter reflects assumptions rather than the aggregation of detailed empirical analysis of individual cases.

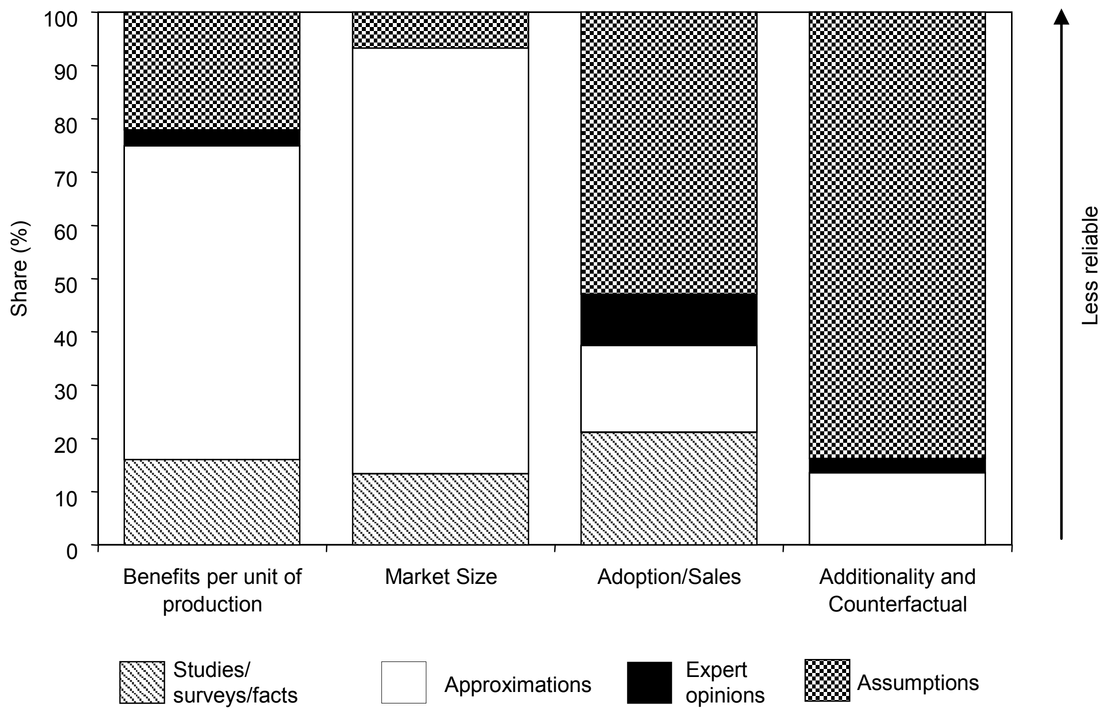
The coverage of the case studies considered in this report was small compared with the total research output of the relevant agencies. For example, CSIRO successfully produced, on average, 81 new technologies or products per year in the three years from 2002-03 to 2004-05 (while these technologies or products were not all yet at the utilisation or commercialisation stage, a significant proportion of these are likely to become utilised/commercialised). In contrast, fewer than 50 cost-benefit studies were identified for CSIRO research conducted over the 1980s and 1990s.

Quality of estimates made in selected cost-benefit studies

The quality of information used in calculating the benefits of the selected projects is mixed (figure 4.5), which reduces the reliability of any estimates. In projects that aimed to reduce production costs (a common objective in many of the projects), judgments about benefits per unit of production were reasonably well-based, but judgments about market size, adoption and counterfactuals/additionality became increasingly subjective. Judgments about the latter were mostly hunches.

Figure 4.5 **What is the quality of the case studies?**

The role of hunches versus information in reaching conclusions[a]



[a] Information was collected across case studies of the basis for judgments made about four different aspects of the benefits: the benefits per unit of production; market size; adoption or sales and the nature of additionality and technological displacement. Higher quality sources included scientific trials (examples include studies that show yield increases for new crop varieties) and company surveys (often used to determine sales volumes). Approximations were considered as slightly less reliable but still fairly reliable (examples include estimates of yields or prices of new crop varieties based upon yields or prices of older crop varieties). In some cases, the opinions of researchers or industry experts were sought where hard data was not available. The least reliable form of estimation were assumptions made with little supporting data (examples include assumptions of likely market adoption rates where sales have not yet started).

Data source: Appendix I.

Part of the reason for the mixed quality of the information underpinning the studies was that many of the case studies were undertaken on at least a partly ex ante basis (before prolonged application in the field), sometimes to serve planning and research management processes in public sector research agencies. Inevitably, evaluations that are undertaken on an ex ante basis must make more assumptions than those that consider ex post outcomes.

This does not necessarily imply that such ex ante studies produce biased results, just ones with very high noise-to-signal ratios. In fact, ex post studies may face a greater risk of bias because the projects are more likely to be chosen on the basis of proven commercial success. Though this has not been investigated for Australia alone, the large meta study by Alston et al. (2000) has examined this question and found that, internationally, ex post case studies tended to increase reported rates of return by about 18 percentage points (reflecting a ‘picking the winners’ selection bias).

Estimates of returns from individual case studies

More than 100 individual case studies were initially selected for examination. These covered agricultural research in the CSIRO, RRDCs and State agricultural departments; research undertaken by CSIRO for industrial, mining, transport, animal health and pharmaceutical applications; and research undertaken in CRCs. A number of project results were omitted because they were underpinned by too many assumptions. Overall, appendix I discusses 75 individual projects across various PSRAs and an additional group of portfolio/CRC studies. The available case studies were biased towards agriculture — probably reflecting the greater ease of estimating returns for this sector.

The Commission's analysis focused on the projects' midrange or base-case estimates of benefit-cost ratios (BCRs). A BCR exceeding one meets the minimum standards for projects to be socially worthwhile. Additional costs associated with raising taxes to fund the projects are not taken account of in the results. A bigger deficiency, discussed later, is the generally inadequate treatment of additionality in the studies. This means that the results should be interpreted as the possible private and public returns from the projects, but will not, in many cases, indicate the returns to research that was genuinely induced by public funding support.

The simple average of project BCRs was high — with benefits exceeding costs by an average of about 40 to 1 (table 4.6). Given that some projects were estimated to provide extreme BCRs — with a maximum of 716 to 1 — the average will give a biased perspective. A graphical depiction of the rates of return underlines the strong skewness of the BCRs (figure 4.6), even among projects selected on the basis of commercial success. The extreme returns associated with a few projects push the bulk of the density leftwards. The graphical depiction of the distribution of the log of the BCR provides much more information about the observations otherwise cramped together in the unscaled graph.

Table 4.6 **Major characteristics of benefit-cost ratios**

Selected publicly supported R&D projects

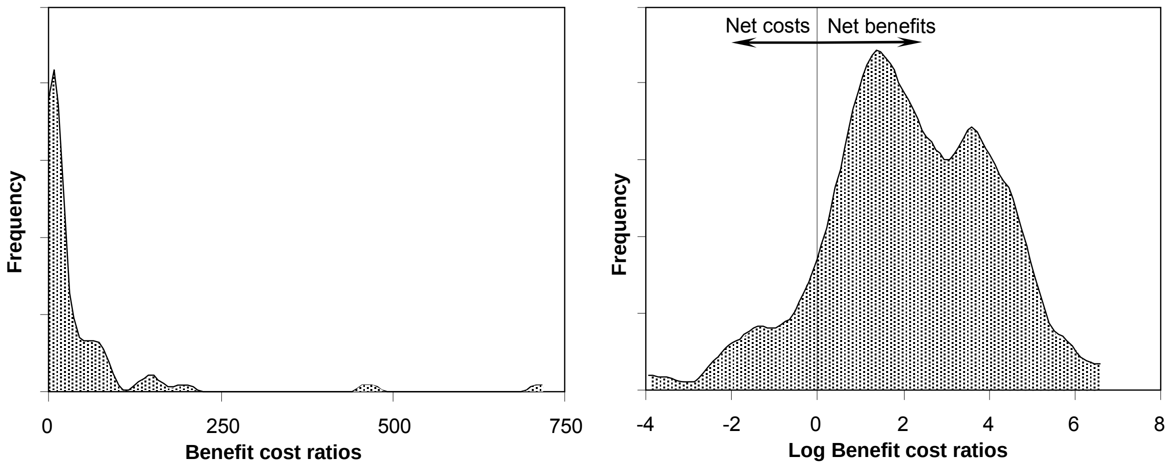
Statistical measure	*Results*
Mean	41.1
Median	7.0
Standard deviation	102.0
Skewness	5.1
Excess Kurtosis	29.6
Minimum	0.0
Maximum	716.7
25th percentile	2.7
75th percentile	37.8

[a] Based on data derived in appendix I from 75 projects. It should be noted that the costs from the study have been increased by 20 per cent to take account of the marginal excess burden associated with raising the finance for the projects, so that the benefit-cost ratios are the true net returns to society. The skewness and kurtosis measure the extent to which the distribution is asymmetric and peaked respectively. Given the sample size involved, the log distribution is statistically significantly different from a normal distribution. This could be a reflection of the true underlying distribution of returns, but it may also suggest some selection biases associated with benefit-cost studies that truncate poor returns on the left-hand side of the distribution.

Source: Appendix I.

Figure 4.6 **Distribution of benefit-cost ratios**

Selected public sector projects, 1970s–2000s



[a] Based on 75 projects, reviewed in appendix I. The benefits and costs are expressed in present value terms and then a ratio formed to give the BCR. The density functions are estimated using a Epanechnikov function. The first is the density of the raw BCRs, while the second is the density of the natural logs of the ratios. In log terms, those studies with returns below zero fail the minimum project selection criterion.

Data source: Appendix I.

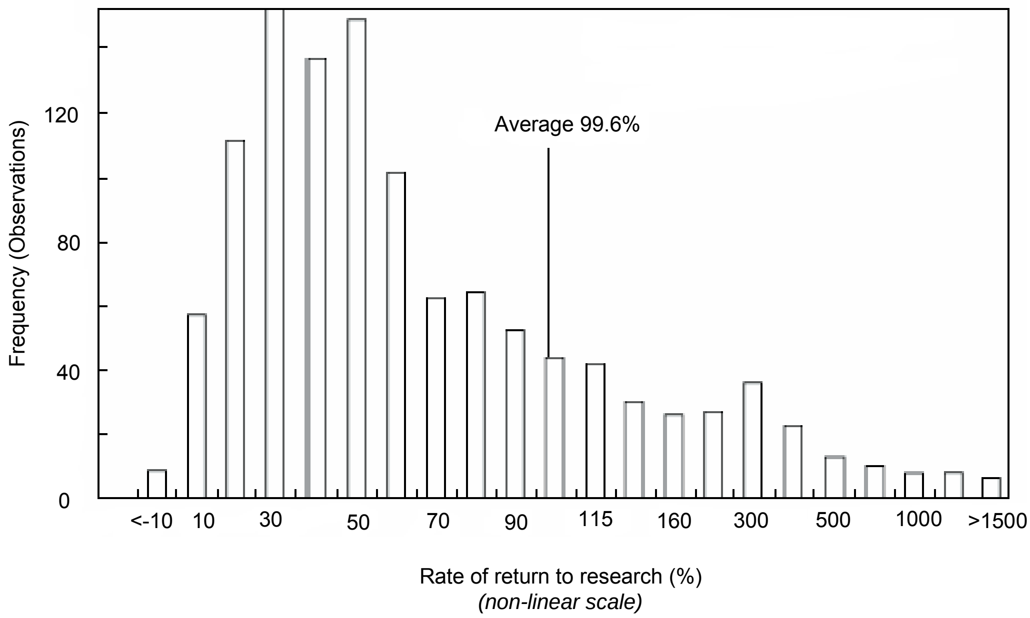
When returns are as skewed as this, other measures of central tendency can be useful. It is notable that the median (or middle) rate is lower at seven to one, though this is still high. The weighted average can also sometimes constitute a better measure since it takes account of the varying scale of projects and considers the return on the overall portfolio. The weighted average of the BCR (formed by aggregating the present value of the benefits and costs to a single base year) is around 12.

A rough translation of the BCR to the internal rate of return is *i* times the BCR, where *i* is the discount rate (Alston et al. 2000). This suggests that with *i*=5 per cent the internal rates of return have a median value of around 35 per cent and an average of 205 per cent.

The high rates of return implied by these case studies are characteristic of the literature on case studies. For example, in a large meta study Alston et al. (2000) were able to estimate the returns on over 1000 agricultural R&D projects conducted worldwide (of which around 10 per cent were performed in Australia). They found an average rate of return of 100 per cent (figure 4.7).

Figure 4.7 **The international literature on agricultural returns reveals similarly high rates[a]**

Results of a meta study



[a] Based on averages of 1144 international case studies. Studies that examine extension services are excluded.

Data source: Alston et al. (2000).

The other characteristic feature of the case studies reviewed by the Commission is the large dispersion in results. The 50 per cent middle range of BCR estimates (that is, those between the 25th and 75th percentile of the distribution) was 2.7–37.8. The corresponding 50 per cent middle range in the rates of return was 13.5–189 per cent. Alston et al. (2000) found the same phenomenon in their much larger (and therefore, more reliable) study, observing that the usual assertion that most R&D projects had returns within the range 40–60 per cent was poorly based, with only 25 per cent of case studies in their analysis falling within this narrow band. This degree of dispersion is a consequence of the real variability of returns to R&D projects and the large variations between case studies in their conceptual underpinnings and data accuracy. It underlines why seemingly precise figures from individual cost-benefit analyses should be regarded as being as imprecise as those generated by the macroeconometric methods described earlier. Some case studies make this uncertainty transparent. For example, ACIAR have used assumptions about the distribution of gains to estimate probabilities on returns (sub. 81).

The Commission attempted to discover any feature of case studies that it retrieved[23] that would suggest where returns were lowest or highest:

- There was no evidence that later studies exhibited lower rates of return, as might be expected if there were diminishing returns to knowledge accumulation in the sectors in which the research was focused (agriculture and natural resources). Alston et al. (2000) also found no diminution of returns with a larger sample, over a longer period and in agriculture alone, which provides even stronger evidence that returns can be sustained over time.[24]
- There was some evidence that returns were higher in agricultural applications, but the statistical significance of the result was sensitive to data omissions and the sample size was too small for this to be a reliable inference.

23 This was undertaken by regressing the log(BCR) against the log of the size of the R&D project (LSIZE); a dummy indicating whether it was in agriculture or not (AGRIC), the starting year of the R&D project (STY), a dummy indicating whether a counterfactual was considered or not (CFACT), the benefit period in years (BPER), and a dummy indicating whether the costs and benefits were estimated after or before the project had been utilised commercially for some years (EX). Models were estimated with and without outliers removed. A general form of the specification was estimated and reduced to a specific model (which led to only the inclusion of LSIZE, CFACT and BPER). Bilateral regressions were also estimated to see if coefficients in the reduced specific model were dependent on the presence of the other variables in the regression. Where numbers are cited in the dot points below, they are from the reduced specific model without outliers.

24 This does not imply that the gains, *at any one time*, from further R&D would also stay constant were the amount of R&D funding to increase. There is an implicit investment demand schedule for public R&D that, at any given time, represents the opportunities for profitable investments. If investments were increased in this given time period, it could be expected that the returns would fall as the best prospects were exhausted. Of course, in another time period, there may be fresh opportunities for investment — with as good a set of average returns as in past periods. So stable average rates of returns *over time* says nothing about the slope of the investment demand schedule at any *particular time*.

- Larger initial scale of R&D projects was associated with smaller average benefit-cost ratios. A 10 per cent increase in project R&D expenditure was associated with a 5 per cent reduction in the BCR.
- Long benefit periods were associated with higher benefit-cost ratios. A ten per cent increase in the benefit period results in a percentage increase of the BCR of (0.04*period*10). So if the initial period is 10 years, an increase to 11 years would increase the BCR by around 4 per cent, all other things being equal. Long benefit periods were more commonly associated with research projects that had a narrow Australian focus. Such projects would be less likely to invite parallel research efforts overseas that would erode the benefits that could be attributed to the Australian project. This might explain some of the reasons for the higher apparent returns to agricultural projects. (When the benefit period is included in the model, the gap between agricultural payoffs and other projects is reduced considerably and is not statistically significant.)
- As discussed below, studies that did not consider whether future research projects conducted globally might cannibalise the returns tended to measure high returns, some of which would be spurious. A study that considered a counterfactual had, all other things being equal, a 60 per cent lower BCR than one that did not.
- Studies that were conducted after information on the utilisation of the research was available (ex post case studies) tended to estimate lower returns than studies that based the benefit estimates on ex ante information alone. However, this effect was not statistically significant.

Counterfactuals: additionality and displacement

The treatment of counterfactuals — what would have happened to technology in the absence of the publicly funded research — can exert large influences on the outcomes of the cost-benefit analyses. Counterfactuals in case studies have two dimensions.

- First, the publicly funded research might have large expected private returns such that in the absence of public funding, the same research project might have gone ahead at the same time, even being performed by the same researcher (albeit funded from a private source) — the concept of low additionality.
- Second, even if no other private firm would have immediately invested in the particular research project, it is typical in research for at least several agencies around the world — private and public — to be exploring different research approaches to the same problems. This means that the absence of a particular project is unlikely to deny the world the benefits of a given research application

for long periods. This implies usually fleeting periods over which the benefits of any publicly funded project should be counted.

While both of these are aspects of the counterfactual, in appendix I and this sub-section, we refer to the first as *additionality* and the second, temporary nature of benefits, as technological *displacement*.

Additionality

Few of the studies made a rigorous assessment of additionality, with the most common assumption being that the projects would not have proceeded without public support. This may be a reasonably realistic assumption for projects that focus on problems that have management or technological solutions largely specific to Australia. These include research projects of various divisions of CSIRO's Institute of Plant Production and Processing and the RRDCs that targeted plant diseases affecting Australian crops.

However, as noted in chapter 10, the existence of voluntary levies among rural industry groups enables them to cooperate in their R&D goals. This reduces the 'free rider' problem that would discourage individual producers from investing in commercially oriented R&D. This at least raises the question of whether, in the absence of public support, levies might in some cases be increased voluntarily and some projects might still proceed.[25] In other cases, there may be farm intermediaries, such as seed wholesalers, that may be potential financiers in the absence of public support (this could apply to the cotton breeding project discussed in appendix I). In non-agricultural contexts, the potential beneficiaries are sometimes relatively few in number, and the potential private returns high, *at least after a certain stage in project completion*. This implies that the assumption of additionality and prospective benefit-cost ratios should be reassessed as projects evolve and the prospects for full private funding increase. This may hold, for example, to the technologies developed by CSIRO's Light Metal Flagship, though the initial research may have had reasonable additionality.

Consequently, the ongoing assessment of additionality has subtle effects on the measurement of BCRs. More importantly, from a policy perspective, the ongoing decisions by public research agencies on whether to seek greater or full funding from industry of further stages of research (or whether even to proceed with the research at all) will depend on dynamic evaluation of the prospective costs and benefits. Undertaking continuous evaluation of this kind increases the initial option

[25] This condition could still hold even if there were some spillovers outside the industry (chapter 3).

value of public research projects because it reduces the future risks of low additionality (and, for that matter, the risks of failure, since early failing projects can be terminated). This is an area where case studies, and particularly those that adopt an options approach (ACIL Tasman 2006e), have policy insights that extend beyond the macroeconometric impact analysis discussed earlier.

How temporary are benefits?— displacement

The Commission considered the effects of this aspect of the counterfactual in several ways.

First, the average BCRs of studies that explicitly considered the possibility of technological displacement[26] were compared with those assuming no displacement, while controlling for several other influences (such as R&D scale). As shown above, those studies incorporating the latter assumption were found to produce a significant positive bias to benefit-cost rates.

Second, the potentially large effects of different assumptions about potential displacement may be gauged by comparing studies that examine the same project using different methodologies. The automated mining research project[27] was one of these. It was initially estimated to produce $5.2 billion of benefits for $54 million in costs (in 2005 prices) — a BCR of about 100 (CIE 2001a) — with the implicit assumption of infinitely realised benefits. In contrast, a recent ACIL Tasman (2006a) study considered that the project brought forward by five years a technology that would eventually have been discovered by another research agency. With that assumption and a slower adoption rate than envisaged, the benefits fell to $343 million, but so too did the costs (to $25 million), with an overall BCR of 14, or around one seventh of the original estimate (albeit still high).

Estimates of returns from portfolio cost-benefit studies

The majority of the benefits of research are often generated by a few successful projects. In the case studies analysed by the Commission, nine out of the 75 studies

[26] In many case studies the issue of technological displacement was considered, but was not regarded as a relevant issue over a long time horizon because of the specificity of the research to unique Australian circumstances. Accordingly, it should not be assumed that studies that considered displacement necessarily used short benefit periods in their calculations of benefits and costs.

[27] A project undertaken in CSIRO, but with large co-funding by industry partners. The two studies differed also in when they were done, so the first involved more assumptions and the second could use more observed data. However, the judgment was that the differing treatment of the counterfactual was the decisive difference.

generated about two thirds of the cumulative gains (in present value terms) and 20 per cent of projects (15 projects) generated 80 per cent of the gains. And as noted earlier, many research projects fail to produce any tangible applications and are not even analysed in case studies, generating a selection bias. For example, in CSIRO, the Wool Technologies Division undertook 109 projects from 1993-94 to 1997-98, of which eight were adopted in industry (Collins and Collins 1999). Accordingly, for more insights into the returns from public research it is useful to offset highly successful projects against less successful ones, and to also count the resources used in projects that failed to produce any apparent social or economic returns.

The portfolio results across eight broad research areas (table 4.7) reveals more modest BCRs than those suggested by considering individual published case studies, probably reflecting the importance of selection biases. The weighted average BCR is about two. However, since portfolio studies generally include all the costs of the portfolio, but exclude the benefits of some projects, this approach probably produces biases of the opposite direction.

Other evidence

Case studies from submissions

The submissions to this study also provided many detailed qualitative/quantitative case studies that provide insights into the nature and magnitude of benefits from publicly funded research. These included the CSIRO (sub. 50); the Department of Agriculture, Fisheries and Forestry (sub. 100, p. 51); the State Government of Victoria (sub. 84, pp. 46–47); the NSW Government (sub. 91, pp. 26ff); DCITA, (sub. 101 attachment and sub. DR180), Combined CRCs (sub. DR164) and the Rural R&D Corporations (sub. 96).

Some of these discussed formal benefit-cost results (sub. 91, sub. 96 and sub. 100), while others noted the broad nature of the benefits (sub. 84) or specific qualitative examples (sub. 101). The results for the NSW Department of Primary Industry's evaluations are shown in table 4.8. While some are included in the Commission's meta analysis, others are not due to incomplete information about the nature of the underlying assumptions. The RRDC and Department of Agriculture, Fisheries and Forestry submissions also suggested similarly high average benefit-cost ratios, commensurate with those identified by the Commission in its own meta study.

Table 4.7 **Minimum portfolio cost-benefit estimates**[a]

	Authors	*Comparison period*	*Dis-count rate*	*Expend-itures*	*Benefits*	*BCR*
				$m	$m	
Ex post utilisation studies						
CSIRO divisions for soils, plant industry, horticulture and tropical crops and pastures	Jonston, Healy, I'ons and McGregor (1992)	1970–1990	5	3549.0	2865.1	0.8 (7.9)[b]
CSIRO Entomology Division	IAC (1980)	1960–1975	5	508.2	2252.3	4.4
Ex ante utilisation studies						
CSIRO Wool Technologies Division	DJ and BA Collins & Collins (1999)	1993-94 to 1997-98	6	356.2	717.6	2.0
CSIRO Preventative Health Flagship[c]	ACIL Tasman (2006d)	2003-04 to 2006-07	6	83.0	359.2	4.3
CSIRO Light Metals Flagship[c]	ACIL Tasman (2006c)	2003-04 to 2007-08	6	14.3	31.1	2.2
CSIRO Water For a Healthy Country Flagship[c]	ACIL Tasman (2006e)	2003-04 to 2007-08	6	around 170	around 860	At least 5.1
Australian Cotton CRC	BDA Group (2004)	1999-00 to 2003-04	6	90.2	611.7	6.8
General equilibrium models					*ΔCONS*	*ΔCONS/ Costs*
CRC Program (PC adjusted)[d]	Allen Consulting (2005a)	1991–2005	..	1 920	190	0.10
CRC Program (PC adjusted)[d]	Insight Economics (2006)	1991–2005	..	2 332	1 189	0.51

[a] All data are in 2005 present value prices and are adjusted from the original studies to be on this basis. All costs have been increased by 20 per cent to take account of the marginal excess burdens of taxation. The details regarding these portfolio studies are in appendix I, including discussions of assumptions underpinning them. [b] The BCR of 0.8 should be interpreted with care. It is a significant underestimate of the BCR for the divisions collectively. This is because it is based on the costs of all the relevant CSIRO divisions, but the benefits for only eight of 22 successful research projects over the comparison period. The BCR for the 8 projects was 7.9, hence the estimate in parentheses. The portfolio analysis shows that 8 out of 22 projects can almost realise enough benefits to pay for the divisions as a whole. [c] Studies use an options approach. That is, possible outcomes are weighted by probability of success and project expenditures are weighted by their probability of being incurred (which take into account scenarios where projects are cancelled). [d] Based on general equilibrium modelling (appendix I). The Allen Consulting study is based on a subset of projects (though the costs relate to all projects), which is why the benefits are smaller than the subsequent Insight Economics study. In these GE studies the net benefit is measured as the change in consumption (ΔCONS). An idea of the return on expenditure is given by the ratio to expenditure in the final column (ΔCONS/Costs). Since these are positive, they relate to a BCR that is above one. See appendix I for the basis for PC adjustments.

Source: Appendix I.

Table 4.8 **Recent evaluations by the NSW Department of Primary Industry suggest large public benefits**

Evaluations 2003 and later

Investment area	*Cost for DPI*	*Share of total cost*	*BCR*	*Environmental impact*
	$m	%	Ratio	
Evaluations in 2003:				
Net feed efficiency in beef cattle	13.9	70	4.9	Greenhouse gas reductions
Annual weeds in temperate pastures	8.7	67	22.2	Reduced accessions; better water quality
Wheat breeding	43.0	45	8.4	Reduced chemical dependence
Conservation farming in northern NSW	29.0	68	20.5	Reduced soil erosion; soil structure gains
Extension in water use efficiency	19.8	100	4.5	Environmental water savings
Total	114.4		11.5	
Evaluations since 2003:				
Ricecheck	3.8	67	18	Water use efficiency
Beef CRC III	3.8	9.5	66	Greenhouse gas savings
Sheep CRC	n.a.	n.a.	8.1	Reduced chemical dependence
Fox control	0.024	4.9	12.4	Save native species

Source: NSW Government (sub. 91, p. 26).

An important set of benefits are realised overseas

Some Australian publicly funded research explicitly aims to provide benefits overseas. Generally, within an economic framework, spillovers that flow overseas are irrelevant to judgments about the net benefits of funding for Australians. However, this is not always true. First, there are intangible benefits associated with Australia's contribution to the global knowledge pool (chapter 3) and goodwill from overseas partners.

Second, sometimes research applied overseas can be perceived as a form of foreign aid. In this role, it may be more effective than alternative forms of aid. It engages positive incentives, unlike some other aid forms, is resistant to expropriation, is enduring and can have large benefit-cost ratios. As noted by Alston et al. (2000) and ACIAR (sub. 81), it has been shown that R&D undertaken in developed countries for applications in developing countries have higher rates of return than those undertaken in the developing countries themselves. There is good evidence of the nature and magnitude of these returns. The submission by Innovative Research Universities Australia (sub. 54, p. 9) cited the successful introduction of a novel (beer-based) fruit fly management technology in Vietnam, which has lowered the costs of managing this problem, as well as environmental and human health benefits from lower pesticide residues. More comprehensive evidence of large benefit-cost ratios from foreign R&D aid in which Australian research was central was provided in the meta study by Alston et al. (2000) and by ACIAR (sub. 81) for more recent research (table 4.9).

A third dimension of benefits is spillovers from R&D undertaken for developing countries by Australia that flow back to Australia, for example through reduced pest incursion (University of New England sub. 17, p. 10 and ACIAR sub. 81, p. 18). ACIAR examined 20 projects for which these benefits had been quantified, with total benefits of an estimated $735 million (relative to costs of $60 million) and a BCR of 12.

Table 4.9 **Benefit-cost ratios from Australian R&D aid abroad**

Examples given by ACIAR of projects

R&D type	*Benefits*	*Costs*	*BCR*	*Source cited*
	$m	$m	Ratio	
Sample research activities partly attributable to ACIAR				
Conservation tillage for dryland cropping in China	>1000	5	205	Vere (2005)
Breeding and feeding of pigs in Vietnam	878	4.9	118	Tisdell and Wilson (2001)
Controlling Phalaris Minor in the Indian rice-wheat belt	422	1.5	275	Vincent and Quirke (2002)
Bio-control of the banana skipper pest in Papua New Guinea	555	2.1	258	Waterhouse, Dillon and Vincent (1998)
Analysis of socioeconomic and agribusiness developments in the Chinese beef and cattle industry	..	..	60	Pearce (2005)
Raw wool production and marketing in China	..	..	40	McWaters and Templeton (2004)
Emergence and integration of regional grain markets in China	..	..	6 to 30	Watson (1998)
Establishment of a protected area in Vanuatu	..	..	4.5	McMullen (2004) and CIE (1998)
Overall attributed to ACIAR research program[a]	3500	134	26	CIE (2006) forthcoming

[a] This includes research projects not listed above.

Source: ACIAR (sub. 81) and CIE (2006 forthcoming).

Conclusion

Overall, the case study approaches suggest high rates of return to publicly funded research, consistent with a large overseas literature. These results are influenced by the availability of the case studies, which focus on research projects that are successfully utilised and where the benefits are more readily quantifiable.

Modifying the results for the omission of failed research projects by considering whole portfolios of research reduced the benefits, but average benefit-cost ratios were found to be still high — of the order of two to one. The case study approach also provides useful lessons for the management of research and in particular, the insights afforded by an options approach.

The existing case studies, with a few exceptions, tend to accentuate R&D that is aimed at increasing productivity and, consequently concentrate on measuring effects that show up as higher GDP. Some types of research — particularly in the social and environmental fields — have effects that are more diffuse than this. This research can affect the market economy, but it is often mainly aimed at achieving unpriced, but still valuable, outcomes. The impacts of research in these areas are considered next.

4.6 Environmental impacts

The hybrid nature of environmental impacts

Investments in R&D can often produce benefits for the market economy and the environment simultaneously:[28]

- Reductions in salinity, pesticide use and invasive weeds/pests — all areas of substantial publicly funded research in Australia — can increase agricultural productivity, as well as generate less easily measured environmental and social benefits.
- Similarly, research about the potential impacts of climate change affects investment timing, pricing and technological decisions by businesses and government owned utilities.
- Research into improved energy efficiency increases abatement of carbon and sulphur dioxide with environmental benefits, but also has large potential economic gains.

[28] This list ignores a subtle, but important source of benefit flowing from the market system to the environment. Gains in market-sector productivity stemming from innovation reduce environmental damage in its own right, as well as generally relaxing national budget constraints and creating higher preferences for environmental amenity (Pearce and Palmer 2001). This shows up as a strong correlation between measures of spending on the environment per capita and GDP per capita (in PPP terms). Similar relationships between GDP per capita and more general environmental performance (the Environmental Performance Index — described later) are apparent (Esty et al. 2005).

- Biodiversity can have unexpected benefits. For example, the State Government of Victoria (sub. 84, p. 40) noted the discovery of an antimicrobial protein in Tammar wallaby milk.
- Research by CSIRO in agribusiness will boost growth rates, but also reduce methane production by cows (CSIRO sub. 50), a gas with a larger global climate warming potential than CO_2. The NSW State Government also observed benefits of this kind, suggesting that the adoption of new genetics in the NSW beef herd would save methane emissions worth around $28 million over the 25 year simulation period, which was around 10 per cent of the private benefits of the research.
- An improved understanding of water management and flows can increase the likelihood of properly timed investments in water infrastructure, potentially savings hundreds of millions of dollars (box 4.1).

The estimated value of impacts have been large (table 4.10). Despite the links between environmental benefits of R&D that are realised as market benefits, aggregate macroeconometric measures are not adequate for revealing them.

- Business R&D — the basis for the results of Shanks and Zheng's (2006) models in table 4.3 and for the new specification of this study — largely excludes publicly funded environmentally oriented R&D. In any case, market-sector MFP excludes gains in productivity in several industries, including government services, where some of the benefits of environmental R&D would be realised.
- GERD does include such spending and is used in the Commission's State-based estimates of the returns from R&D. However, the separate effects of environmental research could not be inferred from these results.
- Shanks and Zheng (2006) have produced estimates of around a 25 per cent rate of return to public R&D realised as productivity gains for the Australian agricultural sector.[29] This will include some gains that occur through environmental improvements, but obviously also include gains that are not generated in this way. Moreover, the gains for agricultural productivity from R&D may sometimes be adverse for the environment, as noted by Alston et al. (2000, p. 29).

The deficiencies in aggregate approaches suggest alternative approaches. These often have the advantage that they also consider some of the non-market benefits of environmental research. Case studies of particular projects or streams of projects (of

[29] The gains are also to the total of public sector R&D, not just public R&D directed at agriculture (Shanks and Zheng, pp. 142–3).

which the Water for a Healthy Country Flagship is an example — box 4.1 and table 4.7 in the previous section), suggest substantial gains in particular instances.

Box 4.1 **CSIRO Water for a Healthy Country Flagship**

Current water policy by Australian governments is focused on managing competition between alternative uses for increasingly scarce water, including optimal investment strategies.

The CSIRO Water for a Healthy Country Flagship continues a long history of public sector research into Australia's water and related natural resource systems. Established in 2003, its current budget is $125 million over the next four years.

The flagship aims to increase efficiency of water use through better decision rules and tools for investors and policymakers (including better information to use as inputs for decisions), lowered costs of provision and better allocation of water among users with different values for the resource. The flagship is conducting research in six themes: Urban Waterscapes; Murray River Region; South West Western Australia Region; Great Barrier Reef Catchments; Australian Water Systems (concerned with the extension of lessons across regions); and Water Resources Observation Network (concerned with developing the water accounts and data needed to allocate water to its highest value use). The flagship brings together a range of skills ranging from: hydrology, climate assessment and modelling; wider complex-systems modelling; to natural resource economics.

Many State Governments are also active in these areas, so that there are attribution problems in determining the role of the flagship in achieving better efficiency. Nevertheless, ACIL Tasman (2006e) considered that there were sizeable gains that could be attributed to the research, albeit with judgment being the basis for many of the estimates.

One of the key potential economic gains from the flagship is the development of specialised decision-making and information tools (for example, computer modelling software) that may avoid or defer inappropriate investments in high cost, irreversible, investments. ACIL Tasman noted that currently around $2.5 billion is spent annually by water utilities on water infrastructure, so even modest savings in this area can be valuable.

Overall, it was estimated that the flagship would return at least $900 million in cost-savings and community benefits in present value terms. It was estimated that the urban waterscapes theme could produce cost savings of the order of $200 million over the next few years, with around half of this being capital cost savings. The development of advanced computer modelling tools for the Murray River Region could produce risk-weighted community benefits of $100 million from the restoration of environmental river flows. Over the longer term it was estimated that advanced computer modelling techniques could advance the development of water property rights systems and reduce monitoring costs with the potential to return a risk weighted value of $600 million.

Source: ACIL Tasman (2006e).

Table 4.10 **Impacts by types of environmental spending**

Organisation	*Investment*	*Example of Impacts*	*Source*
CSIRO Sustainable Energy and Environment Group	$170m from government and $246.53m in total	Direct Impacts: Estimated average cost-benefit ratio of 8:1. This represent the average of 12 backward looking CBAs on environmental projects. Indirect Impacts: Of the 52 other manufacturing, mining and agricultural projects examined, 13 were found to have at least a 'minor' impact on the environment.	CIE (2001a)
CRCs in the environmental sector	Program funding $55.7m $242.1m in total (CRC directory)	Impacts: There is a diverse set of outcomes for environmental CRCs, but outputs typically take the form of information provision and policy influence through: expert advice; influence over policy documents; publicly available research; journal articles; and conferences and public awareness activity.	
Antarctic Division	$94.6m (DEST 2005a)	Indirect Impacts: Output contributes to knowledge of Antarctic ecosystems, resources and climatic change. The Antarctic Division produces 150–200 refereed papers per year.	
Land and Water Australia	$12.5m from government $27.9m total (annual report)	Direct impacts: Cost-benefit ratio of 1–3.5. This is the aggregates triple bottom line CBA estimate for 25 innovations (covering 278 projects) and representing 25% of LWA's R&D investments. 17 of the 25 cases non-exclusively contain environmental benefits. Estimates were based on 'willingness to pay' surveys in 10 cases and projected cost savings in 8 cases.	Schofield (2005)
Greenhouse Gas Abatement Program	$16.m from government (DEST statistical snapshot)	Direct impacts: Reduction of greenhouse emissions of 17.9 million tonnes. This is a projected outcome based on a selection of 10 GGAP projects over the period 2008 – 2012. Lifecycle funding of these projects amounts to $67m, which implies a return 0.26 tonnes per dollar of GGAP investment.	GGAP webpage[a]
Bureau of Meteorology Research Centre	$11.8m	Indirect impacts: Outputs are information relating to atmospheric modelling, climate change, air quality analysis used generally as an important basis for private and public investment decisions (farm investments; land-use decisions, insurance premium settings; infrastructure and technology decisions).	

[a] http://www.greenhouse.gov.au/ggap/index.html.

As noted in the cost-benefit literature examined earlier, some benefits to Australian publicly funded research accrue overseas, and these nevertheless can produce incidental environmental benefits for Australians, such as reduced pest incursions in Australia. For example, ACIAR (sub. 81, p. 16) noted that an estimated 47 per cent of the (sizeable) spillover benefits to Australians from Australian R&D for overseas applications were from direct or indirect benefits in reducing pest incursions. Such pest problems often have environmental as well as agricultural productivity effects.

Uncertainty is high

The basis for estimates of some kinds of environmental benefits is likely to be more uncertain than those for research activities directed at economic benefits. For example, the valuation of technologies that abate carbon dioxide and reduce climate change depend critically on the likely benefits of successfully achieving that objective. A recent meta study of 28 studies by Tol (2005) gave a 90 per cent confidence interval of the value of carbon reduction at between -$2 per tonne (a loss) to $165 per tonne, with a mean, median and mode of $93, $14 and $1.50 respectively.[30] Similarly, the present best estimates of the marginal costs of achieving reductions vary by similarly large margins. Despite the uncertainty, Tol's (2006) conclusion is that a portfolio approach to global risk warrants sizeable investments in new technologies, but the problem for cost-benefit analysis means that reliable rates of return are particularly hard to formulate in this area.

The potential costs of global warming also mean that the long-run returns from conventional long-lived energy infrastructure are now also increasingly uncertain. This is why some of the research aimed at estimating the costs, as well as mitigating them, has large option values.

The fundamental issue here is that uncertainty has two edges and these apply beyond the case of climate change risks. Uncertainty makes it harder to give precision to standard cost-benefit analyses, but it also provides a value to preparedness (Mathews in FASTS sub. 83) and to delay in making costly long-lived legacy investments (for example, a new dam).

Are there any other ways of looking at this issue?

The case study information is useful, but clearly partial. This raises the question of whether there are any other ways of looking at this issue.

[30] Other studies confirm the uncertainty of benefits per tonne and observed that there is also variation across regions (Downing et al. 2005).

An MFP equivalent?

One possibility is to estimate the role of research capabilities, particularly in the environmental area, in contributing to some measure of gains in environmental quality. This is akin to the MFP approach adopted for the market economy, but extended to environmental benefits. Two reputable measures of environmental quality and management are:

- the Environmental Sustainability Index (ESI) (Esty et al. 2005) The ESI utilises 76 variables combined into 21 environmental indicators to calculate an overall index value for each of the 146 countries examined (figure 4.8).
- the Environmental Performance Index (EPI) (Yale Center for Environmental Law and Policy et al. 2006), which uses a similar approach to the ESI, but is more focused on factors affecting the environment that are within the control of governments.

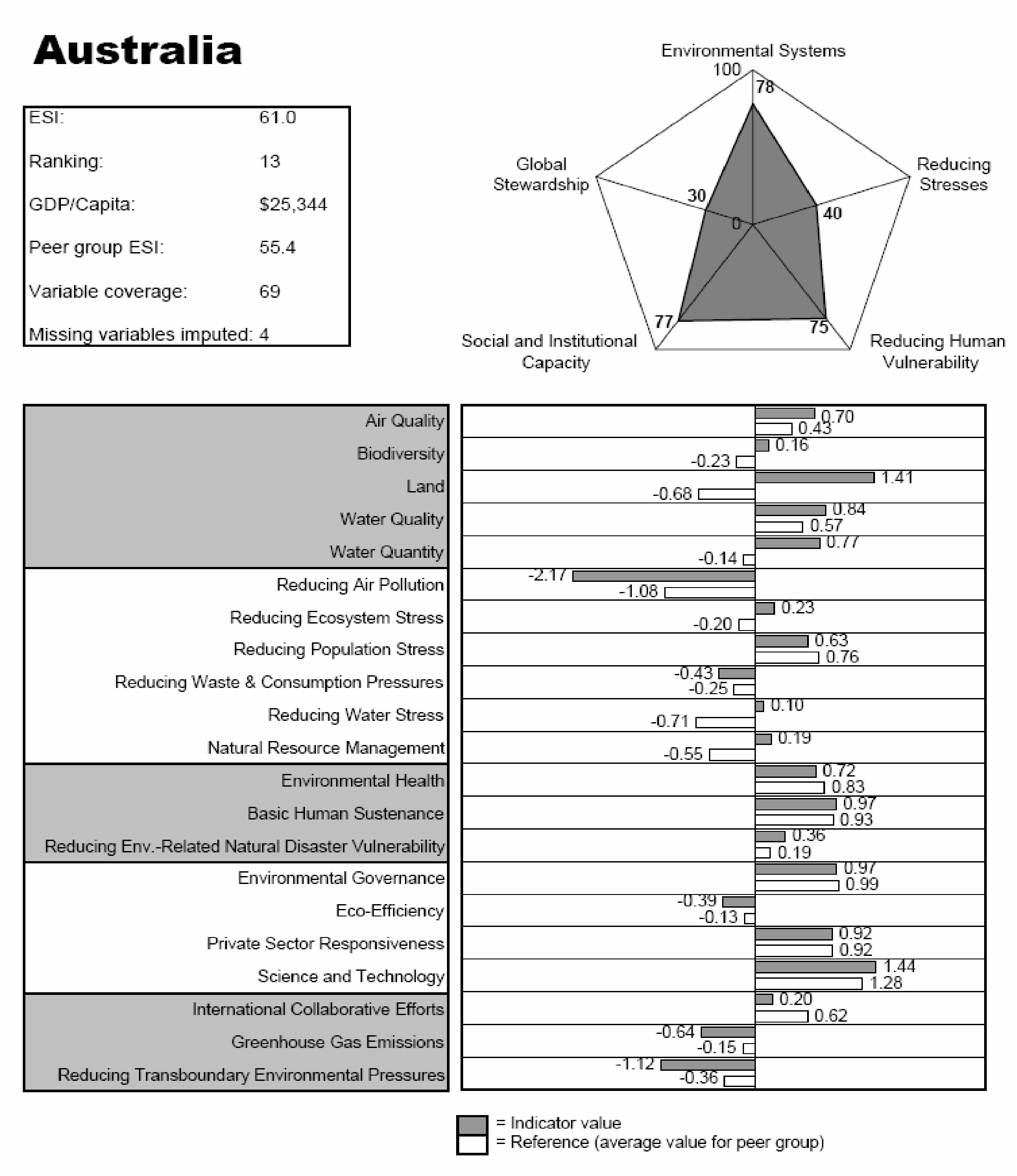
The most useful aspects of the ESI and the EPI are the particular environmental indicators that can be derived from them rather than the summary measures themselves.

To probe the links between these environmental indicators and various measures of research capability, a suite of regressions were run:

$$\begin{aligned} log(E_i) = {} & \alpha_1 + \alpha_2\, log(\text{Income per capita}_i) + \alpha_3\, log(\text{Research capability}_i) \\ & + \alpha_4\, log(\text{Quality of research}_i) + \alpha_5\, log(\text{R \& D care \& control}_i) \end{aligned}$$

where E_i are various environmental indicators — components of the ESI and EPI (and the summary measure EPI itself) (table 4.11). The selection of indicators to be used was based on whether they had a sound theoretical link to research capabilities, which only extended to a handful of the components. Many components were excluded on the basis that they were clearly exogenous to research capabilities — such as the total fertility rate (a component of the ESI). In that regard, for the purpose of considering the environmental impacts of research capabilities, the ESI is less satisfactory as a summary measure of potential environmental outcomes than the EPI or various appropriate components of the EPI and ESI.

Figure 4.8 **The composition of Australia's ESI**
2005[a]



[a] The GDP per capita is in US currency. It should be noted that Australia's high relative Science and Technology score is not specific to the environment, and so should not be seen as a measure of capability in this area. The per capita PPP spending on R&D on care and control of the environment and bibliometric measures probably provide better measures of that general relative global capacity.

Data source: Yale Center for Environmental Law and Policy et al. (2005) available from http://www.yale.edu/esi/.

Research capability is the number of researchers (including outside the environmental area) per capita. *Quality of research*[31] is a bibliometric measure of the quality of environmental research. *R&D care and control* is spending per capita (PPP) on R&D devoted to care and control of the environment. The latter data item was only available for a selection of OECD countries and is, in any case, a narrow measure of government spending on environmental R&D.[32] The regressions, while simple, controlled for GDP (PPP) per capita (*Income per capita*) which might otherwise hide or exaggerate the relationship between environmental indicators and research indicators.

Table 4.11 **Environmental indicators used**[a]

Description	*PC code*
Quality of environmental governance — based on WEF survey questions on several aspects of environmental governance: air pollution regulations; chemical waste regulations; clarity and stability of regulations; flexibility of regulations; environmental regulatory innovation; leadership in environmental policy; consistency of regulation enforcement; environmental regulatory stringency; toxic waste disposal regulations; and water pollution regulations (From ESI: WEFGOV).	*GOVNCE*
Quality of private environmental innovativeness — based on WEF survey questions on private sector environmental innovation covering environmental competitiveness, prevalence of environmental management systems, and private sector cooperation with government. (From ESI: WEFPRI)	INNOV
The share of missing data from a major index of the environment (the CGSDI 'From Rio to Johannesburg Dashboard'). The index covered facets like fuel emissions, urban air pollution, use of pesticides and withdrawal of ground and surface water that may require environmental expertise to collect. A lower value of MISS is preferred cf all other indicators in this table. (From ESI: CSDMIS)	MISS
Quality of resource management based on sustainable forestry, fishing and agricultural policies. (From EPI: RESOURCE_MGT)	RESRCE
Wilderness protection based on an overlay of areas that are wild and areas that are protected. (From EPI: PWI)	WILD
Ecoregion protection: extent to which unique ecologies are sufficiently protected. (From EPI: PACOV)	ECORGN
Water quality management as measured by oversubscription to water resources and nitrogen loading per average flow of river basins (From EPI: WATER)	WATER
Environmental Performance Index: index of environmental performance based on indicators of the quality of the environment that are amenable to policy action. (EPI aggregate)	POLICY

a WEF = World Economic Forum; CGSDI = Consultative Group on Sustainable Development Indicators.

Source: Esty et al. (2005) and Yale Center for Environmental Law and Policy et al. (2006).

31 In the ESI database, this corresponds to KNWLDG, but with its categorical ordering reversed. In the ESI database KNWLDG has a value that is lower for higher quality knowledge generation. Reversing the order of its scales provides a more easily interpretable measure.

32 The amount spent on R&D for 'control and care of the environment' is one of the few internationally comparable indicators of environmental science and innovation spending. It is available for most OECD countries. The 2005 Frascati manual defines this spending category as the amount of R&D that is directly used to promote an undestroyed physical environment including: the identification and analysis of the sources of pollution and their causes; the dispersal of pollutants in the environment; the effects of pollutants on man, fauna, flora, micro-organisms and the biosphere; and the elimination and prevention of all forms of pollution in all types of environment. It is not a comprehensive measure of R&D devoted to environmental issues, as shown by comparing expenditures with ABS data on spending in environmental R&D — but is at least available on a reasonably consistent basis for many OECD countries.

Table 4.12 **Regressions of environmental outcome indicators against research capabilities (models 1–8)**

	Environmental outcome indicators (1) to (8)							
	(1) GOVNCE	(2) INNOV	(3) MISS	(4) RESRCE	(5) WILD	(6) ECORGN	(7) WATER	(8) POLICY
Dependent variables								
OECD countries								
Income per capita	**0.21**	**0.09**	-0.35	0.04	0.78	**-1.86**	**-0.27**	-0.01
	(2.8)	*(1.7)*	*(0.9)*	*(0.1)*	*(0.8)*	*(2.2)*	*(1.9)*	*(0.1)*
Research capability	**0.12**	**0.15**	-0.06	-0.35	**0.90**	**1.07**	**0.15**	0.02
	(2.6)	*(4.4)*	*(0.2)*	*(1.4)*	*(2.3)*	*(2.4)*	*(2.0)*	*(0.8)*
Quality of research	-0.01	0.01	-0.05	**0.10**	0.09	**0.36**	0.02	0.01
	(0.8)	*(0.5)*	*(0.7)*	*(1.6)*	*(0.4)*	*(1.6)*	*(0.4)*	*(1.4)*
R&D care & control	0.01	0.01	**-0.24**	**0.09**	0.28	0.17	-0.01	0.01
	(0.3)	*(0.8)*	*(2.4)*	*(1.5)*	*(1.3)*	*(0.7)*	*(0.5)*	*(1.1)*
All countries								
Income per capita	**0.23**	**0.14**	**-0.41**	**-0.21**	-0.26	-0.30	**0.08**	**0.12**
	(4.5)	*(3.6)*	*(5.4)*	*(3.9)*	*(1.1)*	*(1.4)*	*(1.5)*	*(6.6)*
Research capability	0.01	-0.01	0.04	**0.04**	0.03	0.08	-0.01	0.01
	(0.3)	*(0.4)*	*(1.2)*	*(1.5)*	*(0.2)*	*(0.8)*	*(0.4)*	*(0.6)*
Quality of research	0.01	0.01	-0.04	**0.07**	**0.49**	**0.55**	-0.01	0.01
	(0.5)	*(0.6)*	*(0.5)*	*(1.6)*	*(2.0)*	*(3.1)*	*(0.1)*	*(0.6)*

[a] Coefficients that are statistically significant at approximately the 10 per cent level or better are boxed. Statistics in brackets are the absolute values of robust t statistics. Sample size vary by regression.

Source: PC calculations.

The regression results (table 4.12) suggest that scientific capacity and R&D have some associations with environmental outcomes:

- General research capabilities were associated with improved levels of government environmental governance; private sector environmental innovativeness; eco-region and wilderness protection; and water policy for OECD countries. There was a weakly significant link between such capabilities and improved resource management for the all-country dataset.
- Per capita spending on R&D care and control of the environment in OECD countries has a weakly significant effect on environmental resource management and a strongly significant improvement in the availability of environmental data used to make policy decisions. The latter is an important, if obvious, benefit from environmental R&D.
- Environmental research quality is weakly positively related to resource management for both the OECD and 'all-country' datasets. It is also associated with higher eco-region protection for both the OECD and the all-country datasets and for wilderness protection in the all country dataset.

The results above must be regarded as tentative. The various indicators of environmental outcomes, with the possible exception of information adequacy (MISS), will have complex, dynamic relationships with research capabilities, and the causality may run both ways. Cross-sectional data analysis, such as that above, also ignores the cross-country variations in the various environmental indicators that are generated by historical circumstances. For instance, some country's values of eco-region protection may be low due to historical exploitation. Through environmental R&D and mitigation, such countries may improve the level of protection above what it would have been otherwise, but the positive impacts will not be apparent in simple cross-sectional data. Fixed effects analysis or other panel data methods (for which there is currently insufficient present data) are required to address this methodological concern.

Moreover, it is not clear that per capita R&D inputs — as in *R&D care and control* — would be a good measure of the effect of R&D capability on the various environmental indicators. Aspects of the Australian environment are population- and industry-dependent (air quality, water pollution). But other aspects may be better captured by land and adjacent water resource areas, and global location (for example, biodiversity). In that instance, spending per capita is not an appropriate metric for the right-hand side of a regression against environmental indicators. Factors such as spending per square kilometre; spending per unique species; and a whole range of other possibilities may be more appropriate.

These issues highlight some of the subtleties of links between measures of environmental effort and environmental outcomes. These conceptual and measurement issues, combined with limitations in the availability of data, suggest that the challenges presented by an MFP-type approach appear too formidable at the moment, but in future such modelling strategies could be trialed.

Policy needs and the option value of environmental science

Another way of measuring the impact of environmental R&D is to revisit the concept of option values raised previously under the rubric of uncertainty. Just as insurance has a value (or impact) because it provides future options (such as replacement of a stolen car), knowledge and analytical skills in science provide options or values associated with preparedness. An indicator of the size of the existing option value of environmental science is captured by three complementary dimensions:

- the degree and complexity of Australia's future potential environmental problems and needs;
- the quality of present environmental scientific resources; and

- the quantity of existing resources.

Weaknesses in any of these three dimensions reduce the option value and impact of environmental science.

Starting with the first issue, countries with complex environmental problems — potential or existing — need to gather objective information for evidence-based policy decision-making. R&D is also required to develop solutions that reflect local circumstances and opportunities. For example, the viability of geosequestration depends on its technical and economic feasibility, but also on the availability of suitable geological conditions, which are country-specific.

The Environmental Sustainability Index provides some useful objective indicators in this sense, suggesting that Australia does have complex and emerging needs (table 4.13). As an illustration:

- Australia has the sixth highest degree of species abundance (biodiversity) in the world, reflecting the size, climatic variation and isolation of its landmass. It is also somewhat vulnerable, as evidenced by its high risk of extinction threats to mammals relative to other countries.
- Various emissions — sulphur dioxide, carbon dioxide and nitrogen oxides — are relatively high by world standards given the populated land area and population — a result of legacy technologies.
- There are potential problems associated with present agricultural sustainability that need to be investigated and may be potentially addressed with new technologies or management practices.

On the second and third issues, it appears that Australia has high quality environmental science capabilities relative to other countries and devotes considerable national resources to research in this area:

- Australia was ranked third best of 78 countries (for which evidence was available) on the excellence of its environmental knowledge by Esty et al. (2005).
- Australia contributes just a little less than one in every 20 global publications on ecology and the environment and more than this share in plant and animal sciences (with which there are significant complementarities). This is much higher than Australia's average scientific contribution. Overall, about 20 per cent of the R&D budgets of PSRAs and 6 per cent of higher education budgets are directly related to environmental science.

Taken together, these indicators suggest that environmental science has a relatively high option value for Australia.

Table 4.13 **Australia-specific risks requiring environmental knowledge**

Measures[a]	*Australian score*	*Mean*	*Median*	*Country rank*[b]
	Index	Index	Index	Number
Biodiversity index	0.85	0.55	0.55	6th of 160
Threatened mammals species as a share of known species	24.23	14.91	11.19	17th of 155
Anthropogenic emissions of:				
Nitrogen oxides (NOx) per km of populated land	14.28	3.32	0.56	6th of 157
Sulphur dioxide per km of populated land	11.86	56.18	0.64	5th of 151
Volatile organic compounds (VOC) per km of populated land	12.79	5.0	1.65	9th of 159
Metric tons of carbon emissions per capita	18.32	5.14	2.59	10th of 197
Hectares of biologically productive land required per capita	7.09	2.55	1.73	8th of 145

a High values equal more. **b** Country numbers for the ranking vary due to missing values for some countries. The ranks refers to rank from highest to lowest among the relevant countries. For example, Australia has the 6th highest biodiversity index among countries.

Source: Esty et al. (2005) based on the ESI index of Yale Center for Environmental Law and Policy (Yale University); and the Center for International Earth Science Information Network (Columbia University) in collaboration with the World Economic Forum and the Joint Research Centre of the European Commission.

Summary

The challenges in capturing, in any summary measure, the environmental impacts of R&D appear to be currently insurmountable (and in any case may be an unrealistic aspiration).

However, there is abundant case study evidence that public funding support for environmental R&D is associated with positive environmental impacts and, in many cases, associated economic gains. There is also aggregate quantitative evidence from cross-sectional international evidence that suggests links between scientific capacity and positive environmental outcomes, though that evidence is only tentative due to deficiencies in the data and methodological concerns. There are also strong arguments on the grounds of increasing preparedness to continue to make substantial investments across a wide diversity of environmental concerns, especially given Australia's unique ecosystems; the particular concerns about water scarcity and climate change risks; and one of the largest marine assets per capita in the world.

4.7 Social and health impacts

In this section, the Commission has interpreted social impacts to include health, as well as broader social impacts, a view that is in generally reflected in submissions from participants in this study. As in the case of environmental impacts, it is important to distinguish between research generally that has social and health impacts from research undertaken in the humanities, social sciences and health fields that have impacts, social and otherwise. Much of this section relates to the latter.

Many social impacts are, as in the case of the environment, as much a consequence of broad innovation in the market economy, as they are of research specifically directed at social outcomes. For example, strong economic growth is probably the most important single determinant of lower poverty and unemployment, which are also important goals of social research. More broadly, many of the most pervasive social trends — female labour force participation; population ageing; urbanisation; fertility; and changing leisure patterns — have foundations that reflect, in part, economic and technological innovations.

And much social and health research has implications for economic growth, such as: new management methods; macroeconomic research; the creation of new media content; the development of medicines that increase productivity; workforce longevity and so on.

Indeed, the only Australian assessment of the aggregate return to research that encompasses the social sciences concentrated on market-sector impacts. The study was an evaluation of the impacts of competitive funds distributed by the ARC, which cover the spectrum of research areas, including a considerable contribution to the social sciences (Allen Consulting Group 2003). The evaluation claimed that the research permanently increased GDP, with overall returns to ARC funding of around 40 per cent. However, these impacts:

- are too narrow, given that many of the social impacts of R&D are not counted in the market sector, so missing one of the key factors that it would be desirable to assess;
- are the result of assumptions about effects, rather than empirical estimates; and
- have been elusive in standard econometric analysis of market-sector impacts, for reasons that have been set out in section 4.3, so raising the question of the reliability of the inference that they might be around 40 per cent.

While clearly humanities and social research have economic impacts, the principal concern of this section is on the social impacts of such research that is not focused on economic gains, since it is these that will not be adequately picked up in MFP and other conventional analysis.

A framework for considering 'non-economic' impacts

The conception of the points in the innovation process where evidence of impacts can be detected (shown in box 4.2) is a useful means of comparing the disparate methodologies that have been suggested for evaluating the impact of social science research.

Cost-benefit analysis

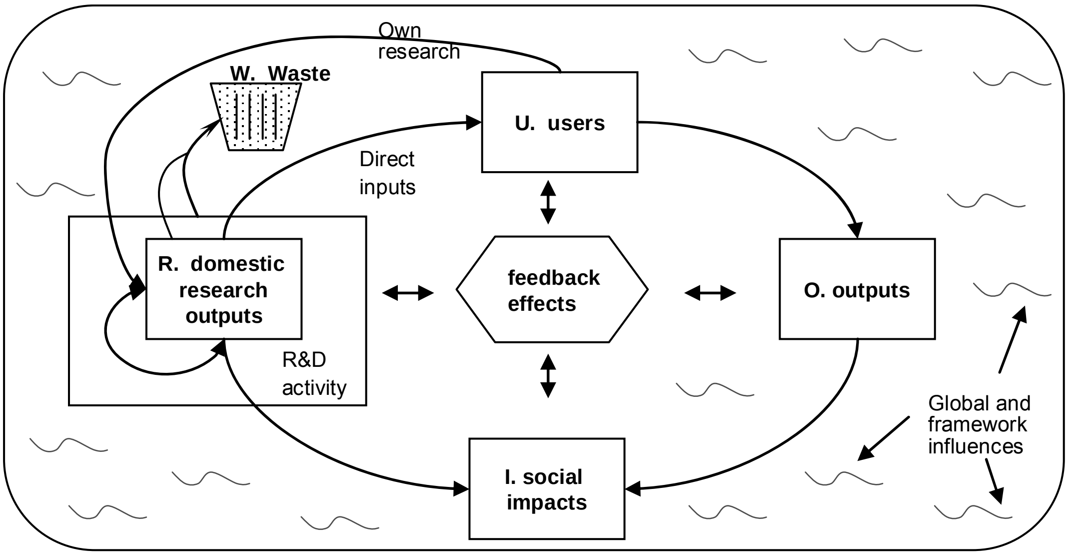
In theory, the most appropriate impact assessment tool is cost-benefit analysis because it allows social science research to be evaluated in terms of the value of outcomes compared with the costs of achieving them. The International Food Policy Research Institute has developed some of the best tools for assessing social impacts using this framework (Norton and Alwang 1998), though others have now specified similar methodologies (such as the Canadian Institutes of Health Research 2005). The most important aspects of the methodology are: clear specification of the expected social impacts; collection of data on the outcomes that the research aims to achieve; the use of interviews to attribute the extent to which the research may have contributed to these outcomes compared with other influences; and measures of outcomes that can be compared across successive case studies.

The latter valuation approach presents the greatest conceptual difficulty.

In the conventional cost-benefit analysis, the goal is to consider the statistical evidence that research costs have certain measurable benefits after controlling for other major influences. As described in the first part of this chapter this statistical task is not easy to undertake on its own terms. But those issues aside, there are important missing elements from the impacts of research. Research can also have other unmeasured impacts on society and the community — some good and a few bad (such as pollution). Once the benefits are not captured adequately in some measure, such as GDP, systematically tracing pathways from the diverse array of specific research efforts to impacts is often problematic.

Box 4.2 **The pathways to influence in the social sciences**

The stylised features of the complex pathways connecting social science research to social outcomes is graphically depicted below. Isolating the impact of public support is profoundly difficult due to the numerous factors that influence R&D, the development of applications by users, and the outcomes themselves.



The system is characterised by complex multilateral flows of information and feedback effects. Existing outcomes and applications shape the efforts of both users and researchers. Researcher and users collaborate, interact and influence each others work. While some research is directly incorporated into the applications developed by users, which in turn influences social outcomes, a large portion of social research has a direct effect only upon other researchers within the R&D square and its influence may be hidden. For instance, a clinical guideline that affects clinical practice may cite Smith's paper, but ignore Jones's whose findings were critical to Smith's paper. Some research is wasteful, producing no valuable inputs to other valuable research or impacts of its own. The best indicator of waste is low peer ratings of quality and a failure to be (positively) cited in other papers, which suggests little valuable addition to the stock of knowledge.

There are three points in this process where evidence of individual impact (if not aggregate impact) can be detected. These are:

- **research outputs**. This is the easiest to estimate through bibliometric analysis (though that is particularly flawed for the social sciences — see later), but is the most distant from actual social impact;
- **applications in businesses or by government**. Evidence of interactions between researchers and users provides a good indicator of valuable impacts. However, it is likely to be biased towards policy-based and empirical research and, in the absence of careful additional analysis, to excessively subordinate the research on which this applied research depends; and
- **outcomes.** In certain cases it may be possible to attribute a social outcome to specific research. For example, wider access to university education can probably be traced to the development of the HECS funding. But in many cases, the links to given social outcomes will be tenuous, slow, and interdependent.

One immediate challenge is that the beneficial impacts are often diffuse and their value cannot be added easily (as the elements of GDP can). Research approaches that use 'willingness to pay' are still highly contested and unreliable as ways of monetising different benefits. In any case, these methods are most suited to demand-driven social and health science research with relatively specifiable impacts. Even when appropriate as a methodology, their cost is too great to apply except across a sample of projects. Some examples in the health area are discussed later in this chapter.

As an illustration of the problems of diffuse benefits, demographic research into fertility can have effects on people directly, government service provision, population policies, welfare policy and politics that cannot readily be added to give some total measure of benefit. This incommensurability of effects means that impact analysis in the social area is often driven by multiple indicators of their effects and disaggregated analysis by discipline or even specific research project (the case study approach again). Of course it is only an illusion that social and humanities research suffers from this 'problem' more intensively than the natural sciences. In the latter case, their links to technological outcomes tends to mask their potentially significant, but less tangible, effects.

This incommensurability also increases the risks of double counting of benefits (box 4.3). As in all sciences, the majority of research is dependent on other research findings, which implies that the value of accumulated knowledge is likely to be less than the sum of the values of discrete research findings. The latter valuations tend to exaggerate the benefits. Where the ultimate effects of research are on some measurable aggregate like GDP, this problem is resolved by using the MFP approach discussed earlier in this chapter because this method can assess the effects of the aggregate stock of knowledge. Where the effects are not on a countable aggregate the best that can be done is to try to look at groups of research that have close links between each of its elements and weaker links outside the group. The boundaries of these groups are hard to define sharply. Judgments about where those boundaries lie will affect valuations.

There are many other problems in the valuation of the social sciences that reflect the nature of advancement in the sciences.

It is not obvious how to value research work that reinforces conventional wisdom. It may appear that such replication studies have low value because they do not make new discoveries. On the other hand, ex ante, replication studies have the valuable potential to contradict earlier empirical studies, thus increasing the credibility of 'established' facts and theories. This is particularly important in the social sciences where control through experimental methods is rare, so that the circumstances surrounding empirical studies may not be generalisable. As an illustration, it has required multiple research studies across countries to reveal the difficulties associated with generalising studies of the benefits of early childhood development programs (Lattimore 2006, pp. 247–251). A single research study is usually not sufficient for policy action (except, in rare circumstances, in a precautionary way to avoid high possible costs while further research is undertaken). At some point, however, the marginal value of an additional replication study is low.

Box 4.3 **Double and treble counting of benefits is hard to resolve**

It is common to conceptualise the benefits (B) of a research finding (F) as being the difference between the world with and without the findings. Suppose that there are many findings (F1… Fn). Then this would suggest the incremental benefits for each one of them, holding fixed the existence of each of the other findings, was of the form: $NetB_1\big|_{F2,F3,...Fn} = (\mathrm{B}_{1,\mathrm{with}} - \mathrm{B}_{1,\mathrm{without}})$. However, each finding's value has some (varying) dependence on other research findings because of the interlinked nature of much research. In that case, the cumulative value of all findings is not equal to the sum of the single NetBs above, but less than this. If the effects of findings are on GDP, the problem is resolved by considering the effects of ΣF as a knowledge stock on MFP growth, rather than the sum of the individual benefits suggested by n sets of MFP equations. If the effects are more diffuse and cannot be expressed in an index such as GDP, one strategy is a combined qualitative and quantitative study of groups of closely interdependent research findings.

The valuation may need to consider the case where research is not only fruitless, but also the case where it has adverse effects on people — referred to as a 'poisoned well' effect in the literature on the impacts of the sciences (Ryan 2002). It is hard to actually implement such a valuation because many adverse effects only materialise well after the event, and can themselves be overtaken by subsequent research. For example, in the therapeutic area, thalidomide appeared to be a successful treatment for morning sickness in pregnant women, was then discovered to cause infant abnormalities, and is now a frontline treatment for leprosy (and potentially as a treatment for metabolic wasting due to HIV and for cancer). At different points, valuations of this drug would have been very different, and these perspectives change as information about treatments grow. This same uncertainty about efficacy and harm particularly affects the social sciences because of the complex nature of the knowledge generated. It is common for social scientists to advocate opposing strategies, apparently underpinned by evidence (for example, advocates for phonics or 'whole word' approaches to acquisition of reading skills in children).

The implication is that any valuation of knowledge should be seen as highly uncertain. While the apparent benefits of widespread policy adoption of research findings may be high, it raises the potential costs if the research results are actually wrong (for example, an educational policy implemented across all schools that results in poorer literacy outcomes for hundreds of thousands of children). With risk aversion, generally this means lower valuation rates than would apply in a certain world. One of the major benefits of sophisticated research capabilities and rich feedback mechanisms between policy makers and researchers is that these uncertainties can be reduced more quickly, lowering the potential costs of mistakes — this capability has a high option value. The Commission agrees with Scott-Kemmis' observations (sub. DR183) regarding the value of program evaluation as a mechanism for policy learning. One of the Commission's key concerns in some areas of policy is that the feedback mechanisms are not always candid or deep enough to encourage such learning. This for example, appears to affect program evaluations for business programs (chapter 10).

In addition to these profound valuation problems, there are also many difficulties establishing a link between inputs and outcomes, which are not specific to cost-benefit analysis:

- socioeconomic indicators are influenced by a wide range of factors, of which social science research is only a minor contributor;
- it is hard to disentangle the contribution of research performed in Australia from research performed elsewhere when assessing the impact of research; and
- there is a large amount of variation in the time it takes social science research to influence socioeconomic indicators. When the research is demand driven (by policy makers), effects are likely to be more rapid, but be less revolutionary. However when research is supply driven, the findings may not be acted upon for decades.

Broader approaches

The usual absence of a measure that combines diffuse impacts into a monetary aggregate means that assessment of outcomes tends to consider other approaches, including:

- input measures, such as funding amounts, numbers of full time equivalent researchers or field coverage;
- research outputs, such as publication numbers and citations (measured by bibliometrics); and
- more qualitative measures of outcomes (such as gathered through surveys or from case studies).

Input measures are sometimes cited as an 'output'. For example, funding was used as an output indicator in an evaluation of Australian heart research (Clay et al.

2006). If the funding is properly applied to productive ends, then it will proxy outputs, but generally funding should be seen as a cost, whose outputs and outcomes need to be judged. Cost and input measures do at least indicate the large scale of resources applied in the humanities and social sciences. As CHASS (sub. DR171) noted, these disciplines might account for about one quarter of national R&D spending. This means that the collective impacts required to justify these costs also need to be large.

Bibliometric indicators are more directly useful for assessing potential impact, given the importance of codified knowledge as a mechanism for diffusion. Researchers themselves rate publications as their most important output. For example, a survey of biomedical researchers (Shewan et al. 2005) found that 87 per cent considered that publications were 'very or extremely important' research outcomes, compared with 25 and 19 per cent for patents and company spinoffs respectively. Since bibliometrics can sometimes be used to assess quality, it also allows some differentiation between different outputs. There is evidence that higher quality research generates higher quality impacts, though the evidence shown (figure 4.9) relates to use-inspired research not just any research.

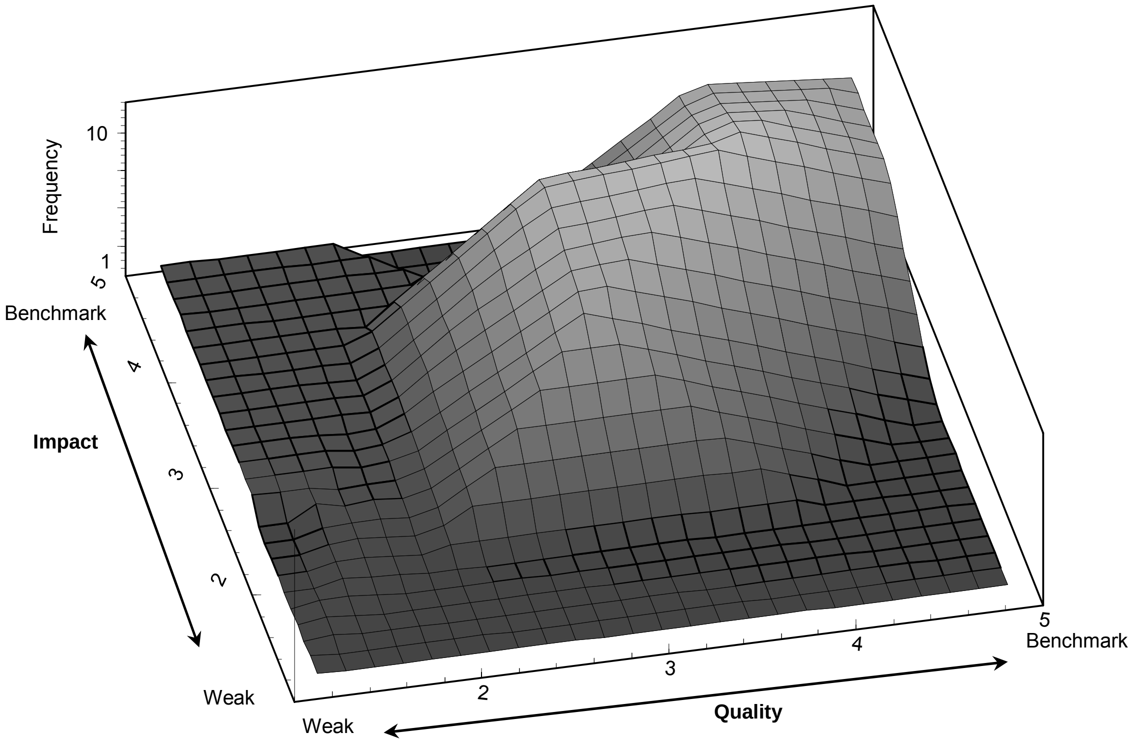
Unfortunately bibliometric evidence has many known deficiencies as a proxy for impact. In addition to the problems that are ubiquitous to all fields (self-citations, citation circles, language barriers, and data errors), the evaluation of the impact of research in the humanities and social sciences using bibliometric tools is hamstrung by several major deficiencies:

- the established ISI bibliometric measures understate key research outputs in these disciplines, such as books and working papers (Butler 2003b). Other indexes can be formed, but no ideal accessible index exists.
- measures lack comparability across fields. Citation practices vary across disciplines and can also be influenced by variations in multi-authored papers. For example, the mean number of references per article varies by field, and yet is central to citation rates (Seglen 1997). Moreover, papers published in a highly cited journal will be recorded as high 'impact' (or high quality) even if the methodology and practices of that journal are questioned by other disciplines. This concern is heightened in the social sciences due to the importance of ideology in framing research and peer review practices (Harzing 2005). The hoax[33] perpetrated by the physicist Alan Sokal on a leading postmodern cultural studies journal, *Social Text*, in 1996 highlighted the tensions between different disciplines;

[33] This was a nonsensical article on physics that was published uncritically.

Figure 4.9 **High quality user-oriented research is associated with high impact**

A case study of CSIRO research[a]



[a] The CSIRO data were based on ratings from 1 to 5 with 0.5 gradations from weak to benchmark. The ratings were based on an independent peer assessment review process undertaken every three years of the major research areas of CSIRO. It was apparent from the data that assessors were more likely to choose a whole number rating than half way gradations between whole numbers. This led to 'holes' in the data distribution that hide its most important features. Accordingly, the original data were recategorised as follows: 4.5-5 = 5 (benchmark); 3.5-4 (strong); 2.5-3 (favourable); 1.5-2 (tenable) and 0.5-1 (weak). The data were subjected to a 5000 sample bootstrap to make the graph smooth.

Data source: Data are from CSIRO (and are also reported in its Annual Report).

- many of the key, 'high impact', journals are published outside Australia and are likely to be less receptive to research that has a purely Australian relevance, though this research may well have the greatest benefits for Australia; and
- there has been a large increase in the numbers of papers published by Australian academics, but the greatest growth has been in lower quality journals. For instance, Butler (2002) found that between 1993 and 1999, Australia's share of SCI publications rose by 20 per cent in the top quartile of publications, by 50 per cent in the second and third quartiles and by 100 per cent in the bottom quartile. This phenomenon was unique to the higher education sector (Butler 2003a), suggesting that the effect was elicited by the use of primitive bibliometric indicators of research productivity by funders of higher education (also seee chapter 12);

- there can be significant publication delays between initial research and diffusion through journals that Harzing (2005) claims to affect some of the social sciences more than the natural sciences. This has several possible implications. It could mean that the impact is weakened by the obsolescence of the analytical tools and empirical findings. On the other hand, if prior to publication in a refereed journal the results are diffused through working and conference papers — which are not included in the bibliometric measures — then the timing of the impacts suggested by the bibliometrics will be misleading.

Generally, analysis of the impacts of the humanities and social sciences give considerable weight to bibliometrics, but they also have sensibly applied a range of other methods given the limitations described above. For example, the Development Advisory Group to the RQF have suggested several potential impact and quality metrics that could be useful in establishing evidence of the impact of social science research (table 4.14). As panel specific methodologies are yet to be released at the time of writing, these prototypical examples are not always well suited to capturing the impact of the social sciences. The citation measures are based on the Thomson scientific database, which, as noted above, is weak in the social sciences. Effects on business or government that arise from the educating function of research universities are absent. Allen Consulting (2005b) have derived specific measures of impact for the social sciences that overcome some of these deficiencies (also shown in table 4.14).

The Council for the Humanities, Arts and Social Science (CHASS 2005) has incorporated the metrics suggested by Allen Consulting and the Development Advisory Group into a peer reviewed system of evaluation. This functions in the same basic manner as the RQF. Research output would be assessed according to its quality, impact and capability, with the institution or individual having some discretion as to the weights applied to each area. CHASS (2005) represents the most complete methodology to evaluate the relative merits of the research conducted by individuals, research groups or departments. However, as with the RQF measures, this methodology is aimed at an ordinal measure of academic social science performance, not a cardinal measure that can be used to decide the national impacts of government funded social science research. Judgment would need to be applied to convert research impact rankings into implicit dollars of benefits.

The International Food Policy Research Institute, while advocating limited use of cost-benefit analysis, has also articulated broader methods to measure the impact of social science research (Ryan 2002). The focus of this methodology is economic research that elicits policy change, but nevertheless, it yields some insights that can be generalised to the social sciences. The techniques centre on systematic analysis of case studies, although bibliometrics and econometric methods are also considered as useful tools. The use of multiple indicators means that some subjective assessment is possible even if formal cost-benefit analysis proves too demanding.

Table 4.14 **Proposed measures of academic research impacts**
Australia 2005 and 2006

RQF September 2006 measures for all sciences	*Allen Consulting measures for social sciences 2005*
Research output/academic impact	
Number of citations; proportion of research that falls into the top citation deciles for the discipline (using international benchmarks); ranked research outputs	Bibliometrics: the number of highly cited papers published; number of papers in high quality journals; books with high quality publishers; and the number of citations of papers within papers published in high quality journals
Grant success rates	Success rates in securing competitively allocated research grants
Invitation to be a visiting researcher or researcher in residence at an end user institution (if based on research merit) or invitation to be on reference advisory and/or steering committees	
Government or market interface	
Spin off companies	Invitations received to act on government advisory boards
Contracts and industry funding, and repeat business	The value of research contracts received from industry and government
New products and inventions	The number of research students that are subsequently employed within government departments, ministerial offices and industry
Licences and royalties	Results from surveys of heads of policy sections in government departments as to who they regard as 'high impact' academic researchers
Citations in government reports, Hansard etc	Citations of research in court judgments, government policy publications, government inquiries and in the popular press
Number of presentations involving contact with end users	Presentations given at learned societies and at academic conferences
Provision of expert advice and submissions to enquires	Submissions made to government inquiries
Community awareness of research	Articles published in the popular press
Non-academic publications and performances	
Positive reviews of creative publications and performances	
Increased cultural awareness	
Creative works commissioned	
Changes in procedures, behaviours, outlooks	
Collaborative projects with end users	
Outcomes	
Reduced pollution	Education attainment
Reduced cost and resource usage	Suicides
Regeneration or arrested degradation of natural resources	Crime and incarceration rates
Lives saved	Unemployment rates
Reduced infection rates, treatment times and cost	Surveys of happiness
Increased literacy and numeracy rates	Divorce rates
Increased employment	Life expectancy
Increased competitiveness of Australian industry	

Source: Allen Consulting Group (2005b) and RQF (2006a,b).

Other specific frameworks are probably appropriate for measuring specific types of social impacts, such as the poverty measurement issues described by ACIAR as part of its consideration of the impacts of Australian-performed R&D in developing countries (sub. 81, p. 23).

Another alternative approach focuses on the subjective extent of linkages between researchers and government to measure the utilisation of social science research. For example, Landry et al. (1998) surveyed 1229 Canadian social science researchers about their perceptions of the utilisation of their own work. The survey divided utilisation into a six stage process, (described in table 4.15) with the respondent indicating the frequency that their research achieves at each stage. Despite the novelty of this technique, there are some serious methodological problems with its realisation in this case. It is based on self-assessment, with the obvious biases this could entail. The survey response rate was 42 per cent, raising a large risk of non-response bias. This problem is compounded by the progressively larger proportion of researchers who decline to provide a response for the most important types of research utilisation. The stages do not appear to be sufficiently distinct and the profile of responses across ratings looks (implausibly) very similar for stages 3 to 6. Finally, it is difficult to believe that around 15 per cent of respondents do research that usually or always gives rise to applications and extension by the practitioners and professionals concerned.

Table 4.15 **Use of academic research**

	Extent of utilisation						
Stages of Utilisation[a]	NA or missing data (0)	Never (1)	Rarely (2)	Sometimes (3)	Usually (4)	Always (5)	Average score
	%	%	%	%	%	%	
S1 Transmission	15.4	4.8	9.2	23.0	26.5	21.1	3.2
S2 Cognition	20.2	2.2	7.3	22.9	32.3	5.1	3.2
S3 Reference	20.5	6.4	14.3	29.4	20.2	9.2	2.7
S4 Effort	27.3	8.4	13.7	26.7	17.6	6.3	2.4
S5 Influence	28.8	8.2	16.8	30.8	11.9	3.5	2.2
S6 Application	31.3	10.1	14.7	28.2	12.3	3.4	2.2

[a] The various stages (S1 to S6) are as follows. *Stage 1 Transmission*: 'I transmitted my research results to the practitioners and professionals concerned.' *Stage 2 Cognition*: 'My research reports were read and understood by the practitioners and professionals concerned.' *Stage 3 Reference*: 'My work has been cited as a reference in the reports, studies, and strategies of action elaborated by practitioners and professionals.' *Stage 4 Effort*: 'Efforts were made to adopt the results of my research by practitioners and professionals.' *Stage 5 Influence*: 'My research results influenced the choice and decision of practitioners and professionals.' *Stage 6 Application*: 'My research results gave rise to applications and extension by the practitioners and professionals concerned.'

Source: Landry et al. (1998).

Other research suggests that the extent of linkages is not as strong as implied by Landry et al. Since transmission often arises from access to published articles, it is notable that many academics have a low publishing profile. For example, Pomfret and Wang (2003) found that 385 of 640 economics academics did not publish a single article in any of the 88 journals considered. Neri and Rodgers (2006) found that in eight Australian university departments 90 per cent of the economics staff did not publish anything in any of the top 159 economics journals. They also found that 21 of 29 departments published less than one page per person year in any of around 600 journals.

This pronounced skewness in performance is not only a feature of economics, but across disciplines more broadly. For example, Valadkhani and Worthington (2005) found that publications per academic (generally) varied from 0.37 per academic in the poorest performing university to 1.24 per academic in the highest for the period 1998–2002. PhD completions per academic staff (an indicator of the capacity of universities to create complex problem solving human capital) varied even more from a low of 0.01 in the poorest performing university to nearly 20 times this at 0.176 in the highest. Grants per academic varied by about the same amount. These are results at the aggregate university level. Results would be much more skewed across individual academics.

Neri and Rodgers considered the differential research performance across universities to be partly a reflection of the fact that many Australian universities originated from specialised teaching colleges and are still more universities in name than in function. That appears to be breaking down as research excellence develops in certain specialised areas.

It is also important to recognise that the outputs of universities relevant to the innovation system are not isolated to published papers in recognised journals, but may take the form of informal advice, working papers, government and business contracts, and well-educated undergraduates. However, an important question is whether the generally measured indicators of academic excellence — the quality of research publications — is a complement or a substitute for these rather more elusive knowledge diffusion mechanisms. As noted above in figure 4.9, it appears, at least in the case of CSIRO, that there were positive links between impacts and academic quality. There is also strong evidence that quality as measured by the research capability of Australian universities is closely correlated with broader measures of the quality of universities that encompass their academic quality, excellence of their graduate and undergraduate programs, resourcing and general peer review (Williams 2005). This suggests the complementary function of research. But given the inadequacies of bibliometric indicators described above, this can only be a generalisation and will not hold for all individual research outputs.

Some notionally 'high impact' papers — as measured by bibliometric indicators — will be of no consequence to society, while some non-peer reviewed material will produce valuable social or economic outcomes.

The Research Quality Framework aims to better identify academic impacts and to reduce some of the dispersion in research performance among academics — though its efficacy in achieving that objective is uncertain (chapter 12). Either way, evidence on highly variable research performance suggests the potential for research impacts to be improved through changes in university practices and resourcing.

This raises the importance of recognising and measuring the size of the 'waste basket' in box 4.2. This is not failed research per se. High quality research that fails to meet its objectives is not necessarily wasteful because it can identify unprofitable areas for others or reduce the credibility of certain theories. Failed research can often still be published. But some research is of poor quality (in method, execution or subject) or makes findings that are inconsequential. This will often not be published or, if so, in a low quality journal. Such waste should be counted. As noted by Iain Chalmers, the director of the Cochrane Collaboration (which supports evidence-based medicine):

> A more radical and informative approach would be to identify a body of basic research funded some time ago. In this way its 'payback' could be assessed not only in terms of whether it led to an eventual improvement in health, but also whether it was completed successfully and if completed, whether it was ever published. Failed research or failure to publish successful research are unambiguous costs to the public, yet I am not aware of any public or charitable biomedical research funding organisation that routinely publishes audits of its investment decisions using criteria such as these (Iain Chalmers, Director, UK Cochrane Centre 2000)[34]

Productive portfolios of research

For the broad social impacts of applied social science R&D, it may be that policymakers' subjective judgments about portfolios of research can give as reliable an indicator of value as more costly alternatives.

A substantial share of publicly funded R&D is intended to produce social impacts, including research activities in health and in the humanities and social sciences. There are strong a priori grounds for significant publicly funded research into such areas because of the prominent role played by government in the provision of: health care; education; community services; social welfare; urban planning; policing

34 'Audit of biomedical research funding decisions', 26 April 2000 from http://www.bmj.com/cgi/eletters/320/7242/1107#7550.

and community safety and so on. Research can play a large potential role in increasing innovation in the provision of these services, generating resource savings for governments or improving outcomes for Australians. As noted by CHASS (sub. 52), social research can often involve collaborative research between the humanities and social sciences and other sciences.

There are many individual cases of social research with large potential qualitative social and economic impacts. A small sample includes:

- the development of new public health initiatives — such as sudden infant death syndrome research undertaken in Tasmania and discussed in chapter 1;
- determining the best responses to global warming. This involves far more than scientific and technological issues, but also many research questions that draw on the social sciences generally;
- effective water policies, which rely on understanding how consumers, farmers and other producers behave under different institutional arrangements, as well as the engineering and scientific issues of water infrastructure and management. Often the latter are more effective when combined with collaborative research with the former;
- many technical evaluations of government social and educational programs that are undertaken by academics in universities or informed by their expertise;
- research into the dynamics of families, youth suicide and management of difficult children. CHASS (sub. DR171), for example, note the *Pathways to Prevention* program as an example of a research-based intervention of this kind;
- identification of people at higher risk of unemployment, as a basis for case management in unemployment management;
- research into indigenous health, employment and communities to achieve better outcomes;
- research into social problems, such as problem gambling problems and substance abuse;
- understanding the public's behavioural responses to public health initiatives; and
- development of large social research databases that have had large impacts on public policy — the HILDA social and economic longitudinal data; the Longitudinal study of Australian Youth (fundamental in a large series of research activities in education and youth unemployment); and the large, comprehensive, datasets collected and managed by the ABS.

This list is at the applied end of the social sciences, but there is a counterpart to basic physical sciences in the social sciences. For example, new statistical procedures are initially developed as basic research, but may eventually spread widely to applied practitioners.

No systematic inventory of case studies is feasible, given the large quantity of projects that are undertaken. Unlike research in PSRAs, less social research takes place in large themed sets of projects. It tends to be more diffuse and is harder to categorise into a few taxonomies.

The gains from research in these areas are not included in existing national accounts' measures of the productivity of government services due to measurement deficiencies.[35] Consequently, improvements in the quality of outcomes, which conventionally are translated to output increases, are not measured. For example, long-term improvements in literacy rates and hospital care, and reduced vehicle fatality rates and crime rates do not show up in the national accounts as 'service improvements', though research activities will have contributed to these positive outcomes. As noted by the Australian Business Foundation (sub. 72), the ABS has proposed an alternative to orthodox economic measures. This is a broad framework for assessing innovativeness that would include measurements of social cohesion, demographic patterns, health status, crime levels and income distribution as metrics of social gains.

Gains from public research in the health sciences are evident

In the health sciences, development of metrics of social impacts is probably more advanced than elsewhere, because this area lends itself to greater causal attribution and more quantitative measures of outcomes. For example, a particular intervention may lower incidence of a disease by a given margin, reduce costly side effects, increase quality adjusted life years, and allow carers to work, all of which are subject to some degree of quantification and valuation. The ACIL Tasman (2006d) evaluation of the CSIRO Preventative Health Flagship represents an example of an options-based appraisal of the overall benefits of a particular stream of health research (box 4.4), which indicates the nature of some of these benefits.

At the broader level, Access Economics (2003) has estimated returns of between 100-500 per cent on Australian health R&D, with the base case delivering a 240 per cent return. While it is difficult to ascertain the reliability and validity of measures that are fundamentally driven by assumptions, it highlights an important point about the impact of health R&D. Even if health R&D is only a very small

[35] This is because outputs are measured as equal to inputs in these parts of the economy, reflecting the difficulties of defining appropriate output measures for goods or services that are not sold in markets.

contributor to health outcomes, and Australian R&D is only a very small contributor to world health R&D, the returns are still likely to be reasonable. This is because people attach a very high value to quality of their lives and to longevity. In addition to being intuitively obvious, numerous studies (Viscusi 1993; Nordhaus 1999; and Cutler and Richardson 1998) consistently find that people value their own life beyond their lifetime earning power (Access Economics 2003, p. 60).

Box 4.4 **The CSIRO Preventative Health Flagship**

The Preventative Health Flagship was launched in 2003. The flagship's budget for the three years to 2006-07 was $61 million, with roughly equivalent external revenue and in-kind support. The flagship concentrates on the development of early detection and prevention approaches, rather than cures per se. The research is conducted in several, sometimes overlapping, areas: colorectal cancer and gut health; neurodegenerative diseases with an emphasis on Alzheimer's disease; cardiovascular diseases (CVD); and health data systems (data integration, imaging and sensing diagnostics and health informatics). The main emphasis was on research into colorectal cancer, using novel approaches such as preventative foods. (Australia and New Zealand have the second highest male rates of colorectal cancer in the world and the highest female rates.)

ACIL Tasman estimated that the total option value for the colorectal cancer research was $138.6 million in 2006-07 present values. The option value for neurodegenerative disease was estimated to be at least $237.8 million. Contributing to these gains were reductions in health care costs, values attributed to improvements in the sufferer's quality of life, savings in carer payments, increases in earning capacities and values attributed to prevention of deaths.

The major benefits from the Alzheimer's research are derived from the potential development of early detection techniques. However, even if it is technically successful, the benefits will only be achieved if competing global technologies do not find solutions ahead of Australia. ACIL Tasman considered that there is still a 98 per cent chance that researchers in the rest of the world will solve the problem first. The ability for the flagship to achieve benefits will also depend upon complementary advances by external health researchers. New diagnostic technologies will only be beneficial if better treatments for Alzheimer's are also found. The fact that positive net option values are still realised with such risks is testimony to the enduring costs of the disease.

The other notable finding of the ACIL Tasman research was that there can be significant gains in achieving solutions to large national (or international) problems from the application of a different set of skills to the norm.

Source: ACIL Tasman (2006d).

The inference of likely high impacts is corroborated by other less direct information. As noted above, high quality is often associated with high (potential) impact. Using measures of relative citation rates in clinical medicine suggests that Australia has above average global capacity in this field (figure K4 in appendix K).

The use of published studies in clinical guidelines provides another route by which health and medical research can have impacts. It is typical for such guidelines to give references for any practice to a set of papers. In a sample of 15 clinical guidelines in the United Kingdom some 1761 papers were cited of which most were based on papers in clinical observation, but only 0.2 per cent were founded on basic research (Grant et al. 2000). However, basic research is much more important than this suggests because the clinical observation papers often draw on basic research themselves, even if the guidelines do not (i.e. basic research has influence by proxy). Grant et al. tracked this by considering the reference lists of the various generations of publications that successfully influence each other, going back four generations. They found that the importance of basic research as an influence on clinical practice then increased by 40 fold (to 8 per cent), though other research types still dominated. The other interesting aspect of their finding was that UK clinical guidelines disproportionately cited UK research. This appears to suggest that domestic research is indeed relevant to medical practice.

A subsequent analysis has confirmed the broad findings of this study, but has also considered the contribution to British clinical guidelines by other countries, including Australia (Webster et al. 2003). This shows that compared with Australia's global presence in published biomedical papers, Australian biomedical research is about as prominent as expected in the National Institute for Clinical Excellence health technology appraisals and about 25 per cent more prominent than expected in the Scottish Intercollegiate Guidelines Network clinical guidelines (p. 91). Australia is in a middle group of countries like the United States, Belgium and Austria whose influence is roughly in line with their publishing share. Some countries' research has a greater influence (the UK particularly, but also Finland, Denmark, Sweden, Canada and the Netherlands). But some countries with a large presence in the global biomedical literature — Germany and Japan — have much less influence than would be expected. (This appears to be more than a consequence of language differences). The other interesting insight of this approach is that it highlights that global shares of papers — sometimes perceived as a measure of the adequacy of a country's research capability (or its inadequacy if that share is declining) — is a misleading indicator of the actual usefulness and diffusion of research.

While a labour intensive undertaking, replicating these approaches using Australian medical guidelines would provide a useful insight into the impact of medical science research. The Cochrane Database of Systematic Reviews may provide another (or better) basis for considering the links between published research and evidence-based approaches to clinical practice.[36]

This approach could also be extended to other areas of the sciences to give a richer indicator of the influences of academic research in the natural and social sciences. For example, DEST and State Education authorities often cite research supporting particular pedagogic or educational approaches. The generational approach of Grant et al. could be used to uncover the broader research influences shaping their decisions. In the case of the social sciences one limiting factor (other than expense) in applying this method is the inference that a cited paper is an influential factor in the public decision. Where politics and ideology is involved, as is often the case in the social sciences, this inference may not always be well founded. A government may make a decision for political reasons and *then* choose selectively any academic basis for this decision, without any suggestion that the research itself is influential in the decision. The Cochrane approach above would solve this problem, but there are not Cochrane equivalents for most of the social sciences.

Summary

Ultimately, the nature of social science research precludes its *collective* impacts from being adequately measured. However, there are several compelling reasons to believe that public support for social science research does have significant impacts:

- Individual case studies in any area of social impacts reveal high quality social research in Australia and well-recognised local research capabilities.
- The R&D conducted in this area is unlikely to be undertaken in the absence of government support so that the challenges presented by additionality in other areas of research are not as prevalent.
- Given the unique natures of cultures and societies, there is often a need for Australia to invest in research into its own social institutions and challenges. For example, regional and indigenous issues in Australia are often distinctive.
- Social science research plays an important role in complementing the other forms of R&D that occur within Australia's innovation system.
- The social sciences focus on areas of large importance to people, such as the quality of their education, mental wellbeing, security and social cohesion.

[36] Response to Grant et al. paper by Chalmers (director of the Cochrane collaboration) (http://www.bmj.com/cgi/eletters/320/7242/1107#7550).

4.8 Other impacts

As noted previously, there are several measures that may provide useful indicators of impacts of public support, while not being impacts themselves. Given their indirect quality, this chapter does not deal with these at length, but they are considered in appendices to this report. Four broad measures are considered.

First, while section 4.7 discusses some of the issues for the social sciences, more general measures of academic papers and citations provide indicators of the quality — on a peer reviewed basis — of Australian science by world standards. This is important because it provides a measure of research capabilities, and to some extent, given the links to training, of the development of advanced problem-solving human capital. While the limitations of such impact measures are well known (such as citation rings), the evidence suggests that Australian science is high quality by world standards. The details are discussed in appendix K.

Second, the Commission considers innovation indicators. These suggest the extent to which R&D can be translated into particular forms of commercialisable knowledge. The evidence suggests Australia is a middle tier performer on this metric, but is improving (appendix J).

Thirdly, the Commission considers the extent to which firms receiving commercialisation assistance have, as a result, been able to grow successfully. From an economic perspective, other impacts (such as the broad ones discussed above) are more relevant for Australians' overall wellbeing. However, from the perspective of the programs concerned, a desired impact of these programs was the growth of globally competitive, commercially successful Australian firms. A reasonable question then is whether these desired program impacts can be confirmed.

The Commission formed a large longitudinal database of firms that have received Australian Government R&D grant assistance with a commercial orientation to try to assess that question. Unfortunately, the data can only partially address the question of transformation. It is clear that no commercial transformations among grant recipients have occurred of the kind represented by Finland's experiences with Nokia. There *are* a reasonable number of grant recipients among successful leading edge companies (as indicated by the BRW top 500 public companies, Australian Export award winners and Australian Design award winners), but limitations in the data prevent a careful consideration of the critical issue of causality (appendix T). In many cases, there is evidence that such firms would still have been commercially successful in the absence of the grants. For example, a significant share of grant recipients were listed in the BRW top 500 *before* grant recipiency. Moreover, appendix M provides suggestive evidence that many firms would still have undertaken the R&D supported by grants in the absence of the grants. On that basis, the Commission notes emphatically that using any of the data in appendix T to claim a link between the varying measures of commercial success and grant recipiency without confirmation of the causal pathway would be misleading. The Commission has proposed a methodology that might better disclose the additionality of grants (appendix M) and their commercial effects (appendix T).

Lastly, the Commission considers a variety of measures of the health of the innovation system (discussed in chapter 2). As indexes, these gave mixed signals about the performance of the innovation system, but there were significant questions about the usefulness of the indexes themselves.

4.9 What are the implications of good returns to public support?

This chapter uses a variety of quantitative and qualitative indicators that suggest that, on balance, Australia is likely to obtain good returns from its *aggregate* public funding support of R&D, though not necessarily from any given component of that funding.

It should not, however, be assumed that these likely good returns necessarily imply that *more* should be spent.

- The case studies and qualitative evidence are strongly supportive of sizeable benefits from publicly supported R&D, but the evidence relates to average returns, not returns at the margin. It is these returns that are relevant for funding adjustments. The studies are also variable in quality and suffer some significant deficiencies that can bias their results.
- The econometric evidence about benefits is too imprecise for calibrating funding.
  - The Commission's evidence about returns to business R&D shows positive returns, but this has only partial relevance to publicly funded R&D, since so much of this R&D is conducted in public agencies and universities.
  - Using Australia-specific time and panel data series, the Commission was unable to find clear econometric evidence of statistically significant positive impacts on aggregate economic growth from publicly conducted R&D. This is not surprising, given the difficulties in single country data, but it reduces certainty about the effects of public support.
  - There is only one authoritative panel data study that considers the aggregate economic returns from publicly conducted R&D (including for Australia). It finds positive returns. This result is supported by many industry and case studies.

- The evidence is based on a simplified characterisation of the effects of R&D and the data used are subject to considerable risk of mismeasurement. They could not reliably indicate the marginal gains from expanding support. In any case, it is possible that the apparently marginal returns suggested by the empirical analysis also include some gains that are made at investment rates lower than current levels (inframarginal gains).

- In the short-run at least, there are resource constraints that apply to R&D spending, because this spending utilises specialised, highly talented research expertise that is in finite supply. This is one reason for incremental approaches to adjusting aggregate public support for R&D.
- New spending measures have transaction costs associated with compliance and unexpected incentive effects, as well as the costs of raising finance through distortionary taxes (or displacement of other areas of public spending). A decision to spend more has to balance the marginal benefits against the marginal costs.

So while collectively the evidence favours good returns from publicly funded support of science and innovation, the evidence cannot be used to decide optimal investment strategies by government. As emphasised in chapter 9, decisions about increments to spending or alteration of the distribution should be made against the backdrop of well-established budget processes that take into account the tradeoffs.

FINDING 4.1

Taking account of multiple sources of evidence, there are likely to be significant aggregate economic, social and environmental benefits from publicly supported science and innovation, but quantitative estimates are unreliable.

5 Impediments to the functioning of the innovation system

Key points

- Participants identified a range of possible impediments to the operation of the innovation system. These mainly related to perceived deficiencies in public support programs. Remaining identified impediments focused on intellectual property rights, research infrastructure, privacy and ethics regulation, and access to the results of publicly-funded research.
- Legal uncertainty about the use of patents for research has the potential to impede knowledge dissemination. One option proposed by the Australian Law Reform Commission and the Advisory Council on Intellectual Property is to introduce an experimental use exemption in the Patents Act. However, the extent to which legal uncertainty actually acts as an impediment is unclear, as are the costs and risks of implementing the proposed option. The recent introduction by the New Zealand Government of an experimental use provision should provide useful information on the effects.
- There is poor utilisation of research infrastructure. This could be improved through owners of major research infrastructure charging to recover marginal operating costs (supplemented as appropriate with a congestion charge) and enabling third party access or, at least, making access entitlements transferable. Enhancing information about the existing stock of research infrastructure could also improve utilisation.
- Privacy regulation is having adverse effects on medical research due to the complexity caused by the intersection of Australian Government and State and Territory laws. National consistency in privacy regulation of health information should be progressed by the Australian Health Ministers' Conference as a matter of priority.
- The ethical review processes of human research ethics committees are impeding health and medical research, particularly, across institutions. Implementation of a national system of mutual recognition should help reduce compliance costs of researchers seeking ethical review of multi-centre research.
- The ARC and NHMRC's recent policy of promoting access to the results of research they fund is commendable. However, there is scope for them to do more through the progressive, yet expeditious, introduction of a requirement that research papers, data and other information produced as a result of their funding are made publicly and freely available.

5.1 Introduction

The terms of reference to the study ask the Commission to identify impediments to the effective functioning of Australia's innovation system including knowledge transfer, technology acquisition and transfer, skills development, commercialisation, collaboration between research organisations and industry, and the creation and use of intellectual property. They also ask the Commission to identify any scope for improvements.

Participants' views on what constitutes an 'impediment' (or a 'barrier' or a 'weakness') to the functioning of the innovation system vary widely and, collectively, comprise a long list.

- Many alleged problems with public support for science and innovation such as insufficient funding, poor program design, onerous reporting requirements, inappropriate performance measures, and poor coordination across governments and programs.
- Some perceived problems within other areas of government activity such as intellectual property protection and privacy regulation.
- Some claimed problems in markets such as skills shortages in the labour market and deficiencies in the venture capital market.
- Other participants identified as impediments such economic, structural and cultural factors as declining numbers in schools of students of mathematics and science, the structure of the Australian economy including the preponderance of small to medium-sized enterprises, Australia's geographical size and location, the size of the domestic market, the lack of 'critical mass', the lack of a culture of risk taking and leadership, and the lack of effective communication between academics and businesses.

In the ABS Innovation Survey 2005, businesses were asked to list barriers to innovation (2006d, p. 16). The most commonly reported barriers for both innovating and non-innovating businesses related to costs, of which high 'direct costs' followed by 'government regulations or standards' were the most significant. Of the market-related barriers, most businesses reported 'potential market already dominated by established businesses' followed by 'lack of customer demand for new goods or services'. 'Lack of skilled staff' was also reported by businesses to be a barrier to innovation (table 5.1). A significant proportion of businesses reported no barriers.

Table 5.1 **Barriers to innovation, 2004 and 2005, by innovation status[a]**

Type of barrier	*Innovating businesses*	*Non-innovating businesses*	*Total businesses*
	%	%	%
Cost-related barriers	**58.4**	**36.5**	**44.1**
• Excessive economic risk perceived by the business	19.0	11.5	14.1
• Excessive economic risk perceived by financiers	5.0	2.9	3.6
• Direct costs too high	31.6	21.1	24.8
• Cost or availability of finance	15.8	7.8	10.6
• Government regulations or standards	22.5	17.2	19.0
Market-related barriers	**36.7**	**27.0**	**30.4**
• Potential market already dominated by established businesses	20.0	14.3	16.3
• Lack of customer demand for new goods or services	10.0	12.0	11.3
• Unable to appropriate benefits from intellectual property	3.6	2.3	2.8
• Inability to secure strategic partnerships	4.8	2.0	3.0
• Market too small or unknown	11.6	5.8	7.8
• Lack of information on technology	2.5	1.8	2.1
Lack of skilled staff	**27.2**	**20.6**	**22.9**
Other barriers	**4.6**	**4.9**	**4.8**
No barriers	**26.7**	**48.1**	**40.7**

[a] Businesses could select more than one factor.

Source: ABS (2006d, *Innovation in Australian Business 2005,* Cat. no. 8158.0, December, table 2.3).

That participants have wide-ranging views on impediments is not unusual. As CSIRO noted, the 'reality of discussing impediments is that different parts of the innovation system have their own perspective on possible limiting factors, depending on their own roles, responsibilities and stakeholder interests' (sub. 50, p. 97).

The Commission has taken an economywide approach to defining impediments. It considers an impediment to the effective functioning of the innovation system to be any factor that distorts the allocation of Australia's resources such that too few or too many resources are devoted to science and innovation, resources are misdirected among competing areas of science and innovation, or there is a failure to capitalise on foreign or domestic science and innovation adequately.

Impediments, thus, could include:

- ‘market failures’ in the innovation system — where the market fails to provide or allocate goods and services to their most efficient use (that is, allocation is not one that maximises overall community wellbeing) ; and
- ineffective or inappropriate government regulations, policies, programs and administrative decisions. These are government actions where the costs to the community outweigh the benefits.

Some specific areas of government activity that were seen as impediments by participants include:

- competition policy (Business Council of Australia sub. 58, p. 6);
- corporate governance (Business Council of Australia sub. 58, p. 6);
- taxation policy (such as the treatment of personal income and capital depreciation) (Business Council of Australia sub. 58, p. 6);
- the ‘state’ of the nation’s infrastructure (Business Council of Australia sub. 58, p. 6);
- the regulatory regime in which the health and medical industry operates including that relating to clinical trials (NHMRC sub. 80, p. 6; Medicines Australia sub. 99, p. 34; and the NSW Government sub. 91, p. 10);
- regulations governing the use of chemicals, precursors for drugs, and explosives and therapeutic substances (Science Industry Australia sub. 22, p. 10);
- regulation of biotechnology including of genetically modified organisms (Institute of Public Affairs sub. 76, p. 10; CRC for Beef Genetic Technologies et al. sub. 85, pp. 35-6; and DITR sub. DR185, p. 16);
- regulation of pharmaceutical and devices (DITR sub. DR185, p. 17);
- regulation of nuclear energy (Institute of Public Affairs sub. 76, p. 11);
- regulation of stem cell research (Institute of Public Affairs sub. 76, p. 11; Victorian Government sub. 84, p. 12; and DITR sub. DR185, p. 16);
- communications policy and regulation (DITR sub. DR185, p. 16); and
- regulation applying to access to genetic resources of native species (ANZAAS NSW Division sub. DR189, p. 2).

While recognising the importance of these specific concerns, for the purposes of this study, the Commission has confined its attention to impediments to the functioning of the innovation system, rather than to particular industries, products or technologies. Accordingly, this chapter addresses the following areas:

- government policy and regulation;
- intellectual property rights;
- research infrastructure;
- privacy regulation;
- ethical review of health and medical research; and
- access to the results of publicly-funded research.

Related issues and impediments covered in more detail elsewhere in the report include:

- the main market failure rationales for public support for science and innovation (chapter 3);
- deficiencies in public support programs, including issues about coordination, institutional decision making, governance as well as funding levels and mix, and performance benchmarking (chapters 8, 9, 10 and 11); and
- ineffective or inappropriate government actions affecting commercialisation, collaboration and skills development (chapters 6, 7 and 10 on CRCs).

5.2 Government policy and regulation

Several participants drew attention to the impact of 'framework conditions' such as taxation, education and skills, macroeconomic conditions, infrastructure, and policy and regulation on the functioning of the innovation system (for example, Medical Devices Industry Action Agenda Implementation Group sub. DR182, p. 3; DITR sub. DR185, p. 4; Business Council of Australia sub. DR204, p. 6; and the Victorian Government sub. DR211, pp. 1–2). This section focuses on the impact of one set of framework conditions — policy and regulation.

Policy and regulation have numerous impacts on science and innovation, both positive and negative. For example, DITR said:

> Regulation is an important influence on the extent and nature of innovation. While regulation incorporating technical requirements can be a driver for innovation, regulatory permissions are equally important in allowing scope for industry innovation.
>
> Regulation can impede innovation by direct regulatory requirements that increase the cost and slow the pace of product innovation. It can impede innovation indirectly by taking businesses away from their 'strategic roles of driving innovation, securing investments and increasing productivity', as put to the Taskforce on Reducing Regulatory Burdens on Business … . (sub. DR185, p. 16)

The nature of the impacts depends on the objectives that policy and regulation seek to achieve as well as on regulatory design. Well-designed regulation that addresses market failures such as environmental externalities, or facilitates market competition, is likely to promote science and innovation. But restrictions on competition, on the use of particular technologies, FDI restrictions, and tariff and non-tariff barriers to trade are likely to impede science and innovation.

There have been numerous studies on the impact of different kinds of policy and regulation on science and innovation. Although the Commission has not undertaken an extensive review, a recent OECD study (Conway et al. 2006) on the link between anti-competitive regulation and productivity found that:

- in all countries examined, anti-competitive regulation slows productivity growth, particularly the diffusion and adoption of new technologies — this is most important for sectors that produce or use ICT intensively;
- anti-competitive regulation impedes the ability of those countries that are lagging in productivity growth to catch up with the productivity leader;
- rates of investment in ICT are several percentage points above average in countries with more ‘competition-friendly’ regulations (such as the United States, United Kingdom, Canada and Australia); and
- a restrictive regulatory stance vis a vis the establishment of multinational firms is also likely to inhibit the international diffusion of technology.

In considering directions for the reform of policy and regulation, governments should focus on those measures that enhance community wellbeing more broadly rather than innovation alone, while recognising that such reforms can have beneficial spin-offs for the operation of the innovation system. In this regard, the reform agendas detailed by the Commission in its Review of National Competition Policy Reform (PC 2005d) and by the Taskforce on Reducing Regulatory Burdens on Business (Australian Government 2006c) continue to be relevant (box 5.1).

5.3 Intellectual property rights

Intellectual property (IP) rights — such as patents, trademarks and copyright — confer legal ownership to the creator of IP. As with any other legal property rights, IP rights exclude others from freely using the IP, can be bought and sold, and can be licensed to others for a royalty.

Box 5.1 **Two reform agendas that promote economic wellbeing and support the innovation system**

In its 2005 Review of National Competition Policy Reforms, the Commission recommended a nationally coordinated reform agenda that involves:

- giving high priority to infrastructure reform particularly in the energy, water, freight and passenger transport, and broadcasting and telecommunications sectors;
- continuing a more focused legislation review mechanism;
- improving other aspects of the competition and regulatory architecture such as improved prices oversight arrangements for regulated infrastructure services and a national review of consumer protection policy;
- extending coordinated national reform to areas beyond National Competition Policy such as health care, education and training, and natural resource management; and
- promoting reforms in child care and aged care.

In 2006, the Taskforce on Reducing Regulatory Burdens on Business recommended priority directions for reform in three areas:

- reforms to existing regulations that could be readily implemented that have one or more of the following features — excessive coverage including 'regulatory creep', overlapping and inconsistent regulatory requirements, regulation that is redundant or not justified by policy intent, excessive reporting or recording burdens, and variations in definitions and criteria;
- further reviews of
  - Australian Government regulation — superannuation tax provisions, anti-dumping regulations, procurement policies, private health insurance regulations, directors liability provisions under the Corporations Act, and health technology assessments;
  - State and Territory regulation — child care accreditation and regulation, privacy laws, food regulation, chemical and plastics regulation, consumer protection policy and administration, national trade measurement, and energy efficiency standards; and
- systemic reforms, namely, applying 'principles' of good regulatory process, undertaking better analysis and consultation, enforcing good regulation-making, and ensuring good performance by regulators.

Sources: PC (2005d); Australian Government (2006c).

The main areas of concern about IP rights expressed by participants are their impact on knowledge sharing and dissemination, their interaction with competition policy and the costs to small and medium enterprises (SMEs) in accessing IP rights. Concerns about the management of IP in universities, publicly funded research agencies and CRCs are covered in chapters 7 and 10. Other concerns raised by participants and commentators relate to the overall costs and speed of acquiring patents, the breadth of patent protection, dispute resolution and the impact of IP-related provisions in international agreements: these matters have been well-traversed in the public policy arena. The IP system itself is described in appendix N.

Common to all these concerns is an inherent underlying tension associated with IP rights. In making IP excludable, IP rights increase the incentives for business to invest in innovation and commercialisation. Without the protection given by IP rights, and because of the 'public good' nature of IP (that is, its use is not capable of being excluded and is 'non-rivalrous' in that its use by one person does not diminish the amount that can be used by others), businesses are less likely to invest if there is a risk that others would freely use their IP. However, if IP rights are cast too restrictively, they can confer undue monopoly power on the owners. This could, for example, manifest in owners of IP rights extracting excessive licensing royalties or placing unnecessary restrictions on knowledge dissemination with further knock-on effects for the rest of the innovation system.

In assessing participants' concerns, it is useful to remember there are market-based alternatives to IP rights. Businesses can exploit or protect their IP through first mover advantage, marketing and product differentiation, confidentiality agreements, technological solutions and the like. The importance of market-based alternatives to IP rights should not be understated. In 2004 and 2005, 27.1 per cent of innovating businesses claimed to use a formal protection method, while 31.6 per cent claimed using informal methods, the most common of which was secrecy (ABS 2006d, p. 32).

Open source

Some participants have expressed a broad concern about the adverse impacts of IP rights on the sharing and dissemination of knowledge and, thus, on further research. For example, Rooney and Mandeville noted that 'overly strong IP can block the knowledge flow and thereby block new knowledge creation as well' (sub. 2, p. 9). In a similar vein, Prof. Fitzgerald considered that IP rights can in some instances 'stifle the flow and spontaneity of an innovation system' (sub. 21, p. 1). The Business, Industry and Higher Education Collaboration Council observed that 'unused intellectual property has no value explicitly' (sub. 55, p. 5).

Many of these participants have advocated an ‘open source’ (or ‘open science’ or ‘open innovation’) approach to IP. Prof. Fitzgerald supplied the following definition:

> Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology. (Chesbrough (2003) cited in sub. DR114, p. 1)

The underlying premise of the open source approach is the free sharing of knowledge, particularly for research purposes. Although there are different ways in which this approach could manifest itself, it could encompass:

- holders of IP rights freely licensing their IP to researchers and only extracting royalty payment where the IP is commercialised; and
- researchers in universities and publicly-funded research agencies making their research freely available rather than seeking IP rights or royalties.

It may well be that an open source approach to IP works better for some industries, and research areas, than others. Many of the examples of the application of open source derive from the ICT industry. The Business, Industry and Higher Education Collaboration Council, for example, observed that many ICT companies such as IBM undertake open source licensing (sub. 55, p. 6). The Department of Agriculture, Fisheries and Forestry noted that the adoption of agrifood R&D outputs is largely achieved through an ‘open-source non-competitive extension approach’. But it also noted that food producers need to achieve a competitive advantage, ‘often through exclusive access to IP or the ability to exploit some particular knowledge’ (sub. 100, pp. 25, 26). For industries where R&D takes a longer time, is more expensive and involves greater risks — such as the biotechnology and pharmaceutical industries — the application of an open source approach to IP rights may have more limited appeal. Even so, there are emerging signs of an open source approach being applied in these types of industries; CAMBIA’s Biological Open Source Initiative is one example (sub. 42, p. 3).

Incorporating an open source approach to IP would require careful analysis as to the effects as well as the precise manner of implementation. For example:

- an approach that involved changing Australia’s IP laws such that IP rights were freely licensed to researchers could adversely affect firm incentives to invest in innovation and acquire the resultant IP rights, even though dissemination of the knowledge embedded in the IP may be enhanced; and
- whether research produced by universities and publicly-funded research agencies should go straight into the public domain has implications for their

- commercialisation strategies but also affects the ability of others to gain commercial advantage and, hence, be willing to use that research — this is discussed further in chapter 7 on commercialisation.

Experimental use of patents

A subset of the broad concern about the impact of IP rights on the sharing and dissemination of knowledge is the capacity of researchers to access patents for ‘experimental use’, particularly in the area of biotechnology. Experimental uses of patents could include:

- testing an invention to determine its sufficiency or to compare it to ‘prior art’;
- tests to determine how the invention worked;
- experimentation on the invention for the purpose of improving on it or developing a further patentable invention;
- experimentation for the purpose of ‘designing around’ the patented invention;
- testing to determine whether the invention met the tester’s purposes in anticipation of requesting a licence; and
- academic instructional experimentation with the invention (in ACIP 2005, p. 10).

There is currently legal uncertainty about whether such experimental uses are permitted under the *Patents Act 1990*. The Act does not explicitly exempt experimental use of patented inventions from liability for infringement. And there is no case law as to whether an implied experimental use defence to patent infringement exists (ACIP 2005, p. 2; ALRC 2004, p. 317).

Jensen, Palangkaraya and Webster referred to the problem that this creates for researchers:

> Historically, most industrialised countries have not deemed university research on a patented invention as an infringement of the rights of the patent-holder. However, the *Madey v. Duke* case in 2002 changed the perception of this [discussed in box 5.2]. Without an exemption, it is possible that scientists and universities may be sued for infringement when the work they are doing is for scientific progress generally. As a result, there is now widespread concern that the absence of a research exemption in patent law may have serious long-term effects on scientific progress. (sub. 9, p. 9)

The experimental use of patents has been considered in two public reviews in recent years.

The Australian Law Reform Commission (ALRC 2004) considered experimental use within the context of gene patenting. It expressed the view that the legal uncertainty has the ‘potential to result in underinvestment in basic research; and to hinder innovation if researchers become concerned that their activities may lead to legal action by patent holders’ (p. 331). It recommended amending the Patents Act to incorporate an experimental use exemption for ‘acts done to study or experiment on the subject matter of a patented invention’ (for example, to investigate its properties or improve upon it such as when a patented genetic sequence is being used to investigate the function of a gene, or its association with disease) (p. 335). It further recommended that the provision makes it clear that: the exemption is available only if study or experimentation is the sole or dominant purpose of the act; the existence of a commercial purpose or objective does not preclude the application of the exemptions; and the exemption does not derogate from any study or experimentation that may otherwise be permitted under the Act (p. 335).

The Advisory Council on Intellectual Property (ACIP 2005) effectively found there were no major impediments to experimental use of patents in Australia. It noted this was not a result of formal protection but, rather, of a convention in Australian industry of not pursuing patent infringement that is the result of experimentation. It went on to say however that this will change and there could, thus, be merit in introducing an experimental use exemption:

> Although there is some anecdotal evidence, there is no strong empirical evidence that the current situation is adversely affecting the balance between the incentives to innovate and the ability to use innovations for research and development. However, ACIP considers that this situation will change. There is evidence that more assertive IP practices are developing in Australia. Without clarification of the law, this would increase inefficiencies and lost opportunities. Also, new case law may determine the category of allowable uses of patented invention be very narrow. ACIP therefore considers that, if an experimental use provision can be drafted into patents legislation which prevents a damaging situation without introducing an even greater set of costs, then it should be introduced. (p. 2)

Its preferred option was to introduce an experimental use exemption in the Patents Act to ensure that the rights of a patent holder are not infringed by acts done for experimental purposes relating to the subject matter of the invention that do not unreasonably conflict with the normal exploitation of a patent. Acts done for experimental purposes relating to the subject matter of the invention include: determining how the invention works; determining the scope of the invention; determining the validity of the claims; and seeking an improvement to the invention (p. 3).

Although there are various points of difference between the Australian Law Reform Commission and the Advisory Council on Intellectual Property’s recommendations

— such as whether experimentation is *on* an invention or relates to the *subject matter* of an invention, and as to the existence of a commercial purpose — both come to the same broad conclusions that there is a need for an experimental use exemption in the Patents Act to provide certainty for researchers and to foster research.

Since the release of the Advisory Council on Intellectual Property report, an interdepartmental committee has been established to draft the Government's response. A public consultation paper has been issued by the committee seeking submissions (IP Australia 2006e).

Provisions exempting experimental or research use of IP rights are not new. Experimental use exemptions exist in the patent legislation of other jurisdictions such as the United Kingdom and Japan. New Zealand is also intending to introduce a new experimental use exemption based on the Advisory Council of Intellectual Property's recommendations (box 5.2).

Box 5.2 **Experimental use in other jurisdictions**

New Zealand

The NZ *Patents Act 1953* does not provide an express exemption for experimental use of a patented invention. In at least two cases, New Zealand courts appear to have accepted that such a defence is available. However, although the courts have drawn distinctions between experimental use and commercially-directed research, the law is said to remain 'uncertain as to where the line actually falls between pure research and research for gaining a commercial advantage'.

Following a recent review, the New Zealand Government decided to incorporate an experimental use exemption in the Act. The wording of the provision is to be based on the wording proposed by the Advisory Council on Intellectual Property in its final report.

United Kingdom

An experimental use defence was enacted in the UK *Patents Act 1977* in part to ensure that UK law conformed to the Community Patent Convention (ratified by the United Kingdom and eight other European Union states). The UK provision states that 'An act which, apart from this subsection, would constitute an infringement of a patent for an invention shall not do so if — a) it is done privately and for purposes which are not commercial; b) it is done for experimental purposes relating to the subject-matter of the invention' (section 60 (5)).

(Continued next page)

Box 5.2 **(continued)**

These exceptions appear to have been interpreted rather narrowly. For example, in *Monsanto v. Stauffer Chemical,* it was found that the underlying purpose of the experiments must be technical — 'to discover something unknown or to test a hypothesis' relating to the patented invention.

United States

As in Australia and New Zealand, there is no experimental use exemption in the US Patents Act. US case law recognises a limited experimental use defence. For example, in *Roche Products v. Bolar Pharmaceutical,* the US Court of Appeal for the Federal Circuit found that the defence was dependent on the experiments involved being for 'amusement, to satisfy idle curiosity, or for strict philosophical inquiry' and not for business reasons. In the 2002 case of *Madey v. Duke University,* the Court emphasised that the defence is very narrow and strictly limited:

> … so long as the act is in furtherance of the alleged infringer's legitimate business and is not solely for amusement, to satisfy idle curiosity, or for strictly philosophical inquiry, the act does not qualify for the experimental use defence. (p. 1362)

The Court found that the non-profit (or educational) status of the alleged infringer does not determine the availability of the experimental use defence. Rather the focus should be on whether the act was in furtherance of the alleged infringer's legitimate business.

The *Madey* decision has been widely regarded as narrowing the experimental use exception in the US to the point where organisations carrying out research or experimental work involving patented inventions could find themselves liable for patent infringement.

Japan

There is an express provision in the Japanese Patents Act, dating from 1909, that states that 'the effects of the patent right shall not extend to the working of the patent right for the purposes of experiment or research'. The Act does not define 'experiment'. Japanese courts have held that the testing of generic pharmaceuticals for the purpose of obtaining regulatory approval during the term of the patent on the original pharmaceutical falls within the experimental use exception.

Sources: ACIP (2005); ALRC (2004); NZ Ministry of Economic Development (2006).

Also, other areas of Australian IP law have exceptions for research purposes.

- The *Plant Breeder's Rights Act 1994*, for example, provides an exception for the use of a protected variety in experiments or plant breeding (section 16). Rights cannot be granted for any new variety unless it is 'clearly distinguishable' from the original variety (section 43(2)).
- And the *Copyright Act 1968* contains special provisions that allow for use of copyright material for the purpose of research or study provided that the use is 'fair'. What is 'fair' depends on the circumstances such as the purpose and

character of the dealing, the nature of the work, the possibility of obtaining the work within a reasonable time at an ordinary commercial price, and the effect of the dealing on the potential market for, or value of, the work.

Incorporating an experimental use exemption in the Patents Act raises a host of complex issues at the heart of which is the need to strike an appropriate balance between ensuring that patent holders are rewarded for their investment and ensuring that research that relies on patents is not unnecessarily stifled. DITR considered that an 'appropriately framed research exemption' could do this (sub. DR185, p. 17). Whether the exemption was effective in achieving its intended purport would depend on the clarity of the legislative drafting and subsequent interpretation by the courts.

Although both the Australian Law Reform Commission and the Advisory Council on Intellectual Property recommended the introduction of an exception, neither has made a strong case for change. Indeed, both noted that the evidence of a problem existing appears to be anecdotal, though the mere existence of legal uncertainty itself may be a sufficient basis for further legislative change. Moreover, it is not clear as to what are the costs and risks of either of their recommendations. That said, the New Zealand Government's recent action to implement the Advisory Council's proposed approach should provide useful feedback to the Australian Government of the effects of introducing an experimental use exemption.

IP rights and competition policy

There has been a long-standing debate about whether IP rights should continue to be exempted from the pro-competitive provisions of the *Trade Practices Act 1974* (TPA). Specifically, section 51(3) exempts certain conditions in licences and assignments of IP from some of the provisions of Part IV.[1] (Another complex issue, not considered here, relates to the impact of the TPA on collaboration among firms for the purpose of undertaking research and development.)

On the one hand, because of the public good nature of IP, IP rights are said to be needed to encourage science and innovation and, thus, should be exempted from the TPA. In supporting the exemption, the National Competition Council considered that, given few owners of IP rights have the market power necessary to substantially lessen competition, there was no inherent clash between IP rights and competition

[1] The section provides that conditions that 'relate to' the subject matter of patents, registered designs, copyright, trade marks and circuit layouts are exempt from sections 45, 45A, 47, 50 and 50A. It does not exempt licensing and assignment conditions from the operation of sections 46 or 48.

policy (NCC 1999, p. 13). The US Federal Trade Commission observed that both 'competition and patent policy can foster innovation' when a proper balance between the two is achieved (FTC 2003, p. 1).

On the other hand, as IP rights restrict access to IP, they can have anti-competitive effects including impeding further science and innovation and, thus, some argue that they should be subject to the TPA. Dr Lawson observed that the regulation of IP is 'just another regulatory measure to promote economic development' and, as such it should be 'subjected to the same standards as other legislation with potential anti-competitive effects' (sub. 5, p. 1).

The Australian Government's main review of the interaction of IP rights with competition policy was undertaken in 2000 by the Intellectual Property and Competition Review Committee. It considered the current IP rights exemptions in the TPA to be 'seriously flawed' as 'the extent and breadth of the exemptions are unclear, and may well be over-broad' (IPCRC 2000, p. 11). It recommended that section 51(3) of the TPA be amended such that anti-competitive conditions (specifically, contraventions of Part IV or section 4D of the TPA) by reasons relating to the imposition of an IP statute do not constitute a breach, so long as those 'conditions do not result, or are not likely to result in a substantial lessening of competition' (p. 11). What constitutes a breach would be determined by the Australian Competition and Consumer Commission. Although the Australian Government has stated its intention to further explore the implementation of this recommendation, it has yet to legislatively deal with this particular matter. It has, however, introduced legislation to deal with other recommendations of the Intellectual Property and Competition Review Committee (IP Australia 2006b).

In its 2005 review of National Competition Policy, the Productivity Commission was of the view that IP laws should 'continue to be scrutinised to ensure they are not unduly restrictive' (PC 2005d, p. 285). This would be achieved through the retention of a legislation review mechanism, including provision for periodic review (also recommended in SCSI, 2006, p. 125). In conducting such reviews, however, there needs to be consideration of the appropriateness of Australia's IP laws within the constraints of its international obligations.

The cost of IP rights for SMEs

Concerns were raised by the Australian Industry Group about the cost to SMEs of acquiring IP protection and the barrier that this poses to the 'spread of innovation practices':

> For many SMEs, the cost of international protection is out of their reach preferring to rely on 'first to market' advantages rather than formal registration. Moreover, many

businesses do not have the skills or the necessary processes in place to record and capture basic information on their intellectual property. (sub. DR121, p. 10)

There are already some mechanisms that address the costs of acquiring IP rights by SMEs. Firstly, the Smart Start program run by IP Australia provides basic information about IP rights to SMEs and new businesses. Secondly, the innovation patent offers an alternative to the standard patent, having less stringent information requirements and at a lower cost. While not solely for SMEs, it is a more accessible option than the standard patent.[2]

Although the Australian Industry Group noted that the introduction of innovation patents in 2001 has helped to reduce the costs of patents, it believed that:

> … greater use of patents would be facilitated by SMEs if small grants were available to assist companies to meet the cost of identifying and protecting intellectual property, particularly in overseas markets.
>
> Consequently, AiGroup has put to the Federal Government that it should introduce a grants scheme to support SMEs in meeting the professional costs associated with the auditing and management of intellectual property including the costs of legal, commercial or intermediary services. (sub. DR121, p. 10)

There is no strong evidence that SMEs are disadvantaged by the costs of acquiring IP rights. The relationship between firm size and expenditure on innovation and R&D is ‘not straightforward’ (Australian Academy of Technological Sciences and Engineering sub. 27, p. 20) and the empirical evidence is ‘inconclusive’ (Jensen, Palangkaraya and Webster sub. 9, p. 20). For example, commentators have argued that large firms may be more innovative since they have the retained earnings with which to reinvest in risk innovative activities or there is an advantage to being large if there are economies of scale in R&D production. However, others argued that SMEs have distinct advantages since they may have better information about the expected profitability of an innovation and they may have less inertia than large firms and are thus able to take advantage of market niches (in Jensen, Palangkaraya and Webster sub. 9, p. 20).

Indeed, it could be the case that there is higher usage of IP rights in SMEs. A study by Jensen and Webster (2006, cited in sub. 9) found that SMEs are more likely to apply for patents, trade marks and designs, given their innovation potential, than large firms and, thus, ‘there is no strong positive evidence supporting the contention

[2] The innovation patent was subject to a recent review by IP Australia which found that the objectives of the innovation patent (which include stimulating innovation particularly in Australian SMEs by providing industrial property rights for lower level inventions) are generally being met (2006b, p. 4).

that SMEs are disadvantaged' (sub. 9, p. 21). The authors noted that there were different ways to interpret their results.

- SMEs have a higher rate of research intensity, or do more innovation, than large firms — this may be 'intrinsic' or an 'outcome' of government SME programs.
- SMEs have greater incentives than large firms to obtain IP rights. For example, SMEs may have a greater need for strategic alliances, which make legal contracts such as those offered by IP rights more attractive.
- Many of the 'anecdotally-cited disadvantages' of the IP system claimed by SMEs apply equally to large firms. Thus, their comparable usage rates may 'belie their intrinsic disadvantages in IP usage' (sub. 9, p. 21).[3]

Given the lack of evidence that SMEs are disadvantaged by the costs of acquiring IP rights, the Commission considers there is little case for introducing further mechanisms for cost support.

5.4 Research infrastructure

Research infrastructure is an important input to science and innovation. The Mapping Australian Science and Innovation report noted that:

> Access to world-class research infrastructure is critical to the capacity of Australia's scientists, engineers and technologists to perform high-quality research. In particular, the competitive position of a nation's science base … depend[s] upon access to research equipment which is sufficiently technically advanced to enable scientists to carry out the experiments required to keep up with the leading-edge of research and advances in the technologies which underpin scientific research equipment have driven and continue to drive increases in the quality, quantity and breadth of experimental data that can be gathered by scientists. (DEST 2003c, p. 173)

DEST noted that, as well as providing the 'critical capability for the production of world-class research', research infrastructure is 'essential' to the operation of the innovation system as a whole (sub. DR205, p. 4). In particular, it drew attention to how research infrastructure makes research more productive, assists in attracting talent and facilitating the development of human capital networks and skills, and integrates Australia into the international research system.

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[3] The authors place two caveats on their findings. First, they do not distinguish industries and sectors where 'market failure problems are known to be acute from those where it is less severe'. And second, the analysis is limited to IP rights and not other forms of IP appropriation such as trade secrecy.

Research infrastructure embraces such items as research facilities and equipment (and the services that support them); libraries and ICT networks for storing, moving and accessing research information; and collections, archives, large/complex data sets and records (Australian Government 2006a, p. 35). A taxonomy of research infrastructure capturing such factors as cost, complexity and extent of collaboration required in its provision is given in box 5.3.

Box 5.3 **A taxonomy of research infrastructure**

In its 2004 report, the National Research Infrastructure Taskforce described five broad categories of research infrastructure to capture such factors as cost, complexity and extent of collaboration required in its provision.

Australian foundation facilities are basic, systemic infrastructure such as broadband communications, high performance computing and major data repositories and services.

Australian landmark facilities are large scale research facilities, such as synchrotrons and research vessels, typically involving funding in excess of $100 million.

Australian major research facilities are used to pursue regional, institutional and thematic groups' research priorities, typically requiring funding of $1 million to $100 million.

Australian research sector facilities facilitate regional and institutional strategies and priorities, require regional and institutional collaboration and access, and are implemented in a coordinated way, typically requiring funding of $0.15 million to $1 million.

Institutional research facilities usually facilitate institutional research priorities, are of relatively low cost, are site specific in nature, and are funded entirely from the institution's resources.

Source: DEST (2004e, p. 9).

Total public support for research infrastructure in Australia is estimated to be around $1 billion in 2005-06, with the Australian Government being the main source of funds (appendix O). A key form of public support is ongoing research infrastructure programs as distinct from one-off expenditures (box 5.4). For the Australian Government, these include the Department of Health and Ageing's Medical Research Infrastructure Projects ($215 million in 2005-06) and DEST's Research Infrastructure Block Grants ($200 million), Systemic Infrastructure Initiative ($61 million) and Major National Research Facilities Programme ($42 million). The National Collaborative Research Infrastructure Strategy (NCRIS, box 5.5) is another major program ($542 million from 2004-05 to 2010-11). More information on public support for research infrastructure is given in box 5.4 and appendix O.

Box 5.4 **Public support for research infrastructure**

The array of public support for research infrastructure includes:

- Australian Government and State and Territory Government research infrastructure programs involving either recurrent or one-off expenditures;
- Australian Government funding of public sector research agencies such as CSIRO and ANSTO, as well as of universities — these institutions then allocate funding to research infrastructure; and
- State and Territory Government support for 'in-kind' research infrastructure provided, for example, to cooperative research centres and major national research facilities.

Funding under research infrastructure programs — which presents a lower bound on total public support for research infrastructure — amounted to around $1 billion for public support for science and innovation in 2005-06.

Source: Appendix O.

Box 5.5 **National Collaborative Research Infrastructure Strategy (NCRIS)**

Previous concerns relating to large and systemic infrastructure have been the ad hoc nature, inadequacy and lack of strategic direction of funding, particularly under the Systemic Infrastructure Initiative and the Major National Research Facilities program.

The Australian Government established a National Research Infrastructure Taskforce in 2005 to develop a national research infrastructure strategy framework to inform it of investment in research infrastructure for universities and publicly-funded research agencies. The Taskforce issued its report at the end of 2005.

The Government accepted the Taskforce's central finding that there is a need to 'strengthen, plan and prioritise research infrastructure needs' (DEST 2004e, p. ix). It committed $542 million from 2004-05 to 2010-11 to NCRIS, which seeks to bring greater strategic direction and coordination to national research infrastructure investments. NCRIS replaced the Systemic Infrastructure Initiative and the Major National Research Facilities program. A Roadmap and Investment Framework were released in 2006 — the Roadmap identifies the principles underpinning NCRIS as well as priorities for investment (in 'emerging fields' such as biotechnology, nanotechnology, biosecurity and environmental monitoring), and the Investment Framework sets out in more detail how NCRIS is to be implemented.

(Continued next page)

Box 5.5 **(continued)**

Late in 2006, the Minister for Education, Science and Training announced funding to priority areas under NCRIS of $500 million. Among the successful projects are programs that:

- establish a national network of medical imaging facilities across Australia;
- provide facilities to support gene discovery and genome analysis in universities and specialist centres around Australia;
- establish a fabrication capability for Australia's nanotechnology industry; and
- develop a Networked Biosecurity Framework to improve collaboration between the existing agencies and institutions involved in biosecurity research to help prevent the entry into Australia of new diseases and pathogens.

Facilities are being developed by a collaborative effort between the Australian Government, State and Territory Governments, universities, research agencies and industry. In addition to the NCRIS funding, $640 million in cash and in-kind contributions have been pledged for the facilities.

Sources: Australian Government (2006b); Bishop (2006d); DEST (2004e).

Several participants (such as the AVCC sub. 60, p. 37; the University of New England sub. 17, p. 15; Baker Heart Research Institute sub. 40, p. 5; the Australian Society for Medical Research sub. 36, p. 4; and the Association of Australian Medical Research Institutes sub. DR162, p. 1) expressed concerns about the public support for research infrastructure. They claimed various deficiencies such as:

- the failure of funding to keep pace with the costs of provision and with research grant funding;
- the lack of provision for ongoing costs (that then have to be funded from other sources);
- the short-term duration or uncertainty of funding under many research infrastructure programs (for example, funding is available on a calendar year basis under DEST's Research Infrastructure Block Grants program and up to five years under the ARC Linkage Infrastructure Equipment and Facilities program);
- underutilisation of some types of research infrastructure;
- inadequacies in the funding and/or management of university research infrastructure;
- inconsistencies in support for research infrastructure across institutions, particularly between universities and medical research institutes; and
- the lack of knowledge about existing stock.

Many said that such deficiencies had adverse consequences for the type and quality of research.

What follows is a consideration of the key issues and concerns about research infrastructure funding and provision.

Funding ongoing research infrastructure costs

Research infrastructure programs typically fund upfront infrastructure costs, with ongoing costs recovered elsewhere in the system such as from research programs or from institutional block funding arrangements (such as the Institutional Grants Scheme for universities). Some commentators and participants favoured a stronger link between research infrastructure funding and other research funding programs.

In its submission to the NCRIS Advisory Committee, the Australian Academy of Science (2005) favoured 'expensing' access to research infrastructure in research grants such as those provided by the ARC and NHMRC:

> A line item in [ARC and NHMRC] research grants for access to centralised research infrastructure will guarantee that facility users have the means to contribute adequate funds to operate these national research assets. In turn, these funds should support dedicated technical support for the facilities, for the facilities to keep abreast, and indeed contribute to, cutting edge technologies. Competent technical support is essential for efficient and effective use of the facilities and this in turn will be an inducement to researchers to collaborate with the centralised facilities and will help avoid fragmented national research infrastructure. (pp. 4-5)

Medical research institutes supported a stronger link between research infrastructure funding and research grants. For example, the Association of Australian Medical Research Institutes was of the 'strong view' that:

> … as in the US, funding for research infrastructure (viz the indirect costs of supporting research) should track and be directly related to the direct support provided as competitive research grants. The infrastructure funding should follow the grant to the institution where the research is performed and the arrangements and level of support should ideally be the same irrespective of whether research is done in a University, an institute or other public body. The NHMRC could, for example, both award grants to the individual investigator and provide the associated infrastructure costs to the administering institution. (sub. DR162, p. 1)

Two ARC research funding programs already incorporate some research infrastructure costs. The Discovery Projects and Linkage Projects, for example, allow for a small proportion of research funding to be directed to purchasing equipment, or to maintenance and operating costs. If a research facility is not available internally within the university where lead researchers are employed, support may also be provided under the programs for researchers to use outside facilities. The Centres for Excellence program also provides funding to researchers for the purchase, building, maintenance and operation of equipment and facilities.

However, the ARC cautioned that:

- any increase in such arrangements should not be at the expense of reducing the funding for the research activity itself and additional funding may well be required;
- if additional funding or funds diverted from other funding sources are to be made available, careful consideration would need to be given to the appropriate costing of research access and to the incentives that would then confront the owners and operators of existing research infrastructure; and
- in particular, consideration would need to be given to minimising the potential for duplication of funding. (sub. DR167, p. 11)

The Victorian Government considered the roles of governments vis a vis the funding of operational costs (sub. DR211, attachment A, p. 1). It endorsed the continuing role of the ARC and the NHMRC in providing for operational funding in their research grant allocations. It also considered that the Australian Government should meet the full operational costs for all national research infrastructure designated as a major national landmark such as the OPAL Reactor, the Australian Synchrotron and the proposed Mileura International Radio Array for their operational life.

Increasing the linkage between research infrastructure funding and research funding does not necessarily imply an increase in funding for research, but could be limited to a recalibration of existing funding arrangements. For example, some programs that currently support funding of research could be augmented with funding to cover the cost of access of research infrastructure and other indirect costs with offsets from existing block funding programs for universities and publicly-funded research agencies (such as the Research Infrastructure Block Grants Scheme). However, the negative implications arising from adjusting the levels of block funding and the balance of block and competitive funding would need to be considered (for example, see chapter 12 in relation to higher education funding).

Is there a role for access charging?

In addition to program funding, a source of research infrastructure funding is for institutions that own infrastructure to charge for access or use. There is currently no consistent approach in Australia. Some institutions such as the Australian Partnership for Advanced Computing and ANSTO[4] have regimes with a mix of

[4] ANSTO, for example, announced that research access to the new neutron beam instruments at its OPAL reactor will be by peer review based on merit. ‘There will be no charge for beam time if

charging and peer review. Others such as the Australia Telescope National Facility provide access freely but based on peer review. And yet other institutions (Adelaide Microscopy, University of Adelaide) provide access freely on a 'first come first served' basis.

The National Research Infrastructure Taskforce, which focused on large and systemic research infrastructure, identified four basic options for setting access charges:

- full cost recovery of capital and operating costs;
- full cost recovery of operating costs;
- free to designated users, except for marginal operating costs;
- free to designated users (DEST 2004e, p. 31).

The Taskforce recommended that funding of research infrastructure provide both capital and 'standing' operating costs, with marginal operating costs being recovered from designated users (p. 32). It argued that:

> The first two market-driven models place large market and financial risks on the host of the facility. Unless the current arrangements for research funding are changed to a more market-driven, fully funded model, they may place at risk the ongoing viability and relevance of the facilities. These models for charging also introduce additional complexities for management of cash derived from recovery of capital charges by facility hosts, and for the creation of usage models which may be at odds with national, regional, institutional and thematic groups' strategies and priorities. (p. 31)

It also recommended that access charges for users outside the research sector be on a full cost recovery basis, but be flexible (p. 3). These recommendations were echoed in later implementation advice by the NCRIS Advisory Committee and set out in the NCRIS Investment Framework.

For infrastructure where a commercial rate of return is sought — such as electricity and urban water infrastructure — efficient utilisation and investment would require that charges to users expressly reflected the long run marginal costs of provision including operational, overhead and capital costs. Of course, variations to this basic principle would be required depending on the particular circumstances, for example, where there is congestion as opposed to underutilisation.

However, such a commercially-oriented approach to charging is only partly relevant to research infrastructure. Research infrastructure is an input to research and, as such, the main rationale for public support for research — namely, to capture external benefits or spillovers from science and innovation — also applies to public support for research infrastructure.

research results are published in open literature. Access for proprietary work, on the other hand, will be available on a fee-for-service basis' (2006, p. 24).

Even so, the Commission considers that there are aspects of charging to seek a commercial rate of return that could be usefully applied. In this respect, the Taskforce recommended that charges be set to recover marginal operating costs alone. Such an approach would provide a useful signal to funding agencies of the demand for research infrastructure and, therefore, provide some guidance of future investment in capacity. Where utilisation exceeds capacity, the charge could also incorporate a congestion component.

For research infrastructure funded and provided through a collaboration of domestic and/or international institutions, it would appear that there is less scope for such a modest approach to access charging. Here, a protocol typically applies whereby access is allocated to an institutional partner based on the proportion of its contribution to the costs as well as the scientific merit of that partner's research. However, for effective utilisation of capacity, it would be desirable if the initial access entitlement were transferable, not only among partners, but to third parties, with the transfer fee reflecting underlying infrastructure costs.

Some participants agreed with the need to ensure maximum utilisation of research infrastructure. For example, the Victorian Government endorsed the findings of the NCRIS Taskforce and agreed that major publicly-funded research infrastructure should be priced to maximise utilisation, while avoiding congestion (sub. DR211, attachment A, p. 1). DEST agreed that a key consideration in determining infrastructure investment strategies is 'to ensure that there is optimal utilisation of infrastructure already available' (sub. DR205, p. 4). It noted that:

> … the access policies of the National Collaborative Research Infrastructure Strategy (NCRIS) which emphasise opening up infrastructure to all Australian researchers on the basis of merit, will promote the best utilisation of NCRIS infrastructure investments and enable fixed capital costs to be spread across the largest possible user bases. (sub. DR205, p. 4)

Furthermore, DEST noted that a priority area for funding under NCRIS — Platforms for Collaboration — would play 'a central role in promoting access to and utilisation of research data, facilitating information flows throughout Australia's science and innovation system' (sub. DR205, p. 4). The key elements of Platforms for Collaboration are data storage management, access, discovery and curation; high-performance computing; grid-enabled technologies and infrastructure; network access through high capacity bandwidth; and support skills to assist researchers in developing and using infrastructure.

The Commission notes that NCRIS itself has the potential to promote effective utilisation of the new research infrastructure that it funds. That said, there is scope for extending the National Research Infrastructure Taskforce recommended access charging approach more broadly to new and major infrastructure funded under other programs as well as to existing major infrastructure.

Payments by users for accessing research infrastructure could be recovered from research funding (such as discussed earlier in relation to ongoing costs) and, indeed, was recommended by the National Research Infrastructure Taskforce (DEST 2004e, p. 32).

University research infrastructure

Although agreeing that access charging has the potential to promote efficient investment signals and capacity utilisation, some participants argued that a greater issue was whether existing infrastructure capacity, particularly in the university sector, was sufficient or of a quality 'to meet Australia's needs' (for example, DEST sub. DR205, p. 5).

Two particular streams of concern relate to the slow pace of infrastructure funding relative to other funding and the high level of deferred maintenance.

The universities expressed concerns that the funding of their research infrastructure was not keeping pace with research funding. For example, the AVCC noted that:

> …ARC funding more than doubled from 2000-01 to 2005-06 (an increase of 120%). NHMRC funding has increased by 38% since 2003 over this period. Infrastructure funding has not kept pace with increases in project grant funding.
>
> The role of infrastructure in the innovation system cannot be overstated: without sufficient research infrastructure there cannot be an innovative research system. As infrastructure funding through the [Research Infrastructure Block Grants Scheme] falls behind project grant funding, universities are forced to adapt to acquire sufficient project funding to maintain research projects. However, this necessarily results in the shift of funds away from support of research infrastructure, which will, in the long-term, damage the capacity of universities for innovative research. (sub. DR148, p. 4)

Both the AVCC and the Group of Eight recommended that infrastructure funding to universities be increased (AVCC sub. DR148, p. 4 and Group of Eight sub. DR158, p. 4). However, the Association of Australian Medical Research Institutes said that while it supported the universities' 'need for proper and appropriate funding', this should not be 'at a cost to productive research bodies such as medical research institutes' (sub. DR162, p. 1).

It may be misleading to compare research infrastructure funding with research funding as the two are not distinct funding streams. For example, funding under the Research Infrastructure Block Grants Scheme is determined directly in relation to competitive grants income. As DEST observed:

> A [higher education provider's] RIBG amount is determined on the basis of its relative success in attracting research income from competitive funding schemes listed on the Australian Competitive Grants Register (sub. 87, p. 26).

DEST expressed concerns about the high level of 'deferred maintenance' (sub. DR205, p. 5). This is the 'value placed upon the expense of remedying the backlog of maintenance on capital assets' (DEST 2006f, p. 8). DEST estimated that deferred maintenance for 2005 was $1.5 billion:

> While reporting mechanisms prevent a detailed analysis of maintenance requirements on individual areas, as science-related facilities, case studies can give a sense of the problem. For example, work undertaken by the Australian National University … to assess the condition of laboratory facilities at its main campus indicated high levels of deferred maintenance on science facilities. The condition audit, performed by consultant architects, identified that the construction costs of eliminating the deferred maintenance to existing laboratories and associated facilities was of the order of $165 million. (sub. DR205, p. 5)

DEST noted that such high levels of deferred maintenance increased pressure on current funding mechanisms such as evident in the 2006 round of Capital Development Pool funding where:

> … universities submitted applications for 114 projects totalling $528.8 million for available funding of $93.8 million. Of these 114 projects, 75 related to science, engineering or health sciences infrastructure and totalled over $378 million. (sub. DR205, p. 5)

High levels of deferred maintenance could reflect a range of factors including: historical levels of, and trends in, discretionary versus competitive funding; decisions made by universities in allocating discretionary funds to infrastructure compared with other cost areas; and increasing (technology-related) costs of university buildings, plant and equipment.

However, the scale of the problem may be affected by measurement issues. The DEST estimate of deferred maintenance, as it acknowledged in its submission, is not audited. It is based on amounts reported by institutions, which may use different estimation methods.

Even if the scale of the problem of deferred maintenance can be satisfactorily measured, the appropriate policy response is not straightforward. An increase in the absolute level of Government funding to university infrastructure is only one of the possible options, and it would clearly need to be tested against other areas of Government spending.

Further discussion about the funding of university infrastructure, including the appropriate balance between discretionary and competitive funding, is taken up in chapter 12.

Inconsistencies in public support for different institutions

Another concern expressed by participants was inconsistencies in the way in which research infrastructure is publicly provided and funded for different institutions. Funding or support is provided to:

- universities such as through DEST's Research Infrastructure Block Grants program, the ARC's Linkage Infrastructure Equipment and Facilities program and the Institutional Grants Scheme (appendix O);
- public sector research agencies under their block funding arrangements;
- health and medical research institutes under Australian Government research infrastructure programs such as the Department of Health and Ageing's Medical Research Infrastructure Projects, NHMRC programs such as the Independent Research Institutes Infrastructure Support Scheme as well as from the States and Territories (appendix O); and
- CRCs from the States and Territories (treated as 'in-kind' contributions under the Australian Government's CRC program).

The differential treatment of research institutions such as universities and medical research institutes was a particular concern for some participants. The Association of Australian Medical Research Institutes noted that the various infrastructure support schemes available in the higher education sector are not open to medical research institutes, although some institutes do receive some support through their association with a university (sub. DR162, p. 1). However, the Association noted that when infrastructure funding is paid through an intermediary; the organisations at the 'lower end of the feeding chain' do not have their actual costs met. The Walter and Eliza Hall Institute of Medical Research was of the view that:

> … medical research institutes can access only partial contributions to infrastructure. Given the current level of Federal and State Government contributions, we estimate that medical institutes must secure an additional 40 cents in every dollar to cover overheads. This gap is much greater than that experienced by universities and CSIRO, and presents a strong competitive handicap for Australia's medical research institutes. (sub. DR159, p. 2)

Whether the gap between medical research institutes and these other research institutions is as large as the Institute contends is questionable. As noted earlier, universities have expressed concerns about underfunding of their infrastructure and

CSIRO raised 37 per cent of its income from external sources (table 11. 2 in chapter 11).

The implementation of NCRIS (box 5.5) will help to coordinate the funding and provision of large and systemic infrastructure across institutions as well as across jurisdictions. Incorporating the recommended charging approach of the National Research Infrastructure Taskforce to research infrastructure funding would also help to reduce inconsistencies.

Knowledge about the stock of research infrastructure

According to the Western Australian Department of Industry and Resources, there is a lack of knowledge about the current stock of research infrastructure. This extends to what infrastructure exists, where it is kept, its operational state, its current rate of utilisation, and its accessibility. The Department called for a 'national audit of R&D and innovation infrastructure' (sub. 82, p. 5). The Australian Industry Group saw 'significant benefit' in such a 'stocktake' (sub. DR121, p. 8).

A lack of knowledge makes it difficult for potential users to access suitable research infrastructure, thereby exacerbating any problem of under-utilisation of existing capacity. Moreover, it affects the ability of governments to provide effective public support for new infrastructure.

A national audit may help to overcome any such problems. By identifying existing capacity, it could enhance utilisation as well as improve the effectiveness of public support for new infrastructure. As Hϕj et al. (2004) noted:

> Such knowledge would point researcher X in the right direction and assist funding agencies make decisions about the merits of applications as well as assessing the opportunity for transfer of equipment from location A to B or simply grant researcher X at location B access to the required equipment at location A. (p. 3)

However, care would be required to ensure that the national audit is not needlessly costly. It would thus need to build on existing information to hand by universities and publicly-funded research agencies. A coordinating Government agency such as DEST could conduct the audit as well as maintain and determine access to the resulting database.

5.5 Privacy regulation

Privacy regulation generally involves limits or conditions on the collection, storage, access, use and disclosure of personal information. The main source of regulation is the Australian Government's *Privacy Act 1988* (hereafter referred to as the Privacy

Act) (appendix P). Some States and Territories also have privacy legislation that either apply generally to personal information or specifically to health information (appendix Q). Under the Constitution, Commonwealth legislation prevails over State or Territory legislation to the extent that these laws are inconsistent. In addition to privacy legislation, there are privacy, confidentiality and/or secrecy obligations embedded in other legislation — such as in freedom of information legislation, telecommunications interception legislation, and ‘spent’ (or previous) convictions legislation — as well as under common law and industry codes.

While not disputing the objective of privacy regulation, the NHMRC raised concerns about its impact on the conduct of medical research. The main concern was complexity stemming from both the intersection of Australian Government and State and Territory privacy legislation applying to health information and medical research as well as from different provisions under the Privacy Act applying to the public and private sectors. The NHMRC said:

> The privacy regulation framework is a complex patchwork of Commonwealth and State/Territory legislation, administrative decisions and codes of conduct which can hamper health and medical research as it has the potential to act as a barrier to the exchange of information. (sub. 80, p. 15)

The NHMRC considered it ‘essential that Australia has a single, simplified, privacy regime’ (sub. DR. 165, p. 6)

In addition, there were concerns about the obligations placed on human research ethics committees under the Privacy Act to weigh the balance of the public interest in the protection of privacy against the public interest in research as well as reporting obligations. These concerns are explored later in relation to the ethical review of health and medical research.

Specific adverse impacts of privacy regulation on medical research were said to (among other things):

- unduly hamper the ability of agencies or organisations that hold personal or health information to make effective decisions about using or disclosing that information for research;
- unnecessarily increase the administrative/compliance burden on researchers, particularly if data are required from multiple jurisdictions, thereby reducing the amount of public funds directed to actual research and/or preventing certain types of research from occurring;
- restrict the ability of researchers to obtain a more randomly selected and/or larger sample, thereby adding to standards of error in sample estimates; and

- unduly restrict the ability of researchers to undertake data linkage or matching (NHMRC 2004b, 2005d).

Some examples of these impacts are given in box 5.6.

Box 5.6 **Examples of how privacy regulation affects medical research**

Added compliance costs for researchers

A primary health care research evaluation and development research fellowship in the University of Melbourne undertook research which involved mailing a survey to Victorian general practitioners (GPs). The Health Insurance Commission (HIC), an Australian Government public sector agency that collects GP data, provides representative datasets of randomly-selected GPs. To maintain anonymity of potential respondents for this particular research, the HIC required that research materials (for example, surveys and plain language statements) be forwarded to it, from where they are remailed to respondents. The HIC further required that: research materials need to be approved (and altered if required) by its privacy department, despite prior approval from a university ethics committee; there be a limit of two reminder mail-outs (whereas usual protocols for maximising response rates require up to four mail outs); and each mail out be sent with the same HIC covering letter. Additional HIC requirements involved sending envelopes, surveys and plain language statements in bulk to Canberra (numerous times); printing HIC covering letters; and charges for ‘preparing business rules, extraction specifications, project manage processes to completion …’. These requirements, imposed by the HIC to comply with the Privacy Act, increased costs (including adding four weeks in compliance time).

Smaller sample populations

The Vaccine and Immunisation Research Group within the University of Melbourne conducts community-based vaccine trials. It attempted to use school enrolment lists to mail information to parents about a study. Despite approval from the Royal Children’s Hospital human research ethics committee, one major governing body of Victorian public schools rejected the proposal on privacy grounds, as did several independent schools. The main concern expressed was that the use of this information for health research was not related to the primary purposes of collection, and families had not consented to this use. Only a small number of schools raised no privacy concerns at all. The Group claimed that the net result was substantially reduced access to the population eligible for recruitment.

Sources: Brice and Priotta (2006); O’Grady and Nolan (2004).

In countering these concerns, particularly in relation to medical research, the Australian Government Office of the Privacy Commissioner considered that strong privacy provisions are essential for sustaining the community confidence needed to make medical research viable. Referring to the Privacy Act, for which it had administrative responsibility, the Office said:

> The Privacy Act, by placing controls on the flow of health information, provides a structure to support individual's confidence in how their information will be handled. Far from obstructing research, the Privacy Act provides a valuable control on the flow of information, helping to support its long-term viability. (sub. 63, pp. 7–8)

In support of this view, the Office referred to research that it and others had conducted, which showed that many individuals were sensitive about the use of their health information. Of its own research, it noted that:

- 21 per cent of respondents reported a reluctance to provide their medical history or health information to any organisation and 11 per cent reported a reluctance to provide genetic information; and
- 64 per cent of respondents considered that their permission should be sought before de-identified information is used for health research purposes.

Recent government reviews (such as that by the Senate Legal and Constitutional References Committee in 2005 on the Privacy Act, the Office of the Privacy Commissioner in 2004 on private sector provisions of the Privacy Act, and the Australian Law Reform Commission in 2003 on human genetic information) have made recommendations to improve the application of privacy regulation, including to health information and medical research (appendix P). A number of the recommendations have focused on improving national consistency in privacy regulation overall, improving consistency between public and private sectors, and removing significant barriers to the conduct of medical research.

In the course of making these recommendations, the reviews examined specific options including:

- a national privacy regime governing health information and medical research alone that could involve:
  - the adoption by governments of template legislation (such as the draft National Health Privacy Code prepared for the Australian Health Ministers' Advisory Council — box 5.7); or
  - the Australian Government enacting a single piece of legislation with national effect under a constitutional head of power; or

Box 5.7 **Draft National Health Privacy Code**

The draft Code was first prepared in 2002 by a working group of the Australian Health Ministers' Advisory Council (that in turn reports to the Australian Health Ministers' Conference). Among other things, the Code seeks to achieve national consistency in the handling of health information between the public and private sectors. A revised version of the Code, draft mandatory guidelines for research, and draft explanatory notes for the use or disclosure of genetic information were considered by Health Ministers in late 2004. However, since then, no further progress in implementation has been made.

- specific changes within the Privacy Act including:
  - combining the information privacy principles and national privacy principles into a single set of privacy principles that apply to all relevant public sector agencies and private sector organisations;
  - removing distinctions between different types of research;
  - clarifying what is meant by 'impracticality of consent';
  - providing for a single set of guidelines that apply to the collection, use and disclosure of health information without consent for the specific purpose of medical research by public sector agencies and private sector organisations; and
  - simplifying the reporting arrangements applying to human research ethics committees.

Assessing such options for changing privacy regulation requires that account be taken of several factors. One is ensuring that the balance between protecting individual privacy — which is the primary purpose of the regulation — and using personal information for the benefit of others, including medical research, is appropriate.

A second factor is the wide reach of privacy regulation. The Privacy Act, for example, extends to a wide range of activities beyond health information and medical research, such as consumer credit reporting, the administration of personal tax file numbers, law enforcement, and information sharing during overseas emergency situations. Care is needed, therefore, that any specific options under the Act relating to health information and medical research do not perversely affect other areas of the Act.

A final factor to take account of is the constitutional division of powers, with the States and Territories primarily responsible for health matters. Any options involving national consistency in the application of privacy regulation to health information and medical research are likely to involve complex negotiations between the Australian Government and the States and Territories regarding implementation. This would be the case whether negotiations concerned the adoption of template legislation or the referral of power to the Australian Government to enact uniform legislation.

It is anticipated that options for changing privacy regulation, and the concerns driving them, will be comprehensively considered by the Australian Law Reform Commission in its current review of the Privacy Act (for example, see its recently released issues paper — ALRC 2006). The terms of reference require it to address, among other things, Australian Government, State and Territory practices, the need of individuals for privacy protection in an 'evolving' technological environment, and the desirability of minimising regulatory burden on business. It is expected to report in March 2008.

In the meantime, there would be merit in governments, through the Australian Health Ministers' Conference, progressing national consistency in privacy regulation governing health information as a matter of priority. It would help reduce complexity and thus mitigate adverse impacts on health and medical research. Nationally consistent provisions should seek to be as cost-effective as possible.

5.6 Ethical review of health and medical research

A framework of research governance, including ethical review, is one in which 'institutions are accountable for the scientific quality, ethical acceptability and safety of the research they sponsor or permit' (Walsh et al. 2005, p. 468). In Australia, it consists primarily of a series of NHMRC guidelines issued under the *NHMRC Act 1992,* where compliance is a condition for research funding (NHMRC 2000, 2001). In addition, there are legislation, other guidelines and codes of conduct relating to such matters as privacy, confidentiality, consent, biosafety, professional standards and radiation safety.

The key NHMRC guidelines are the National Statement on Ethical Conduct in Research Involving Humans (the National Statement) — a central feature of which are provisions requiring the establishment of human research ethics committees (HRECs) (box 5.8) — and the Joint NHMRC and AVCC Statement and Guidelines on Research Practice (the Joint Statement) (box 5.9). Both are under review by the NHMRC, the AVCC and the ARC with consultation drafts released (NHMRC 2005e, 2007). The joint nature of these reviews implies that the guidelines will eventually cover a much wider field than just health and medical research. Participant concerns have been expressed about ethical review processes particularly in relation to clinical trials. Research Australia, for example, was of the view that complex ethical approvals processes were hampering such trials (sub. 33, p. 5). Many of the concerns of its members related to the performance of individual

HRECs as well as to difficulties in obtaining ethical approval for multi-centre research (sub. 102).

Box 5.8 National Statement on Ethical Conduct in Research

The National Statement seeks primarily to protect the 'welfare and rights of participants in research'. It sets out:

- principles of ethical conduct that institutions and researchers must have towards participants of research. These principles reflect basic ethical values of integrity, respect for persons, beneficence and justice. These are incorporated in provisions on consent, research merit and safety, as well as ethical review and conduct of research;
- provisions relating to the establishment and role of human research ethics committees (HRECs).
- provisions relating to different types of research such as multi-centre research; research involving particular types or groups of people (such as children and young people, persons with an intellectual or mental impairment; and Aboriginal and Torres Strait Islander peoples); research involving the use of particular technologies (ionising radiation and assisted reproductive technology); clinical trials; innovative therapy or intervention; epidemiological research; the use of human tissue samples; human genetic research; and privacy.

Source: NHMRC (1999); Walsh et al. (2005).

Box 5.9 Joint NHMRC and AVCC Statement and Guidelines on Research Practice

The Joint Statement seeks to ensure the quality and integrity of research such as to maintain the community's confidence in the research findings, the reputation of researchers and research institutions, and the safety of all those associated with the research.

It sets out a number of general principles as well as specific provisions covering such matters as data storage and retention, authorship, publication, supervision of students and research trainees, conflicts of interest and research misconduct.

The general principles are that:

- Institutions must establish procedures and guidelines on 'good research practice' and on steps to be followed if suspicions or allegations exist regarding research misconduct.
- Institutions must establish and maintain practices and policies that promote the 'highest possible' standards and discourage misconduct and fraud. These policies should encourage the open presentation and discussion of results via peer review.

(Continued next page)

Box 5.9 **(continued)**

- Institutions must have 'clearly formulated' policies on the maintenance of records, retention of data, publications and authorship, management of intellectual property, research training (where appropriate), confidentiality and conflict of interest.
- Researchers have an obligation to achieve and maintain the 'highest' standard of intellectual honesty in the conduct of their research.
- Researchers must be aware of and adhere to ethical principles of justice and veracity and of respect for people and their privacy and avoidance of harm to them, as well as respect for non-human subjects of research.
- Where research procedures are of a kind requiring approval by a human or animal experimentation ethics committee, or by other safety or validly constituted regulatory committees, research must not proceed without such approval.
- Institutions should ensure that a person with appropriate authority is responsible for monitoring the observance of the guidelines.

Source: NHMRC and AVCC (1997).

The performance of HRECs

The National Statement sets out provisions for the establishment and role of HRECs. A central provision is that research proposals must be reviewed and approved by HRECs, which are established by institutions to provide advice regarding ethical approval of research projects. Other provisions go to such matters as the composition of an HREC, appointment of members, working procedures, recording of decisions, monitoring, complaints mechanisms, and compliance reporting to the NHMRC. There are over 200 HRECs of which about 60 per cent are in health care institutions. Membership is by volunteers drawn from the community or research institution.

Participant concerns about the performance of individual HRECs largely focused on the delays experienced in obtaining ethical approval. A study sponsored by Merck, Sharp and Dohme (Australia) found that the average HREC approval cycle time in Australia based on a review of 18 protocols was 78 days compared with 44 days in New Zealand (sub. 102, p. 3). Dr Maccarrone of GlaxoSmithKline noted various following instances of delays:

- One study with a diabetes drug took over eight months to gain approval at one centre in contrast to best practice of two months.
- One study in a hospital took six months to be cleared by the hospital's legal advisors (which had nothing to do with the science or ethics of the clinical trial).

- An Alzhiemer's disease study at a hospital [was being] delayed by a further two/three months due to relocation of the ethics committee office.
- A study in overactive bladder disease in women [was] still awaiting approval after eight months. (sub. 102, p. 5)

Factors affecting the speed in which HRECs are able to make decisions were said to include:

- slow HREC administrative processes;
- required 'sign offs' from other departments in an institution (for example, pathology, radiology and pharmacy departments in a hospital);
- referral of contracts and indemnity agreements to lawyers with little experience of clinical trials; and
- the need to resolve issues arising from the content of patient information and consent forms (such as patient compensation, privacy and risk) (for example, Dr Bootes of Roche Products, Merck Sharp and Dohme (Australia), Dr Davies of George Institute, and Prof. Horne of Howard Florey Institute sub. 102).

In addition, concerns were expressed about the burden placed on researchers in making submissions to HRECs including the 'cumbersome and lengthy ethics submission forms' (for example, Dr Bootes of Roche Products sub. 102, p. 5).

The approach that some institutions take to establishing and resourcing their HRECs can prevent them from performing their role effectively. For example, Walsh et al. (2005, p. 469) reported that:

- HRECs are overloaded, under-resourced and insufficiently skilled;
- HRECs are lacking in accountability and transparency;
- HRECs' capacity to monitor research is minimal;
- most institutions provide minimal orientation or training for new HREC members; and
- many institutions have come to rely too heavily on HRECs to do tasks beyond ethical review for which they are not well equipped.

Poor performance by HRECs in undertaking ethical review can undermine the primary objectives of the NHMRC's guidelines. Moreover, it can impede the way in which research involving humans proceeds.

Some options for improving upon the current research governance framework, including improving the performance of HRECs, were put forward in an NHMRC discussion paper (2005b):

- promoting a wider appreciation and understanding amongst institutions and researchers of the existing research governance framework;
- embodying the current obligation on institutions to comply with the National Statement on Ethical Conduct in a deed of agreement (or memorandum of understanding);
- basing the reporting or auditing process around the entire institution and not just on HRECs;
- using the deed of agreement as a 'pathway for assuring sensible provisions' for the review of multi-centre research proposals;
- being proactive in setting standards, encouraging the development of educational services and providing education on research ethics and methods for researchers and for HREC members; and
- fostering openness of HRECs by permitting observers (pp. 16–7).

The current joint reviews of the NHMRC guidelines present a good opportunity to consider these options further.

Multi-centre research

The National Statement contains provisions relating to the ethical review of multi-centre research (that includes a research project conducted at more than one institution such as a clinical drug trial) with a view to minimising 'unnecessary duplication' and facilitating 'prompt and efficient consideration'. It encourages HRECs to ascertain whether the same research proposal has been reviewed by another HREC, including reviews conducted overseas. In particular, an HREC may:

- communicate with, and give advice to or receive advice from, any other HREC;
- accept a scientific/technical assessment of the research by another institution or organisation;
- review and, where the same research project is conducted at two or more institutions or organisations, adopt the reasons for ethical approval or disapproval of another HREC in reaching its own decision; or
- adopt other administrative procedures to accelerate timely consideration and avoid unnecessary duplication.

In practice, however, the National Statement's provisions have not been as effectively implemented by institutions and HRECs as initially intended. The Victorian Government noted that 'multi-site trials' face a 'slow and complex' ethical review and approval process, involving several HRECs (sub. 84, p. 57). Also Dr Maccarrone of GlaxoSmithKline noted that:

> The current ethical review process for multi-centre trials can be slow, resource intensive (both internally and externally), inefficient and costly. There is a wide range of variance in speed (and quality) of review of clinical trials by ethics committees. The duplication of effort (wastage) is also considerable. Administrative issues and resourcing are often the reason for delay; and not questions related to the scientific and ethical appropriateness of multi-centre trials. (sub. 102, p. 4)

Box 5.10 provides an example of the challenges faced by researchers in obtaining ethical approval of a multi-centre project.

Box 5.10 **An example of the problems of obtaining ethical approval of a multi-centre project**

A multi-centre project in New South Wales was being conducted on the outcomes of hypertensive pregnancies in a cohort of 1620 women. The project was to be a retrospective review of medical records and did not require the participation of the women. Ethics approval was sought and gained from the New South Wales Department and one other area health service involved in the study. The bulk of the medical records (85 per cent) were held by this area health service and a smaller proportion by eight others. The process of gaining ethics approval from the eight area health services was 'fraught with obstacles' at every stage. After eight months' work, approval was finally received from the HREC of each area health service. The table illustrates differences between the area health services in their approach to considering the project.

	Area health service							
	S	*T*	*U*	*V*	*W*	*X*	*Y*	*Z*
No. of pages of application form	19	20	19	20	12	23	2	11
No. of copies of form required	1	1	17	15	20	16	1	14
No. of hospitals in area health service covered by approval	2	2	4	1	3	5	3	5
Whether approval covered private hospitals	na	na	Yes	No	No	na	No	na
No. of contacts (letter, email, phone) made to gain approval	20	15	20	15	20	30	10	20
Time taken to gain approval	3 mths	5 mths	4.5 mths	8 wks	6 wks	6 wks	1 wk	3 wks
Approved after first submission	Yes	No	No	Yes	Yes	Yes	Yes	Yes

na not applicable

Source: Roberts et al. (2004).

The issue of streamlining ethical review of multi-centre research has been under consideration by governments, agencies and institutions for some time.

Some State and Territory health agencies, notably in New South Wales, Victoria and Queensland, have examined the scope for streamlining their ethical review processes. In New South Wales, for example, a model of single ethical review is being considered by NSW Health whereby a multi-centre research project is reviewed by a lead HREC, representing existing HRECs, which is then recognised throughout NSW Health. The Victorian Government said that it has championed the development of streamlined approval processes from multi-centre trials for 'some time, but noted 'numerous barriers' including that of funding for the governance of such arrangements (sub. DR211, attachment A, p. 2).

The NHMRC has implemented certain measures including a National Ethics Application Form for use by researchers in submitting research proposals to one or more HREC.

Prof. Rosenthal of the Royal Melbourne Hospital noted that a Mutual Acceptance Program applies to Cancer Trials Australia sites where a standard primary site review is mutually accepted by the HRECs of the other sites (sub. 102, p. 8).

After considering the issue since 2005, the Australian Health Ministers' Advisory Council agreed in October 2006 to establish a nationally-harmonised system of scientific and ethics review of multi-centre health and medical research. The system will be based on mutual recognition by all jurisdictions of the single review undertaken by recognised HRECs in any jurisdiction. The national coordinating body will be the NHMRC (sub. DR165, p.6).

Although the application of such a national approach is not without difficulties (for example, it has been suggested that mutual recognition of ethical approval may make it difficult for some institutions to obtain insurance and medical indemnity for clinical trials), if cost-effectively implemented, it should help to reduce the compliance costs of researchers seeking ethical review for multi-centre research across jurisdictions.

5.7 Access to the results of publicly-funded research

There has been considerable interest in recent years, internationally and in Australia, amongst government agencies, universities and other organisations, in 'open access' to the results of publicly-funded research, including data and research papers. This has been prompted, in part, by dramatic changes to ICT including the use of the Internet over the last decade. The issue of open access overlaps with that of open source discussed earlier in relation to IP rights. In simple terms, open access means lawful and free access to material (usually through the Internet), without the need to gain any further permission from the copyright owner (Fitzgerald 2007).

There are various means in which open access to the results of publicly-funded research can be achieved. Open access could involve a research paper being deposited in an institutional or disciplinary digital repository or published in an open access journal (that may involve a formal refereeing process). Some variants of publishing in an open access journal include making:

- all of a journal freely available immediately on publication;
- an article in a journal immediately available by:
  - requiring a subscription to access other 'value added' content such as commissioned review articles, journalism and so forth; or
  - offering authors the option of making their article openly accessible in an otherwise subscription-access journal in return for payment of a fee; and
- all of a journal freely available after a period of time (for example, see Mark Ware Consulting 2006, pp. 16–7; Fitzgerald et al. 2006, p. 113).

The OECD Committee for Science and Technology Policy adopted a Declaration on Access to Research Data from Public Funding in January 2004, which sets out members' commitment to the establishment of open access regimes for digital research data from public funding in accordance with specific objectives and principles such as openness, transparency, legal conformity and the like. A working group has since been exploring commonly agreed principles and guidelines.

The Australian Government has sought to enhance access to the results of publicly-funded research through the:

- development of an Accessibility Framework for Publicly Funded Research (box 5.11);
- allocation of funding under the Systemic Infrastructure Initiative to build technical information infrastructure that supports the creation, dissemination of and access to knowledge, and the use of digital assets and their management (box 5.11); and
- allocation of funding under the NCRIS for such capabilities as platforms for collaboration and population health and clinical data linkage.

These actions have focused on the creation of repositories into which authors can deposit copies of the research they have already published (often in traditional, subscription-only journals).

Box 5.11 Some Australian Government actions to enhance access to the results of publicly-funded research

Accessibility Framework

One aspect of Backing Australia's Ability — Building our Future through Science and Innovation — announced in May 2004 is the establishment of Quality and Accessibility Frameworks for Publicly Funded Research. (The Research Quality Framework has been considered elsewhere in this study.)

The Accessibility Framework will be an agreed system-wide approach for managing research outputs and infrastructure so that 'they are discoverable, accessible and shareable', in order to improve the quality of research outcomes, reduce duplication and better manage research activities and reporting. It is currently being developed by DEST in consultation with universities and publicly-funded research agencies.

Issues that the Framework is seeking to address include:

- common standards and protocols for storing, curating, cataloguing and disseminating information;
- technology infrastructure capable of supporting rapid access to information and facilities; and
- a regulatory environment that both enables and encourages the population of repositories and information sharing.

Systemic Infrastructure Initiative projects

The Australian Government has given $12 million in funding to universities and institutes — under the Backing Australia's Ability, An Innovation Action Plan for the Future 2001 — for projects to build technical information infrastructure that supports the creation of, dissemination of, and access to, knowledge, and the use of digital assets and their management.

Four major projects are the:

- Australian Partnership for Sustainable Repositories, which establishes a centre of excellence for the management of digital collections;
- Australian Digital Thesis Program Expansion and Redevelopment, which creates a national collaborative distributed database of digitised theses produced at Australian universities;
- Meta Access Management System, which supports the development of prototype middleware/common technical services to enhance national research effectiveness; and
- Australian Research Repositories Online to the World, which identifies and tests software solutions to support best practice institutional digital repositories comprising e-prints, digital theses and electronic publishing.

Source: DEST (2006a).

There have been several recent reports to the Australian Government that are relevant to enhancing access to the results of publicly-funded research.

- A report to PMSEIC (Working Group on Data for Science 2006) considered issues relating to access to, and management of, scientific data. Its recommendations cover a national strategic framework for scientific data, a national network of digital repositories, as well as data management, access, sharing and collaboration (box 5.12). The recommendations are relevant to governments at all levels, government agencies that fund or produce data, as well as scientists and researchers in universities, institutions and centres.

Box 5.12 **Recommendations of the PMSEIC Working Group on Data for Science**

Among the working group's recommendations are that:

- Australia's government, science, research and business communities establish a nationally supported long-term strategic framework for scientific data management, including guiding principles, policies, best practices and infrastructure;
- the necessary policy and programmes be implemented with a view to establishing a sustainable publicly-funded national network of 'federated' digital repositories;
- the principle of open equitable access to publicly-funded scientific data be adopted wherever possible and that this principle be taken into consideration in the development of data for science policy and programmes. As part of this strategy, and to enable current and future data and information resources to be shared, mechanisms to enable the discovery of, and access to, data and information resources must be encouraged; and
- funding agencies offer incentives to encourage researchers and institutions to:
  - develop data management plans for each research grant application involving data collection and generation, and that standards be made freely available and widely disseminated so as to encourage best practice in data management;
  - introduce policies and practices to encourage collaboration and sharing of data across Australia's scientific research institutions and across agencies; and
  - analyse and re-use existing data.

Source: Working Group on Data for Science (2006, pp. 11–2).

- Houghton et al. (2006) estimated net gains from improving access to publicly-funded research across the board and in particular research sectors. The estimated benefits from an assumed five per cent increase in access and efficiency and level of social rate of return were between $2 million (ARC competitively-funded research) and $628 million (gross expenditure on R&D). Assuming a move from this level of improved access and efficiency to a national system of institutional repositories in Australia over twenty years, the estimated benefit–cost ratios ranged from between 3.1: 1 (for NHMRC-funded research) to 214:1 (for gross expenditure on R&D). Houghton et al. suggested a range of measures to improve access to publicly-funded research (box 5.13).

- The Open Access to Knowledge (OAK) Law Project, funded by DEST, provided an overview of copyright law, open access to knowledge, and open content models of copyright licensing (Fitzgerald et al. 2006). It proposed a framework for enhancing the management of copyright interests in research and academic output (including electronic theses and dissertations). Its forward work program includes developing template guidelines for open access policies that can be adopted within university and research institutions, and developing model publishing agreements and model agreements to assist the copyright management of open access repositories.

Box 5.13 **Suggestions by Houghton et al. for improving access**

In their recent report to DEST, Houghton et al. (2006) made a number of suggestions to improve access to and dissemination of research including:

- developing a national system of institutional or enterprise-based repositories to support new modes of enquiry and research;
- encouraging higher education and research institutions to develop enterprise-wide digital repositories for the storage, preservation, curation, access, registration and management of their intellectual property;
- ensuring that the Research Quality Framework supports and encourages the development of new, more open scholarly communication mechanisms, rather than encouraging ‘a retreat’ by researchers to conventional publication forms and media, and a reliance by evaluators upon traditional publication metrics (for example, by ensuring dissemination and impact are an integral part of evaluation);
- encouraging funding agencies (for example, ARC and NHMRC) to mandate that the results of their supported research be made available in open access archives and repositories;
- encouraging universities and research institutions to support the development of new, more open scholarly communication mechanisms, through, for example, the development of ‘hard or soft open access’ mandates for their supported research; and
- providing support for a structured advocacy program to raise awareness and inform all stakeholders about the potential benefits of more open scholarly communication alternatives, and provide leadership in such areas as copyright (for example, by encouraging use of ‘creative commons’ licensing). (pp. xii–xiii)

Making the results of publicly-funded research accessible raises a range of issues. For example, the OAK Law Project noted:

> In establishing the legal framework for a system of open access to academic and research materials, it is necessary to:
>
> - determine the degree of 'openness' required in relation to those materials;
> - understand the roles of, and relationships among, the relevant parties involved in funding, creating, publishing, distributing and using academic and research materials; and
> - consider how best to manage the often complex inter-relationships among the various parties, especially with respect to their copyright interests in the materials, so that the relationships and copyright interests can be effectively managed to achieve the desired degree of open access in the system. (Fitzgerald et al. 2006, p. 113)

The remainder of this section focuses on just two specific, but related, areas for further action by government agencies in promoting access to the results of publicly-funded research. The discussion develops a broad course of action, recognising that implementation issues such as data confidentiality, copyright issues and any undue compliance burden would need to be carefully assessed and determined by the relevant agencies.

The scope for funding agencies to promote access

Of relevance is whether funding agencies themselves could become more actively involved in enhancing access to the results of the research they fund. A rationale for them to do so is that publicly-funded researchers, if left to themselves, would have little incentive to make the results of their research publicly available, such as in an 'open access' journal (these are typically peer-reviewed journals that are freely available online but whose costs are met by authors rather than subscribers). For example, researchers may prefer to publish through more costly and, thus, less accessible journals because they:

- generally do not bear the costs directly — subscribers do; and
- consider that their reputation and, thus, the citation impact of their research and the chance of future funding success would be enhanced.

Until recently, neither of the Australian Government's key funding agencies, the ARC and the NHMRC, required the publicly availability of research results. In January 2007, both agencies issued a joint statement in January 2007 encouraging researchers to make the results of research they fund 'publicly available, whenever possible and appropriate' (ARC 2007). The ARC has included new provisions on the dissemination of research outputs in its discovery projects funding rules for funding commencing in 2008 (box 5.14). The ARC expects that similar provisions will be approved for incorporation into revisions of its funding rules for other programs (sub. DR167, p. 4). As the ARC noted, this policy ‘encourages, rather than mandates, the publication of research papers and data in an appropriate, publicly accessible repository’ (sub. DR167, p. 4).

Box 5.14 **ARC discovery projects funding rule on dissemination of research outputs for funding commencing in 2008**

1.4.5.1 The Australian Government makes a major investment in research to support its essential role in improving the wellbeing of our society. To maximise the benefits from research, findings need to be disseminated as broadly as possible to allow access by other researchers and the wider community.

1.4.5.2 The ARC acknowledges that researchers take into account a wide range of factors in deciding on the best outlets for publications arising from their research. Such considerations include the status and reputation of a journal or publisher, the peer review process of evaluating their research outputs, access by other stakeholders to their work, the likely impact of their work on users of research and the further dissemination and production of knowledge. Taking heed of these considerations, the ARC wants to ensure the widest possible dissemination of the research supported under its funding, in the most effective manner and at the earliest opportunity.

1.4.5.3 The ARC therefore encourages researchers to consider the benefits of depositing their data and any publications arising from a research project in an appropriate subject and/or institutional repository wherever such a repository is available to the researcher(s). If a researcher is not intending to deposit the data from a project in a repository within a six-month period, he/she should include the reasons in the project’s Final Report. Any research outputs that have been or will be deposited in appropriate repositories should be identified in the Final Report.

Source: ARC (2006).

The action of the ARC and the NHMRC is consistent with an international trend. For example, funding agencies in the United States and the United Kingdom have, in recent years, encouraged access to the results of publicly-funded research, although there is variation in approaches.

- The US National Science Foundation makes it a general condition of its grants that the grantee is responsible for ensuring that the relevant program officer is provided access to, either electronically or in paper form, a copy of every publication of material based on or developed under the grant promptly after publication.

- The US National Institutes of Health (NIH) have a Policy on Enhancing Public Access to Archived Publications Resulting from NIH-Funded Research, which took effect in May 2005. The Policy 'requests and strongly encourages' all researchers to make their NIH-funded, peer-reviewed, authors' final manuscript available to other researchers and the public through PubMed Central, which is an open access repository operated by the National Library of Medicine.[5]
- The UK Medical Research Council (MRC) requires from 1 October 2006 that, for new funding grants, any research papers supported in whole or part by MRC funding that have been accepted for publication in a peer-reviewed journal should be deposited in an open access repository — UK PubMedCentral (box 5.15).

Box 5.15 **UK Medical Research Council guidance on open and unrestricted access to published research**

Guidance

- From 1 October 2006, the UK Medical Research Council will require that, for new funding awards, electronic copies of any research papers that have been accepted for publication in a peer-reviewed journal and are supported in whole or in part by MRC funding are deposited at the earliest opportunity — and certainly within six months — in UK PubMed Central.
- This applies to all award holders, including MRC staff.
- Deposition of a research paper into PubMed Central (and other PubMed Central institutional repositories such as the soon to be established UK PubMed Central) does not prevent authors from also depositing a copy in their own institutional or another subject-based repository should they choose to do so or be required to do so by their employing institution.
- The MRC also encourages, but does not formally oblige, all award holders and MRC staff to ensure the deposition of articles arising from grants awarded as a result of applications before 1 October 2006.

(Continued next page)

5 If enacted, the US Federal Research Public Access Act, introduced in the US Senate in May 2006, would require US government agencies with research expenditures totalling more than US $100 million to make journal articles stemming from research financed by federal grants available through the Internet. It would also require the journal articles to be publicly accessible online without charge within six months of their initial publication in a peer-reviewed journal (Fitzgerald et al. 2006, p. 121).

Box 5.15 **(continued)**

- The MRC strongly encourages authors to publish in journals that allow them (or their institutions) to retain ownership of the copyright. Requests for 'author pay' charges associated with publishing may be included in applications for MRC funding.
- If author/institution ownership of copyright is not permitted by the publisher, authors should publish in journals that permit deposition of the published paper in PubMed Central and PubMed Central institutional repositories within six months of publication. If a researcher wishes to publish a paper in a journal that is unwilling to agree either to author/institution-ownership of copyright, or to deposition in PubMed Central and PubMed Central institutional repositories within six months, the MRC may, in very exceptional cases, grant permission for authors to submit the paper for publication in such a journal. This position will be reviewed in 2008. The MRC will work with publishers to put in place mechanisms for publishers to deposit publications directly, on behalf of authors, where this is possible.
- The MRC's grant conditions will be amended to reflect the above changes.
- From 1 January 2006, all applicants submitting funding proposals to the MRC are 'expected' to include a statement explaining their strategy for data preservation and sharing. MRC data sharing policy indicates that, where possible, published results should provide links to the associated data.

UK PubMed Central

Based on PubMed Central in the United States, UK PubMed Central will provide free access to an online digital archive of peer-reviewed research papers in the medical and life sciences. It is being established by a number of UK biomedical funders such as the MRC and Wellcome Trust. It is to be operated jointly by the British Library, the University of Manchester and the European Bioinformatics Institute.

UK PubMed Central comprises three key systems:

- A mirror of the data held in PubMed Central, subject to permission from those publishers that participate in it.
- An author manuscript submission and tracking system, with supporting document conversion services.
- A system to provide authenticated login services to the submission system.

Source: MRC (2006).

In the draft report, and prior to the joint statement of the ARC and NHMRC, the Commission proposed that published papers and data from ARC and NHMRC-funded projects should be freely and publicly available. It commented that, given international precedence, there is scope for the ARC and the NHMRC to play a more active role in promoting accessibility to the results of research they fund, such as through their funding conditions. The Commission noted that, although this would required defining what satisfies accessibility, including identifying suitable open access repositories, identification could link to the work currently done by the Australian Government on the Accessibility Framework and under the Systemic Infrastructure Initiatives.

This proposal prompted considerable participant comment, the essence of which are summarised below.

Participants' comments

The Commission's proposal was broadly supported by a number of participants such as the Council of Australian University Librarians (sub. DR163. p. 1), BioMed Central (sub. DR124, p. 1), the Scholarly Publishing and Academic Resources Coalition (sub. DR149, pp. 1–2), the Group of Eight (sub. DR158, p. 4), the Australian Industry Group (sub. DR121, p. 8), and Prof. Harnad (sub. DR110, p. 1). For example, the Council of Australian University Librarians welcomed the proposal and considered that the infrastructure required to realise it was well-developed, as many university libraries had institutional repositories (sub. DR163, p. 2). Prof. Harnad considered the Commission's proposal would maximise impact on Australian research output and, thereby, on Australian research productivity and progress as well as the return on the Australian taxpayer's investment in research (sub. DR110, p. 1). He also considered the resulting research database could be used to monitor, measure, assess and analyse Australian research productivity and progress in such exercises as the RQF.

Some participants focused on how the Commission's proposal could be implemented — whether through repositories, open access journals or some combination of these approaches as well as whether an author pays approach should apply. For example, the Scholarly Publishing and Academic Resources Coalition (supported by the Council of Australian University Librarians) noted that the voluntary public access policy of the US National Institutes of Health has resulted in a deposit of less than five per cent of eligible articles in their digital repository and that to guarantee a better result Australian open access policies should fall within the following parameters, which include an element of 'author pays':

- Research funders should include in all grants and contracts a provision reserving for the government relevant non-exclusive rights … to research papers and data.
- All peer-reviewed research papers and associated data stemming from public funding should be required to be maintained in stable digital repositories that permit free, timely public access, interoperability with other resources on the Internet, and long-term preservation. Exemptions should be strictly limited and justified.

- Users should be permitted to read, print, search, link to, or crawl these research outputs. In addition, policies that make possible the download and manipulation of text and data by software tools should be considered.
- Deposit of their works in qualified digital archives should be required of all funded investigators, extramural and intramural alike. While this responsibility might be delegated to a journal or other agent, to assure accountability the responsibility should ultimately be that of the funds recipient.
- Public access to research outputs should be provided as early as possible after peer review and acceptance for publication. For research papers, this should be not later than six months after publication in a peer-reviewed journal. This embargo period represents a reasonable, adequate, and fair compromise between the public interest and the needs of journals.

  … as a means of further accelerating innovation, a portion of each grant [should] be earmarked to cover the cost of publishing papers in peer-reviewed open-access journals, if authors so choose. This would provide potential readers with immediate access to results, rather than after an embargo period. (sub. DR149, p. 2)

BioMed Central considered repositories to be only part of the solution to open access:

> It is understandable that traditional publishers do not want to allow the final version of their articles to be made immediately available in repositories since if 100% of published articles were available and findable via open access archives, it would clearly make little sense for libraries to pay subscription fees for access to that research. (sub. DR124, p.1)

And concluded that:

> … at the same time as setting up institutional repositories, Australian research institutions and funders should follow the lead of Wellcome, the NIH, and RCUK, by ensuring that their researchers have funds available to them to allow them to publish in open access journals which charge a fee for publication, rather than forcing them to publish in journals with no fees but which are not fully open access. (sub. DR124, p. 2)

Elsevier Australia took a cautious approach to implementation and recommended:

- against the ARC and the NHRMC funding a network of repositories where authors can archive their manuscripts, because this action may not increase access levels, would decrease researcher productivity, would lower quality, and would be highly expensive;
- that the ARC and NHMRC request, but not require, authors to self-archive their manuscripts, and to make it clear that there would be no penalty for not self-archiving. It also considered a six month time frame to be ‘dangerously’ short; and

- that the ARC and NHMRC work collaboratively with publishers to achieve public access goals to research outputs. They could implement a policy such as that of the Wellcome Trust, which has an agreement with many publishers in which it funded authors to post their manuscripts to PubMed Central within six months of publication by paying a fee to the journal. The Wellcome Trust refunds authors who pay the fee for immediate release of the published journal article to non-subscribers (sub DR157, pp 3-7).

Other participants were critical of the Commission's proposal. For example, the Australian Publishers Association, after noting the broad role of the publishing industry in knowledge dissemination and the services that publishers provide such as peer-review, considered that free availability would affect publishers' incentives and 'effectively undermine and destroy the publishing system and peer review mechanisms that scholarship depends upon' (sub. DR141, pp. 1–2). It suggested other options for promoting dissemination such as:

- encouraging scientific publishers to allow extracts and key words to be made available to search engines and library catalogues so that works can be found with the speed and ease the digital environment allows;
- encouraging a voluntary licensing regime whereby scientific publishers may choose to contribute in open access' repositories as part of their commercial operations; and
- facilitating how libraries, through a licensing arrangement between publishers and libraries, might become the repositories for extract of works to assist dissemination of all Australia research works (sub. DR141, p. 5).

The Walter and Eliza Hall Institute of Medical Research considered the Commission's proposal to be 'expensive and unwarranted' and that publication in peer-reviewed journals was the 'appropriate' way of making data publicly accessible with compliance being assured because, 'without publication, a researcher is unable to secure the next grant' (sub. DR159, p. 4).

DA Information Services noted the 'usual problems' of making publicly-funded research freely available such as the global nature of the market for scientific information, the preference of authors to publish in the 'most famous journal' to further their career, the low take-up rate by authors to commercial publishers offering free access to authors who pay, the problem of quality control in institutional repositories, and the problem of compliance by authors vis a vis institutional repositories. (sub. DR129, pp. 1–2). It suggested such alternatives to open access as:

- reviewing university library purchasing decisions to allow greater access and more creative licensing models;

- 'leveraging' public library infrastructure;
- encouraging companies to invest in information;
- improving the publishers' financial model by asking for royalties from publishers for journals; and
- creating an international uniform system (sub. DR129, pp. 3–4).

The ARC expressed caution about the Commission's proposal. It noted a need for 'careful consideration' of any policy that mandates the publication of research papers and data in an appropriate, publicly accessible repository and/or provides researchers with additional funding in order to cover the costs of having their work published:

> Issues requiring further consideration include the creation of repositories (at agency, institutional or international levels), copyright and licensing agreements, the ability to exploit intellectual property arising from the research, the peer review of publications, the financial models that would best sustain the publication of high-quality research delivering practical benefits to the community, the maintenance of repositories and a host of other practical issues. (sub. DR167, p. 4)

It also noted that the 'world-wide push' to open access publishing was shifting the incidence of publication costs onto researchers and funding agencies that support them and the consequences of this shift were 'largely untested':

> At present, the ARC's Funding Rules do not allow for the funding of publication costs incurred by grant recipients. If such costs were to be met through grant funding, which is approved in advance of the research being undertaken and papers being produced, a significant administrative task would fall on funding agencies which would be required to estimate the likely costs of publication at the time of grant approval and, on the expiration of the grant, probably to audit the use of the funds provided for that purpose. Further, if the agencies' budgets were not supplemented to cover those costs in full, then the proportion of grant funding devoted to research activity would diminish. This would occur either because the research activity possible under each grant would fall if an amount had to be left to fund publication costs, or because a smaller number of grants could be awarded if they were to be supplemented for publication costs (sub. DR167, p. 5)

The ARC also considered the benefits of more open access to be unclear:

> Users to whom rapid access to research findings is important have always sought to ensure access to the journals they require in a timely way, as the benefits to them are likely to exceed the costs. Such users are unlikely to benefit directly from any move to more open access (although their organisations' libraries may benefit from lower subscription costs). (sub. DR167, p. 5)

According to the ARC, a better option may be to supplement the budgets of the researchers' home institutions so that publication and repository costs could be funded at the time of publication:

> This would enable the quantum of funding to match more closely the actual costs associated with the publication and reduce the costs associated with attempting to estimate them in advance of the research. (sub. DR167, p. 5)

The Commission's view

The Commission continues to hold the view that funding agencies should take an active role in promoting open access to the results of the research they fund, including data and research papers. Although the ARC and NHMRC's recent announcement of promoting voluntary access is to be commended, the Commission considers that the progressive introduction of a mandatory requirement would better meet the aim of free and public access to publicly-funded research results. US experience suggests that voluntary compliance by authors would be very low.

A concern with mandating open access is that it would reduce the incentives for subscribers to pay for conventional journal access and, in turn, the incentives for publishers to supply journals. Mandated access would, therefore, be likely to require a new payment mechanism to elicit sufficient publishing services such as through the direct subsidisation of providers or of authors.

Among the possible payment mechanisms, the Commission prefers an 'author pays' approach. Here, authors would pay publishers or repositories a fee conditional that the publication is publicly and freely accessible. Fees would reflect the costs and quality of services provided. Funding agencies would need to pay a minimum amount to authors for this purpose.

Thus, for example, the fee paid by an author to a scientific publisher would need to reflect all or some of the costs of providing such conventional publishing services provided as overseeing peer review, editing, and distribution as well as arranging open access publication. Some or all of the fee could be recovered from the funding agency. If all the fee were met by the funding agency, then open access publication should occur without undue delay.

There are two key benefits of an author pays approach.

- The aim of dissemination publicly-funded research results would be better promoted. Improved dissemination would have knock-on effects for further science and innovation.
- Allowing authors to pay and choose how their results are to be published, as well as the services they required, would enhance competition amongst publishers

and repositories in terms of price and the quality of services they provide, as well as help drive down publishing costs.

However, such an approach would clearly redistribute financial obligations.

- Many researchers and institutions (including libraries) would face reduced costs of access to knowledge (including subscription costs) since more material would be freely available and, therefore, funding agencies would not have to support these costs as much as before.
- Funding agencies would need to make up any net deficit in fees imposed on authors by journals and repositories to ensure open access publication.
- Fees paid by authors would be a source of revenue for publishers and repositories. In some cases, this would reduce their direct reliance on government funding for their operations.

Funding agencies need not prescribe the form that open access should take, whether through a conventional scientific journal, an open access journal or a repository. But they would need to provide guidance on what forms of publishing would satisfy its open access requirement. This could link to the work currently done by the Australian Government on the Accessibility Framework, under Systemic Infrastructure Initiatives and under NCRIS.

The Commission considers that its proposal that there be a clear requirement for open access publication be implemented progressively by funding agencies to enable all participants sufficient time to adjust.

Access to government data

Prof. Fitzgerald drew attention to the benefits of open access to government data:

> … open access to knowledge in the form of data held by government and key research institutions throughout Australia could sponsor untold innovation in areas as diverse as water management, construction and precise positioning agriculture. This could lead to the generation of intellectual property, business models or other solutions that could generate revenue. Furthermore, sharing of insights about these processes or products may serve to improve or enhance the original work or may sponsor new innovations. (sub. DR114, pp. 1–2)

He suggested the adoption of whole-of-government open access licensing that facilitates the release of government data and digital content:

> Much government owned data and digital content — which could otherwise be released — is not made accessible on a mass scale because of concerns about the cost and efficiency of licensing, or a simple lack of understanding as to how this might be achieved. With the development of generic open access licensing solutions like

> Creative Commons we now have the framework through which much of this material can be easily made available. It is no longer a legitimate excuse to lock publicly funded data and content away simply because you cannot work out how to licence it on a mass scale in a cost effective manner. (sub. DR114, p. 3)

In 2002, the Australian Government agreed in principle to the Productivity Commission's review of cost recovery (PC 2001a) to funding the 'basic information product set' of its agencies from taxation revenue (Minchin 2002, attachment 1). Basic information products are determined in reference to 'public good characteristics', significant positive spillovers, and other Government policy reasons. Subsequently issued cost recovery guidelines contain advice to agencies on determining basic information products (Australian Government 2005a). Agencies such as the ABS, ABARE and the Australian Institute of Health and Welfare now provide data and information online free of charge to users.

Another approach to making government data accessible is to follow the course of action taken by the United States, which introduced the Data Quality Act 2001[6] to facilitate the dissemination, as well as the correction, of US Government information. In accordance with the Act, the Office of Management and Budget issued guidelines in 2002 that 'provide policy and procedural guidance to Federal agencies for ensuring and maximising the quality, objectivity, utility, and integrity of information (including statistics information) disseminated by Federal agencies'. The guidelines require each agency to:

- issue their own guidelines;
- establish administrative mechanisms allowing affected persons to seek and obtain correction of information maintained and disseminated by the agency; and
- report the number, nature and handling of complaints.

The Act and guidelines have been the subject of some controversy in the United States. As a US commentator observed:

> Some regulatory analysts believe that the information/data quality guidelines will 'revolutionize the role of science in policy making by ensuring and maximising the quality, objectivity, utility and integrity of scientific information.' Others believe that the guidelines will be a 'central battleground for reshaping or repeal of environmental laws and regulations.' Still others say that the effect of the guidelines will be determined by the number and quality of petitions filed to challenge information and the vigor with which the OMB oversees and enforces the requirements. … One observer has predicted that the information quality initiative could degenerate into a 'stakeholder food fight'. (The Water Resources Research Institute 2004)

[6] The Act was enacted as section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001.

In a recent review of the Act, the US Government Accountability Office found that, although the Office of Management and Budget took steps to implement the Act, guidelines and information for many agencies were not available or easily accessible (2006, p. 7). It also found that, of the organisations that filed requests for correction during 2003 and 2004, 38 were ‘business, trade group, or profit-oriented’ organisations with the remaining 17 being ‘non profit or other advocacy’ organisations (2006, appendix III).

The Commission supports the current Australian Government policy on funding the basic information set from taxation revenue, and applied by such institutions as the ABS by making its data and research papers freely available through the Internet. There may be scope for such an approach to be extended to State and Territory agencies and to other research institutions such as universities and publicly funded research agencies. This approach would be particularly worthwhile in respect of data underpinning government decisions or policy that are perceived as controversial — it would make the basis of such decisions or policy more transparent.

FINDING 5.1

Several key impediments to the functioning of the innovation system should be addressed:

- *major publicly-funded research infrastructure should be priced to maximise efficient utilisation and to avoid congestion;*
- *there should be national consistency in the application of privacy regulation and in ethical review of multi-centre research; and*
- *published papers and data from ARC and NHMRC-funded projects should be made progressively, yet expeditiously, freely and publicly available.*

These impediments are not the only ones that the Commission has considered. Others relating to commercialisation, skills development, collaboration and public support programs are dealt with elsewhere in the report.

6 Workforce issues

Key points

- Australia needs adequate numbers of appropriately trained scientists, engineers and related professionals to create and absorb scientific knowledge and undertake innovative activities.
- The supply of scientists and engineers has grown strongly as a result of large increases in graduate completions and net migration flows — although there has been a decline in graduate completions in some areas since 2000 — and employment for science and engineering professionals has also generally been strong.
- There do not appear to be widespread shortages of scientists in many disciplines at present, but there are recognised shortages of engineers and of science and mathematics teachers. Some of these shortages appear to be cyclical, but others, as for teachers, appear to have a structural component.
- In most labour markets, shortages create price signals in the form of higher wages to attract additional labour into these areas. In the case of engineers, unlike teachers, shortages have resulted in a rapid growth in salaries for graduate and experienced engineers. Providing greater flexibility in pay and related reward structures for teachers would help to address the ongoing shortage of high quality science and mathematics teachers.
- While market mechanisms are important in addressing shortages, longer term structural problems may require the consideration of more explicit policies.
- The ageing of the workforce is not confined to the higher education sector and, like other employers, universities will have to implement a range of recruitment and retention strategies to address the challenges posed by ageing.
- There are indications of a number of problems relating to job satisfaction in areas such as career pathways, contract employment and the non-research workload. Many of the issues are best addressed by negotiation and agreement between employers and employees.
- However, job satisfaction can also be increased through: a degree of longer-term funding certainty; performance assessment that appropriately rewards higher performing institutions, research teams and individuals; a level of academic freedom consistent with the strategic interests of the employing institution; and the minimisation of non-research workloads.

6.1 Introduction

High quality human capital is fundamental to the innovation system. A highly skilled workforce not only provides Australia with the capability to pursue scientific knowledge and undertake research and development type activities, but also to utilise and adapt the innovation flowing from research and development undertaken in other countries.

It is important, therefore, that the Australian workforce includes adequate numbers of appropriately trained scientists, engineers and related professionals. There has been considerable concern that perceived shortages will ultimately affect Australia's ability to create and absorb scientific knowledge and undertake innovative activities. Particular concern relates to whether there are sufficient high quality secondary science and mathematics teachers to prepare students to undertake tertiary study in these areas. Of course, it is not just the raw number that is important, but also their 'efficiency' — in turn, this throws focus on working conditions and job satisfaction issues.

This chapter discusses some workforce issues relating to numbers and to job satisfaction. However, given the nature of the reference, the Commission has not undertaken a comprehensive review of science and engineering workforce issues.

Appendix L provides an analysis of such issues as the so-called 'brain drain' of scientists and whether the number and 'quality' of students is declining:

- The appendix concludes that any loss of skilled residents, including scientists and engineers, has been more than offset by immigration and that the majority of Australia's emigrants return home with additional skills and experience gained overseas.
- There is also concern surrounding the level of enrolments in science and mathematics in high schools and the quality of students studying science at university. Much of the concern regarding student quality has focused on the relatively lower tertiary entrance scores required for science courses. However, these lower scores reflect that there are a larger number of undergraduate places available for science courses relative to the demand for these places compared to certain other courses such as medicine, dentistry and law. Relatively lower entrance scores do not mean that only lesser qualified students will enrol in science and that these courses will be filled by students with tertiary entrance scores at or near the 'cut-off' entry score. Indeed, the median entry scores of those commencing science in most Go8 universities in 2005 were in the mid-90s. Also, a post-graduate qualification is often required for a professional career in science and an important selection process occurs following completion of the

undergraduate degree, thus ensuring that the most able students proceed to post-graduate study.

6.2 Numbers of scientists, engineers and teachers

Several bodies expressed concern about the numbers and quality of people available with relevant skills to further Australia's science and innovation interests. Examples of their concerns are summarised in box 6.1.

Box 6.1 **Participants' concerns about workforce numbers**

Current and future shortages

The Department of Education Science and Training (DEST) said:

> The tightening global supply market for scientists and engineers presents an imminent challenge to Australia when coupled with current and projected domestic shortages in key science and engineering professions. (sub. DR205, p. 7)

The Queensland Government pointed to future skills shortages:

> The Queensland Government believes that while there is no present shortage in scientists at a national level, global demand for science, engineering and technology skilled workers is forecast to increase significantly in the near future. (sub. DR203, p. 1)

Increasing the numbers of students and graduates

Others called for an increase in the size of the workforce to allow Australia to increase its research capacity and levels of innovation. For example, the Australian Technology Network said:

> Increasing the flow of students into SET [science, engineering and technology] courses within universities will be crucial if Australia is to build its research capacity for the future. (sub. 34, p. 6)

Similarly, the Australian Academy of Technological Sciences and Engineering commented:

> Hence, to support the increased levels of innovation it is essential that there is a significantly increased number of graduates in science, engineering and technology. (sub. 27, p. 15)

DEST raised the issue of building future capacity or preparedness into the workforce:

> The lead time to train highly skilled graduates is significant, whereas many emerging challenges and opportunities are immediate and require the maintenance of a diverse pool of SET skills that can meet demand as, and when, the need arises. (sub. DR205, p. 7)

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Box 6.1 **(continued)**

The importance of high quality science and maths teaching

The Business, Industry, and Higher Education Collaboration Council said:

> Investment in primary and high school science education, and in training and retaining high quality science teachers is an important part of long term capacity building. It appears that the quality of science, engineering and technology teaching in schools may act as a limiting factor in the long term capacity to graduate students suitably qualified to meet the high expectations of industry. Quality high school maths and science teaching has a critical flow on effect on students' choices and success at university. Investment in world class higher education courses in the enabling sciences is also critical to recruiting and retaining students. (sub. 55, p. 13)

The Australian Vice-Chancellors' Committee commented:

> The development of human capital is a process that starts in early childhood. By the time students reach the age to enter university their interest in further education, and particularly in the fields of science and engineering, has already been shaped by their school education. For this reason, it is critically important that Australia provides a high quality school education that encourages inquisitive minds and an interest in science. The current lack of interest in key disciplines such as physics, mathematics and chemistry is a matter of concern. Australia's universities need well-prepared, competitive students who are motivated to expand the world's knowledge. (sub. 60, p. 21)

Ageing of the academic workforce

The Group of Eight noted that the ageing workforce presented a challenge to the higher education sector:

> … Australia's universities face major workforce planning challenges over the next 5-10 years in particular as large number of their most experienced and skilled academic staff reach retirement age. (sub. 68, p. 11)

The National Tertiary Education Union (NTEU) said:

> … the ageing of the academic workforce is a critical issue facing Australia's universities over the next decade, and one that could seriously impede Australia's overall innovation effort. Universities are likely to face substantial difficulties in replacing the large proportion of academics due to retire in the next decade. (sub. DR128, p. 3)

The current situation

In reality, Australia's science and engineering workforce has grown strongly in the last decade with large increases in graduate completions between 1990 and 2000 and net migration flows. In addition, the number of PhD graduates has increased in both science and engineering. However, there has been a decline in graduate completions in some areas since 2000, including general science, earth sciences and slight declines in chemical sciences and engineering. Employment demand for science and engineering professionals has also generally been strong, particularly in recent years (appendix L).

There do not appear to be shortages of scientists in many disciplines at present, although there is a strong demand for geologists due to the strong growth in the resources sector.

There were no science occupations on the Migrant Occupation in Demand List (MODL) for the skilled migration program as at September 2006 and geologists were the only science occupation on the Department of Employment and Workplace Relations (DEWR) skills in demand list as at July 2006 which identifies skill shortages and recruitment difficulties on a State and Territory basis (DIMA 2006, DEWR 2006b). Although not listed on the MODL or on the DEWR skills in demand list, there does appear to be some difficulty in recruiting those with high level mathematical and statistical skills (DEST 2006c, sub. DR125).

There are, however, significant shortages in a number of engineering occupations. For example, civil, chemical, mining and petroleum engineers have been identified by DEWR as being in 'ongoing national shortage'. They are identified on both the MODL and DEWR skills in demand list (DIMA 2006, DEWR 2006b). A recent Audit of Science, Engineering and Technology Skills undertaken by DEST (2006c) concluded that employers were having considerable difficulties in recruiting engineers. As to graduate engineers, the Graduate Outlook Survey found that around 37 per cent of employer organisations surveyed had problems sourcing engineering graduates (Graduate Careers Australia 2006a).

In regard to teachers of science and mathematics, most jurisdictions have reported ongoing shortages and difficulties in recruitment (MCEETYA 2003 and 2004). More recent analysis indicates that these problems continue. The DEWR skills in demand list (DEWR 2006b) identified shortages of mathematics and physics teachers in Victoria and recruitment difficulties in respect of science and mathematics teachers in nearly all other jurisdictions. Moreover, there are concerns that the extent of these staffing problems may have been hidden through the reliance on teachers not qualified to teach in these areas (appendix L). For example, the Innovation Economic Advisory Board said:

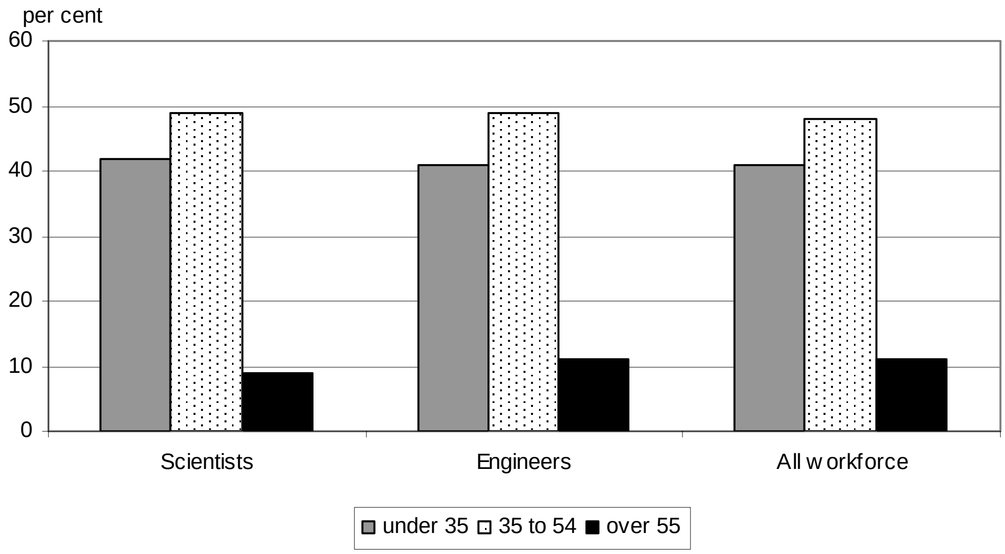
> In IEAB's experience, the shortage in teachers has meant for example, teachers expert in social studies having to teach science. (sub. 89, p. 3)

An older workforce

The age structure of the science and engineering workforce closely reflects that of the wider workforce (see figure 6.1). Thus, in line with the workforce generally, the science and engineering workforce is expected to age over the coming years. The academic workforce (as a whole), however, is significantly older than the workforce in general. It comprises a greater share of workers older than 55 years of age and a smaller share of workers under 35 years of age — and it has been ageing relatively rapidly.

However, there are two important caveats. First, this age structure varies by university with Go8 universities generally having a younger staffing profile. For example, less than half of the academic staff employed at Melbourne University, the University of Queensland and Monash University were older than 44 whereas around 80 per cent of academic staff were over 44 years of age at the Australian Catholic University, 70 per cent at the University of Western Sydney and Southern Cross University and 67 per cent at the University of New England (Dobson 2007, quoted in *The Australian* Higher Education Supplement, 10 January 2007, p. 26).

Figure 6.1 **Age distribution of scientists and engineers[a]**



[a]Based on ABS 6 digit ASCO occupations.

Data source: ABS, *Census of Population and Housing,* 2001.

Second, in an ageing academic workforce, science academics are relatively young. Proportionally more science academics are aged under 30 and fewer aged 50 and over than any other discipline. While having a slightly older age profile than science academics, engineering and information technology academics are younger than the overall academic workforce (see table 6.1).

As a final point, the impact of ageing on the productivity of scientists has been subject to numerous studies and the evidence suggests that the productivity of scientists declines with age (see appendix L). If this is correct, it implies a need for greater numbers of scientists than would otherwise be the case to achieve the same 'volume' of work.

Table 6.1 **Age distribution of academic staff[a], 2005**

Discipline area	*Total*	*Under 30*	*30 to 49*	*50 and over*
		Per cent	Per cent	Per cent
Natural and physical sciences	6 458	9.6	60.4	30.0
Information technology	1 749	7.3	55.9	36.8
Engineering	2 687	7.1	61.9	30.9
Architecture	587	1.2	57.5	41.3
Agriculture, environment and related	806	4.8	59.2	36.0
Health	5 193	6.9	58.8	34.3
Education	2 013	1.2	39.2	59.6
Management	3 384	4.6	52.1	43.3
Society and culture	7 052	3.1	52.9	44.0
Creative Arts	1 882	1.9	51.0	47.1
Mixed field	23	0.0	39.1	60.9
Not in an academic unit	2 443	5.3	52.4	42.2
Total	**34 277**	**5.6**	**55.3**	**39.2**

[a] Full-time equivalent staff.

Source: Information prepared for the PC by Ian Dobson, Centre for Population and Urban Research, Monash University from DEST data.

Discussion

The evidence above is of current shortages in most engineering occupations and for science and mathematics teachers. In the case of science occupations, apart from geologists, there do not appear to be any widespread shortages. Some of these shortages may be cyclical in nature, but teachers appear to have a structural component. However, particularly given the expected continuing strong growth in demand coupled with general supply side issues such as ageing, it is possible that, in the absence of policies to address any structural issues, shortages will increase over the years ahead.

In the short to medium term, market responses through such mechanisms as wages flexibility (where possible) and migration can help to address these shortages. For example, in many labour markets, shortages generate price signals in the form of higher rewards. Over time, these higher rewards should attract increased numbers of people with the required skills into these areas. In the case of engineers (unlike teachers — see below), shortages have resulted in a rapid growth in salaries for graduate and experienced engineers (DEST 2006c). Indeed, such price signals appear to be having an impact, as preliminary data on university applications for 2007 indicated that engineering was one of the major growth areas (QTAC 2006).

Also, immigration programs have been changed to provide a more immediate response for areas of shortage.

However, in the medium to longer term, explicit government policies can help to address any underlying structural issues. In general, such policies should focus on ensuring the system is able to respond to underlying market forces rather than attempt to predict future demand for particular skills and occupations — thereby avoiding the risk of producing graduates with little prospect of gainful employment. Some existing responses and further possibilities are discussed below — although the Commission has not attempted a comprehensive analysis of the issue. The contribution which enhanced working conditions and job satisfaction could make is discussed in a later section.

One response by the Australian Government to shortages has been to increase its funding of higher education places. For example, teaching places at university have been funded as a national priority and additional places have been made available. The Australian Government has also announced that there will be additional university engineering places (Bishop 2006c). A further important role undertaken by all Australian governments is to ensure quality standards in courses and curriculum at Australian universities are maintained, a role undertaken through the independent Australian Universities Quality Agency (AUQA) (see box 12.8).

Information provided by governments can also play a role in maintaining the ability of the system to adjust now and in the future. For example, ensuring school leavers and other potential university entrants are aware of employment prospects for different fields of study can assist the operation of the labour market by signalling to students areas where there are shortages and where there is likely to be oversupply.

Addressing (school) teacher shortages

Price signals have not been able to communicate the shortages in the teaching profession due to the inflexible nature of teachers’ pay structures.

Webster, Wooden and Marks (2004) have argued for changes to teachers’ pay structures. Their research found that fewer science and mathematics graduates, compared to humanities graduates, were attracted to tasks involved in teaching children. However, as attraction was a matter of degree, they concluded that higher salaries and extended career paths should be formalised in teaching wage agreements to ensure such incentives were signalled to mathematics and science graduates, as well as to existing teachers in these areas.

The level and structure of teachers' pay was seen as a negative by year 12 students contemplating a career in teaching. A survey of these students undertaken by Lewis and Butcher (2002) found that there was a critical awareness on the part of year 12 students of the issue of teachers' pay and, while acknowledging the benefits of a relatively high starting salary, teaching was considered not to provide an adequate financial future. Moreover, the year 12 students were conscious of the incremental levels of pay and the lack of career pathways. Concerns with promotional pathways and salary levels were also expressed by senior secondary school students and parents in an attitudinal study conducted for DEST (2006b).

Leigh and Ryan (2006) found that as teachers' pay relative to other professions had declined over time, teaching had become less attractive to high aptitude students leading to a decline in overall teacher quality.

The Review of Teaching and Teacher Education (DEST 2003b) noted that teaching salaries plateau after around 10 years from entering the profession and that this generated considerable dissatisfaction among experienced teachers. Around 70 per cent of teachers in New South Wales public schools were at the top of the scale (NSW Auditor General 2003). The Review found that highly accomplished teachers were disadvantaged in comparison to other professionals by their inability to access pay commensurate with their performance. It recommended that career progression and salary advancement be based on merit and teacher performance rather than years of service and that remuneration for those teachers who perform at advanced levels be increased significantly (DEST 2003b).

To attempt to reward more experienced teachers, most jurisdictions have put in place advanced teacher classifications, known as senior, master or leading teachers, which provide for a limited number of additional steps on the salary scale. In some jurisdictions, access to the advanced teaching classification is based on meeting specific criteria, and/or meeting satisfactory performance benchmarks. In other jurisdictions these positions have been rolled into the normal incremental salary scale (AEU—ACT Branch 2005). However, while such measures have added a number of additional steps, there are no further rewards for those teachers at the top of the scale or those who demonstrate excellent performance. For those seeking further rewards the only option is to progressively move out of the classroom and seek promotion through the administrative stream.

Providing greater flexibility in pay structures, which would involve increasing pay rates for some teachers relative to others, would make teaching more attractive to prospective high quality entrants, including those with science and mathematics qualifications, and provide education departments with greater scope to retain skilled and experienced teachers across the board and attract teachers into areas of shortage. Importantly, credible methods to assess teacher performance would need to be developed that are acceptable to both management and staff in the teaching profession as they have been in other areas of the workforce. Also, any expansion in the number of entrants into science and mathematics teaching would require that staff and adequate resources are available to ensure the quality education and training of such teachers.

Greater flexibility in pay structures could also assist in improving professional development within the teaching profession. For example, in its inquiry into teacher education, the House of Representatives Standing Committee on Education and Vocational Training recommended that ongoing professional learning in teaching be linked to registration levels and recognised in salary structures (HRSCEVT 2007).

A supplement (or alternative) to such an approach would be to provide explicit incentive measures to attract more people into teaching. For example, the action agenda arising from the Review of Teaching and Teacher Education (DEST 2003b) raised the issue of separate incentives for prospective science and mathematics teachers, including removing all student financial contributions and providing scholarships and/or paid internships for those qualifying in these fields who take up teaching appointments.

State and Territory Governments have implemented a number of scholarship arrangements for science and mathematics teachers and retraining schemes for teachers currently teaching in other areas. For example, the Queensland Government offered up to 25 scholarships to an accelerated Bachelor of Education course. The Victorian Government has offered a $4000 up-front payment to attract final year trainee teachers to difficult to staff subject areas and the Western Australia Government has offered a HECS reimbursement scheme of up to $6000 to physical science graduate teachers upon taking up employment (MCEETYA 2004).

However, there is probably a fairly low sensitivity of student response to changes in HECS-HELP contributions — due to both the higher income that a graduate receives and the payment being deferred to the future. Accordingly, such differentiation would need to be substantial to have a significant effect on student numbers and other prospective entrants into teaching. Indeed, Webster, Wooden and Marks (2004) considered that attraction schemes such as scholarships and extra advertising are unlikely to have sustained effects.

In sum, shortages in science and mathematics teachers are exacerbated by the inflexible nature of teachers’ pay and related reward structures. Greater flexibility would make teaching more attractive to high quality prospective entrants, including those with science and mathematics qualifications. It would also provide greater scope to attract and retain skilled teachers, not only across the board, but in areas of particular shortage.

Greater flexibility may have an associated fiscal impact on governments, although any such impact would have to be considered against the overall economic benefit to Australia from attracting, training and retaining high quality teachers.

FINDING 6.1

Greater flexibility in pay and related reward structures for teachers would help to address the ongoing shortage of high quality science and mathematics teachers.

Addressing the ageing of the academic workforce

The ageing of the academic workforce presents opportunities as well as risks. For example, Anderson, Johnson and Saha (2002) considered that the pressing problem associated with the older academic workforce was 'bunching' where several members of a university department retire at the same time. This could either lead to a significant loss of expertise and fields of study or provide an opportunity for a renewal of academic staff.

It is relevant to note that other parts of the workforce face similar concerns. For example, the nursing and medical workforce are also older than the wider workforce (PC 2005a) and, like the academic workforce, there are concerns that the impending retirement of a significant number in those professions will result in shortages and a decline in experience. Indeed, as a result of the demographic 'baby boomer bulge' moving through the system and into retirement, the wider workforce will have to deal with ageing issues.

Thus, to the extent that this situation extends across the workforce generally, responses from government would need to be at a broad level, rather than industry or occupation specific. Indeed, for example, the Australian Government has implemented a number of changes to superannuation and taxation arrangements to encourage workforce participation by older workers. And, of course, increasing the flexibility of market mechanisms can help (see above).

The situation of individual industries, occupations or sectors, can also be addressed at a more detailed level by the particular employers and workforces involved. Universities, for example, are developing their own strategies to deal with an ageing workforce. Many organisations are implementing succession planning and mature age friendly working arrangements to maintain experience within an organisation, avoid shortages and then enable older workers to progressively reduce their workforce engagement.

Hugo (2004), has suggested a range of specific human resource strategies that Australian universities could draw on to address the ageing of the academic workforce. These included identifying the high performing older staff and providing incentives to ensure they do not leave the workforce prematurely, graduated retirement programs for selected staff, recruitment from the broader academic community, family friendly policies (particularly for women), early identification of new talent and ‘new blood programs’. Importantly, policies aimed at attracting and retaining key academic staff need to consider working conditions and job satisfaction issues (see below) as well as remuneration issues. For instance, Winchester (2005), in highlighting the role of non-salary issues in this area, said:

> … the bulk of the academic workforce will be attracted and retained not by salary alone, but by the total employment proposition that a University can offer. …
>
> Retention of key staff beyond normal retiring age depends heavily on the attractiveness of continued employment, often measured in relatively intangible terms such as satisfaction. (p. 4)

Universities have in place or are implementing a variety of recruitment and retention strategies to deal with the ageing academic workforce as part of their overall workforce and strategic direction planning. There is no set ‘formula’ as to the type and mix of retention and recruitment strategies required to manage the ageing issues and, accordingly, the approach taken by each institution will vary depending on their teaching, research and staff profiles and their employment requirements.

As noted above, an ageing academic workforce also provides an opportunity for regeneration. In the case of science and engineering, the strong growth in PhD graduates highlighted in appendix L means there is a growing pool of younger newly qualified personnel to draw on. With the retirement of older academics, there are likely to be improved opportunities for graduates to enter an academic career than there were in the past.

6.3 Working conditions and job satisfaction

Working conditions and job satisfaction are important drivers of both workforce supply and the productivity and retention of the current workforce.

Most of the input to the Commission on this issue came from employee representative organisations, although there were relevant comments from others. The main focus was on researchers working in the higher education sector and in certain publicly funded research agencies. The views of participants are summarised in box 6.2.

Box 6.2 **Views on working conditions and job satisfaction**

Career pathways

The difficulty faced by young researchers in obtaining competitive research grants and post-doctoral fellowships was raised by a number of participants. The Australian Academy of Science said:

> The careers of many young researchers in Australia are in a 'holding pattern'. Some are in their second or third postdoctoral fellowship with low salaries, low status, limited job security and uncertain prospects. This is frustrating for them, but it's also a national concern. This could be resolved in part by increasing the number of Queen Elizabeth II Fellowships and C.J. Martin Biomedical Fellowships. (sub. 24. p. 2)

The NTEU said:

> … junior or middle ranked research staff are at a major disadvantage in applying for competitive research grants when they are competing with other staff with established careers and research records. (sub. 62, p. 24)

In contrast, the Australian Research Council noted that there was a shortage of suitable researchers to fill certain postgraduate awards.

> Participants in the ARC's *Linkage Projects* schemes increasingly report an inability to find suitable postgraduate researchers to fill Australian Postgraduate Awards Industry (APAI) places, even after funding commitments have been made by both the collaborating organisations and the ARC. The problem appears to be worsening with each *Linkage Projects* round. (sub. 73, p. 41)

Contract employment

The NTEU noted that the large majority of its members who were employed mainly on research in the university sector were employed on fixed term contracts from research grants or industry grants. This had resulted in increasing frustration at the lack of certainty around future employment and was a major impediment to continue working in the university sector (sub. 62).

In summarising its members' views, it went on to say:

> By and large, universities provide them with an environment that gives them the freedom to pursue and explore their ideas, but this freedom is being curtailed by a number of factors, perhaps most significantly lack of employment security. This lack of security seems to be a problematic factor not only on a personal and financial level, in terms of the pay and conditions associated with working in short term contract positions, but also on an intellectual level as the need to secure funding increasingly encroaches on the type and fields of research that is being carried out. (sub. 62, p. 27)

(continued next page)

Box 6.2 **(continued)**

The CSIRO Staff Association commented on the costs of contract employment:

> Non-renewal or possible non-renewal of specified term contracts can have damaging social and human costs on a researcher. Our research indicates that it contributes significantly to disillusionment and lower morale towards the end of a contract, reducing the productivity of the individual at a time when it needs to be high to ensure delivery of outputs. … In many cases the contingent employment is a reason for skilled scientific staff moving out of careers in science. (sub. 78, p. 15)

Freedom and flexibility in research

The NTEU noted the importance of freedom and flexibility in pursuing research interests:

> Nearly all respondents to our survey mentioned the freedom and flexibility to pursue their research interests as a major incentive for working in the sector. Along with academic freedom, a large proportion of respondents also expressed passion for their work, intellectual stimulation and the ability to explore issues more substantively as major incentives for working in the sector. (sub. 62, p. 22)

Increases in non-research workload

A number of participants commented on the increasing non-research workload, such as administrative duties and grant applications, being placed on researchers which had reduced the time available for undertaking research type activities. The Community and Public Sector Union (CPSU Group) said:

> There are also the issues of researchers spending an increasing amount of their time preparing applications for grants and contracts rather than on research itself. (sub. 39, p. 5)

The Group of Eight commented that:

> Significant researcher ‘down time’ is required to prepare funding applications and deal with other regulations. Significant researcher ‘dead time’ occurs as researchers wait to hear about the success or failure of grant applications. For some graduates and current researchers this uncertainty detracts significantly from the attractiveness of research as a career option. (sub. 68, pp. 10-11)

The present situation

Career pathways

The vocational focus of engineering and computing undergraduate courses generally provides direct entry into the relevant profession. In contrast, the pathway to a career in scientific research is usually fairly lengthy — science graduates generally require further post-graduate qualifications before entering into scientific research related employment (see appendix L).

This often includes a PhD over a three to five year period followed by further post-doctoral training. This post-doctoral training may require some time overseas to acquire particular skills and involve obtaining a post-doctoral position and/or successfully obtaining funding to undertake research in their field.

A significant challenge to PhD graduates seeking careers in the university sector is to find employment in appropriate academic positions to enable them to establish research programs and develop profiles in their areas of research. This is often against a backdrop of a significant teaching load. While they are often able to access some financial support for their research from internal sources, it is difficult to access independent funding from ARC grants as they lack the 'track record' of more established researchers.

There was also difficulty in obtaining post-doctoral training positions. In the area of medical research, the NHMRC (2005) commented on the lack of available post-doctoral training positions and noted that the number of applications was increasing, but the number of training places had remained static at that time.

The number of fellowships in some areas has recently been increased, following the additional funding for health and medical research announced in the 2006-07 budget. The Australian Society for Medical Research (sub. 36) noted that the increase in the funding of the Health and Medical Research Fellowships scheme would assist in retaining the very best senior health and medical researchers.

Contract and casual employment

The concerns regarding contract employment mostly relate to researchers working for CSIRO and in the higher education sector.

In CSIRO, the use of contract employment arrangements has been increasing over time. Although around 12 per cent CSIRO's research workforce were employed on short-term contract (less than 5 years) in 1992, this had risen to around 27 per cent by 2004 (sub. 78). Over the same period, Government appropriation as a proportion of CSIRO's total revenue declined from around 75 per cent to 62 per cent (CSIRO 2005a and IC 1995). As at October 2006, around 25 per cent of staff were employed on term contracts. Of the annual staff commencements between 2000-01 and 2005-06, staff on term contracts accounted for around half, casual staff around 40 per cent and permanent staff between 6 and 12 per cent (information provided by CSIRO).

To address concerns regarding the long-term use of contract employment, the CSIRO Enterprise Agreement provides for the review of tenure following 7 years of continuous contract employment as to the opportunities for indefinite employment within CSIRO. Only 4 contract employees have been subject to this review since 1998, 2 of whom were converted to permanent employment (information provided by CSIRO).

In the higher education sector there has been a decline in the use of fixed-term staff relative to permanent staff and a slight increase in the use of casual staff over the past decade. Of the split between permanent and fixed-term academic staff, between 1995 and 2005 the proportion of FTE (full-time equivalent) academic staff employed on a permanent basis or tenurable term increased from 64 to 69 per cent and those on limited term appointment declined from 35 to 30 per cent (DEST Higher Education Statistics, FTE for Full-time and Fractional Full-time Staff by Current Duties Term, http://www.dest.gov.au/sectors/higher_education/publications_resources/statistics/publications).

In terms of casual, part-time and full-time employment in the sector, between 1995 and 2004 casual staff as a proportion of FTE academic staff increased slightly from 12 to 15 per cent, part-time staff increased from 9 to 11 per cent while full-time staff declined from around 80 to 75 per cent (DEST Higher Education Statistics, FTE for Full-time, Fractional Full-time Staff and Estimated Casual Staff by Work Contract, http://www.dest.gov.au/sectors/higher_education/publications_resources/statistics/publications).

Such arrangements are ostensibly a response to staffing requirements in an uncertain funding environment in which there is a greater reliance on competitive funding and external source funding (see chapter 2). As each grant is 'won' staff are contracted for the duration of the funding. In contrast, the proportion of short-term contract staff is lower in those publicly funded research agencies, such as ANSTO and DSTO, which are less reliant on competitive funding and externally sourced funds.

A further factor is the fragmented nature of the labour market for scientists. The diversity of science disciplines and the further specialisation within disciplines results in many sub-markets. Moreover, the nature of research means that many scientists are likely to have developed quite specific skills in a particular area over the course of their career. As a result, agencies tend to contract the specific skills required for each project.

Remuneration

In comparison with other professions, the earnings of science and engineering professionals were towards the middle of the range, but behind the earnings of computing professionals while school teachers were towards the bottom — based on the average weekly earnings of full-time non-managerial employees in these professions. In contrast, earnings for university and vocational education teachers were towards the top of the range (see table 6.2).

Table 6.2 **Average weekly cash earnings and paid hours full-time non-managerial employees, Australia May 2006**

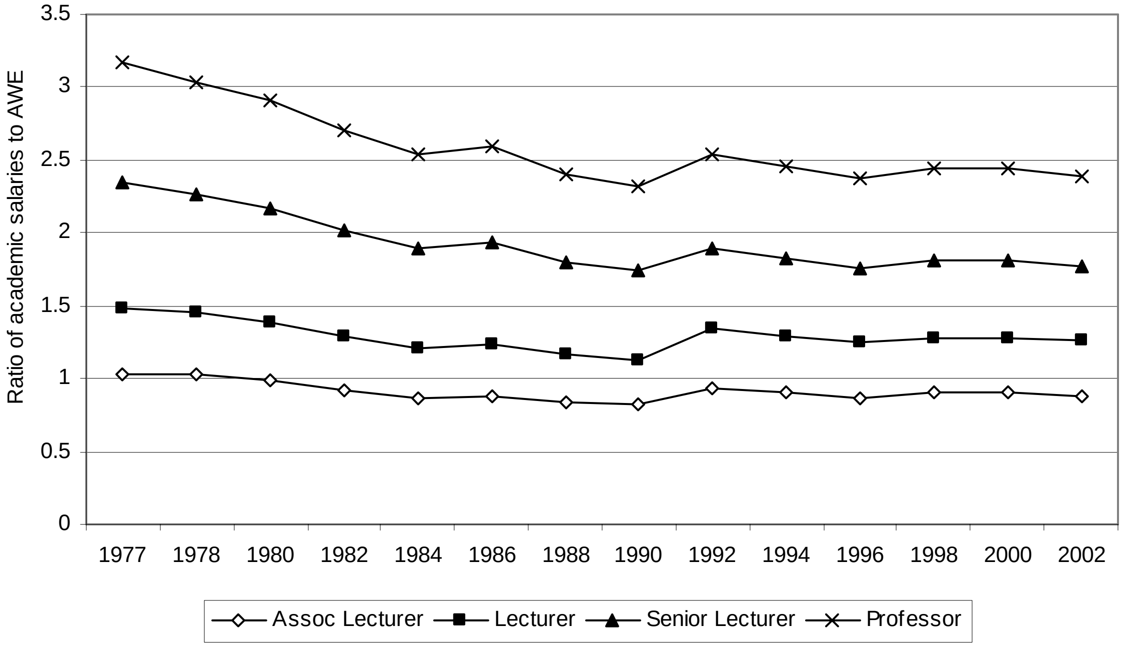
Occupation and ASCO code	*Average weekly cash earnings ($)*	*Hours per week*	*Hourly cash earnings ($)*
Medical professionals (231)	2 492.00	44.6	55.80
University and vocational education teachers (242)	1 463.10	35.8	40.90
Building and engineering professionals (212)	1 450.10	39.0	37.20
Computing professionals (223)	1 429.00	38.0	37.60
Natural and physical science professionals (211)	1 331.60	38.8	34.40
Nursing professionals (232)	1 262.10	38.5	32.70
Accountants, auditors and corporate treasurers (221)	1 207.60	38.0	31.80
School teachers (241)	1 178.60	35.8	32.90
Social welfare professionals (251)	919.80	37.7	24.40

Source: ABS Cat. no 6306.0, *(Employee Earnings and Hours, May 2006)*.

Within each occupation, earnings vary considerably by experience, by industry and activity. For example, in 2005 the annual base salary range for scientists was from around $43 000 for a recent graduate to over $80 000 for a more experienced scientist and for engineers, in 2006, from over $50 000 for a recent graduate to around $120 000 for experienced engineers. For those scientists involved in mining exploration, the average annual base salary was $101 000 in contrast to $74 000 for those in research and development and $62 000 for those working in analysis and testing (APESMA 2006a, 2006b).

Academic salaries have declined in relative terms for most of the past 25 years. Between 1977 and 2002 the salary of a professor and a senior lecturer relative to average weekly earnings declined by around 25 per cent and for lecturers and associate lecturers by around 15 per cent (see figure 6.2).

Figure 6.2 **Academic salaries as a ratio of average weekly earnings (AWE), 1977-2002[a]**



[a] Professor (Academic level E - top of scale), Senior Lecturer (Academic level C - top of scale), Lecturer (Academic level B - bottom of scale), Associate Lecturer (Academic level A - bottom of scale).

Data source: Horsley and Woodburne (2005).

Prior to 1997-98 and the introduction of enterprise bargaining, academic salary rates were largely uniform across universities. Although there has been a compression in salary levels due to the large relative decline in professorial and senior lecture salaries during the late 1970s and 1980s, it appears that since then the decline in academic salaries relative to average weekly earnings has flattened out and the relativities have been maintained (see figure 6.2).

Based on comparisons with other occupational salary outcomes across the period 1997 to 2001, in which academic salaries were determined under enterprise bargaining, academic staff received salary increases of 13.5 per cent. This was above the 12.9 per cent achieved by all workers, but less than the 13.9 per cent received by managers and the 14.9 per cent received by professionals (Horsley, Martin and Woodburne 2005).

Following the shift into more flexible salary setting arrangements, universities have been making extensive use of salary loadings and other incentives to attract and retain certain academic staff. The incidence, size and range of these incentives has varied substantially across universities and by discipline. It has been estimated that around 20 per cent of Go8 academics are being paid loadings in comparison to only a very small percentage of staff at regional universities. In addition, universities have used incentives to recruit appropriate staff through the use of housing subsidies, additional research support, outside earnings, additional superannuation and reduced or no teaching arrangements (Horsley, Martin and Woodburne 2005).

Levels of job satisfaction

According to the CSIRO Staff Association, the major issues affecting job satisfaction of CSIRO staff were the increasing use of contract employment and the increasing administrative burden and multiple reporting requirements placed on researchers (CSIRO Staff Association 2001, 2005).

CSIRO monitors the level of job satisfaction of its researchers through its staff satisfaction survey, the Insight survey. These surveys were undertaken in 2001, 2002, 2003 and 2005. The 2005 survey — the response rate of staff to the survey was 74 per cent — found 67 per cent of staff were satisfied with CSIRO as a place to work. This result was similar to the 2003 survey and slightly below the 2002 survey. Surprisingly, the percentage of staff on fixed term contracts indicating satisfaction with CSIRO as a place to work was higher than for permanent staff (information provided by CSIRO).

There is no similar survey of job satisfaction in regard to academics and researchers in science and related disciplines employed in the higher education sector. However, the level of job satisfaction of the overall academic workforce appears to have declined. A study into the changing nature of academic work by Anderson, Johnson and Saha (2002) found this was due to:

- the deterioration in student/staff ratios;
- pressure on universities to raise funds through fee paying students and by undertaking contract research;
- changes in management style from a collegial to a managerial style;
- the increased use of casual staff; and
- a decline in the relative status, prestige and salaries of academics.

Discussion

A number of factors impact on the level of job satisfaction that is experienced by individual researchers. These factors can be summarised as follows:

- The extent to which employers have a reasonable degree of funding certainty (within the limits of a competitive and dynamic environment), which can flow through to their employing arrangements.
- The ability of performance assessment to reward higher performing institutions, work teams and individuals appropriately.
- The degree to which institutions reward the special needs of particular categories of workers, such as early career researchers.
- The extent to which non-research tasks, such as administration and other overhead distractions, are minimised.
- The level of academic freedom available to researchers, consistent with the strategic interests of the employing institution.

A major issue is that many of the matters relevant to the workplace are externally determined: these include relevant legislation; regulatory constraints; the general IR environment; funding available to research organisations (and businesses); incentives imposed through funding allocation mechanisms (such as the forthcoming RQF — see chapter 12); and the traditional mores of the science and innovation sector (relating for example to career pathways and the non-monetary rewards derived from undertaking challenging and interesting research). It is in addressing some of these broader structural issues that governments can best contribute to improvements in the workforce

In addressing specific issues such as career pathways, contract employment and remuneration there are various competing forces and interests that need to be balanced.

Difficulties in establishing a career pathway in science and innovation are likely to have been exacerbated by the increase in the number of PhD graduates over the past decade. Against this, the ageing of the academic workforce and their subsequent retirement is likely to increase career opportunities in the higher education sector for younger researchers.

The use of competitive funding arrangements had meant that continuous progress along the post PhD pathway can be difficult, even though these arrangements act as a 'quality filter' on those moving through to senior research positions. However, in most parts of the labour market today there are very few occupations that provide secure and guaranteed career paths — career progression in most fields is becoming subject to increasing competitive pressures.

Contract staff make a significant contribution to research. They bring the skills and expertise needed for a particular project and provide research agencies and universities with the flexibility to respond to the opportunities provided by the funding bodies. But these arrangements can also incur a number of costs for institutions and research staff alike. These may include lower morale due to the lack of long-term job security; high turnover and loss of expertise; employees searching for other employment in the final months of their contract; training and inducting new staff; and a trend towards a short-term focus within an organisation.

Remuneration levels are important, particularly those expected over a working lifecycle. Nevertheless, it appears that for science professionals, non-monetary rewards such as autonomy of research, utilisation of skills, peer group esteem and the ability to add to existing knowledge are significant influences on overall levels of job satisfaction. Survey work undertaken by the Australian Council of Deans of Science (ACDS) found that science professionals rated employment that provided interesting work and valued and used their skills more highly than employment that provided job security and income (ACDS 2001).

Even though academic salaries on average appear to have declined relative to average wages in recent decades, there has been some increase in flexibility. Universities have been making extensive use of salary loadings and other incentives to attract and retain academic staff. Other incentives include the use of housing subsidies, additional research support, outside earnings, additional superannuation and reduced or no teaching arrangements (Horsley, Martin and Woodburne 2005). As discussed in chapter 12, the introduction of the RQF may also lead to a widening in the range of academic salaries.

As noted above, there is a role for government in dealing with structural issues. However, in regard to job satisfaction, to a considerable degree, the balancing of the various competing concerns is best left to the negotiations and agreements between individual employers and their employees. Circumstances will differ significantly across workplaces and employers and employees will often have diverging interests. There is no one set of universal prescriptions.

FINDING 6.2

Changes in the broader science and innovation policy environment could have a positive effect on researchers' working conditions and job satisfaction, but the details of working arrangements at individual workplaces are best left to negotiation and agreement between individual employers and their workforces.

7 Commercialisation and utilisation

Key points

- There is often pessimism about Australia's capacity for effective commercialisation, but this overplays the significance of problems.
- However, there are several possible deficiencies within universities that may frustrate effective commercialisation of university research. These stem from:
  - impediments in universities' governance structures, incentives and culture;
  - inadequacies in the management of intellectual property; and
  - inflexible arrangements to support research commercialisation activities.
- While there is scope for universities to improve their linkages with firms and the wider community, this does not require a new dedicated funding stream for universities. However, there are possible grounds for providing access to a non-contingent loan of last resort to help ensure that commercialisable intellectual property is developed to the 'proof-of-concept' stage.
  - Any loan scheme should be piloted and independently evaluated before any expansion is considered.
- New intermediary arrangements aimed at better diffusion of complex knowledge from universities to businesses are being trialed and will provide a useful experiment.
- Claims that public support is required to address a wide range of other potential commercialisation obstacles *within firms* — such as poor entrepreneurship and management skills, and inadequate venture capital — are either ill-founded or ignore programs that already exist.

The terms of reference request the Commission to identify impediments to the effective functioning of Australia's innovation system and to identify any scope for improvements. This chapter focuses on some of the potential impediments that affect knowledge flows and their exploitation. The terms of reference categorised these as:

> … knowledge transfer, technology acquisition and transfer, … commercialisation, collaboration between research organisations and industry, and the creation and use of intellectual property ...

Some of these issues are partly covered by chapter 5 (for example, some key intellectual property (IP) issues and regulatory constraints in general) and others by the Commission's analysis of business programs in chapter 10 (CRCs, a collaborative program; and Commercial Ready, a program that supports some business commercialisation). Some of the commercial issues confronting public sector research agencies, including the CSIRO, are covered in chapter 11. These issues are not re-considered here.

The main preoccupation of this chapter is with impediments to the effective transfer, diffusion and utilisation of the outputs of Australian publicly-funded research for commercial use, particularly that conducted in universities. But the chapter also discusses potential impediments affecting business commercialisation more broadly.

The term 'commercialisation' is sometimes used to summarise all processes for realising commercial value from research. The term can also include some of the benefits for business commercialisation stemming from the stock of expertise in publicly funded research institutions, even where these benefits do not arise from research per se. This broad characterisation was used in the Commission's draft report, and is how the Australian Institute for Commercialisation (AIC) conceives it:

> To the AIC… commercialisation is not only about economic returns, it is about achieving outcomes (products, services, or processes) with market take-up. In short, taking ideas to market. The price may or may not be zero. The path may include granting an exclusive licence, sharing IP, or transferring researchers or staff into industry. It can include contract research, not just IP transfer. It could include giving IP away to a developer. (sub. DR136, pp. 4-5)

This is a very broad definition and clearly wider than that conceived by the Government's terms of reference. For example, a narrower and common conception of commercialisation might include activities by universities that involve selling their IP or creating spin-off companies to exploit particular technologies. Because of these ambiguities, it is often best to avoid using a blanket term like commercialisation, except where in context its meaning is clear, and instead focus on the particular impediments associated with the transfer, diffusion and utilisation of the outputs of Australian research for commercial use.

Conceptually, these impediments fall into one of two categories:

- factors internal to research entities and businesses; and
- those that arise externally. These latter can come from a number of sources: for example, from the constraints that government imposes on research organisations, and from market failures and imperfections. But many of the commonly cited market-related impediments are unconvincing (box 7.1).

Box 7.1 **Impediments that are dubious or not policy relevant**

Some apparent impediments to the commercial exploitation of research in Australia lack policy relevance or plausibility:

- Australia's distance from other major markets and the smaller size of the local market (Queensland Government sub. DR203, p. 7 and the NHMRC sub. DR165, p. 5) is a natural impediment and cannot be changed through policy. In terms of economic power, Australia's market is bigger than its population numbers would suggest because of high relative incomes.
- The structure of Australia's economy is more SME-intensive and more oriented to services and natural resources than manufacturing. This reflects advantages in these areas, and is not an obvious impediment. It does have implications for the realistic aspirations for commercialising some types of publicly conducted research in Australia.
- There is little evidence that Australian cultural traits are inimical to the commercial use of research ideas.

There is sometimes a perception that Australia is not good at translating its research into useful commercial outcomes (Ferris 2001; Gome 2004). Some even regard commercialisation overseas, rather than in Australia, as a failure, though this is an appropriate route if domestic capabilities for exploitation of certain technologies are weak. These perceptions are vaguely targeted because they often rely on specific 'lost' technologies (such as the black box flight recorder), rather than considering more general evidence about problems in exploiting knowledge that might reveal policy-relevant impediments. For that reason, it is better to consider relevant evidence on the effectiveness of existing commercialisation processes, before identifying the key policy relevant impediments in more detail.

7.1 What does the evidence show?

The commercialisation performance of public sector research agencies and universities

Assessments of the commercialisation performance of research undertaken by PSRAs and universities in Australia depend on the metrics and the institutions concerned. At the aggregate level, Australian universities have lower patent intensities per dollar of R&D and lower execution of licences than some key international peers (box 7.2). But incomes per licence are higher than the United Kingdom and about the same as Canada (and lower than the United States).

Box 7.2 **The national survey of research commercialisation**

In October 2004, DEST released the results of a national survey of research commercialisation for the years 2001 and 2002. The survey is based on information provided by PSRAs, universities and MRIs in surveys commissioned by DEST and conducted on its behalf by the AIC. It updates and extends an earlier survey for the year 2000 that was undertaken by the Australian Research Council, the NHMRC and CSIRO.

Among the key messages relating to this *broad* group of public institutions were:

- The stock of income-yielding licences held by the research organisations included in the survey has increased, as has the active stock of start-up companies formed by them and the overall value of organisations' equity holdings.
- Income earned from licences has remained reasonably steady, after taking account of a single, very large transaction reported in the 2000 survey, which inflated the figure reported for that year.
- Universities earned about 59 per cent of total licence income in 2002, compared with MRIs (22 per cent), CSIRO (13 per cent), CRCs (5 per cent) and other publicly funded research agencies (1 per cent). Licence income as a proportion of research expenditure was higher for MRIs (6 per cent) than for the publicly funded research sector as a whole (1.7 per cent). A striking feature of the results is that, across all sectors and all measures used, a small number of organisations accounted for the bulk of the commercialisation activity reported.
- Employment of commercialisation and commercialisation support staff is increasing.
- The number of new invention disclosures grew between 2000 and 2002, but there were declines in the number of new patents applied for and issued.

For universities *alone*, international comparisons of patenting, licensing and start-up company formation activity suggest that, relative to their peers in the United States, Canada and the United Kingdom, and taking into account differences in levels of research expenditure and GDP, Australia's:

- have fewer US patents issued to them than the United States or Canada;
- execute fewer licences than the United States, Canada and the United Kingdom;
- earn income from licences at a rate that is greater than the United Kingdom, roughly comparable to Canada but less than the United States; and
- form more start-up companies than the United States, but fewer than Canada or the United Kingdom.

These findings are subject to a range of qualifications and do not purport to capture the full range of commercial benefits flowing from publicly-funded research.

Source: DEST (2004d, p. xvii).

Australian universities have a higher propensity to spin off new companies than the United States, but less than Canada and the United Kingdom.[1]

The Australian Centre for Innovation et al. (2002, p. vi) claimed that Australia's research-intensive universities (mainly the Group of Eight) performed above the average US university standard and approached that of the best US and European universities. But on several of the usual metrics (such as licence revenue), there was still a significant performance gap between the leading US universities and the leading Australian universities (Allen Consulting Group, 2004 p. 12).

DITR conducted a study in 2004 of the levels of university patent protection and commercialisation for the period 1995 to 2002 (Singhe et al. 2005). Amongst other things the study found that:

- the number of Australian patents granted to Australian universities over 1995 to 2002 shows annual fluctuations with 41 patents granted in 1995, reaching a peak of 72 in 1998, and declining to a low of 30 in 2000;
- the proportion of patents commercialised was remarkably consistent during this time, averaging 70 per cent; and
- there was no evidence of the existence of a large body of unused patents within Australian universities — however, the study did not quantify the extent to which there is university R&D that has commercial potential, but is not being patented or otherwise commercialised (Singhe et al. 2005, p. iii).

The few metrics available across the university system suggest uneven commercialisation performance *between* institutions, matching the distribution of research publications described in chapter 4. The DITR survey found that the Group of Eight universities accounted for 89 per cent of total patents granted and 90 per cent of the commercialisation activity (Singhe et al. 2005, p. iii). DEST (2004d, pp. 8, 9 and 19) found significant concentration of commercialisation outcomes. In 2002:

- three universities accounted for 48 per cent of all university disclosures; one MRI accounted for 42 per cent of all MRI disclosures; and one CRC accounted for 79 per cent of all CRC disclosures;
- three universities accounted for 82 per cent of total university adjusted gross income from licences; five MRIs accounted for 88 per cent of total MRI adjusted

[1] The Science and Innovation Mapping Task Force (2003) describe similar results from an earlier survey. The Task Force drew heavily on data from the first national survey of research commercialisation, conducted in 2002. The survey collected baseline data for the year 2000, and covered universities, government sector research agencies and medical research institutes (MRIs).

gross income from licences; and three CRCs accounted for 87 per cent of CRC adjusted gross income from licences; and

- six universities accounted for 64 per cent of all university Australian and United States patent applications, and three accounted for 62 per cent of all university patents issued worldwide; three MRIs accounted for 46 per cent of MRI patent applications, and three accounted for 67 per cent of MRI patents issued; four CRCs accounted for 70 per cent of CRC patent applications; and two accounted for 61 per cent of CRC patents issued.

However, the fact that a relatively small number of publicly funded research organisations dominate research commercialisation need not imply inadequacies in commercialisation broadly defined. In particular, the metrics used for gauging commercialisation are likely to be biased against smaller regional universities whose role in commercialisation is largely in the provision of advice and consulting services. (The issue of metrics is discussed further below and in section 7.2.) Moreover, some degree of concentration could simply reflect performance hierarchies among Australian universities, which may be an optimal outcome.

The other facet in the commercialisation performance of universities has been improvement, a trend noted by most studies.[2] For example, Howard Partners (2005b, p. 17) found that Australian university income from royalties, trademarks and licences — that is, income mainly associated with technology transfer — rose from $14.6 million (or 0.2 per cent of total university income) in 2000 to $34.9 million (or 0.3 per cent of total university income) in 2003. However, even if this revenue were to double again, it would still represent only about one half of one per cent of total university income.

The above perspectives about the commercialisation activities of universities are university-centric. Another way of looking at these issues is to consider the commercialisation activities of universities and PSRAs from a business perspective. These are often seen in terms of linkages, broadly conceived (for example licensing arrangements, collaborative arrangements, staff movements), between businesses and institutions. These are often perceived as relatively poor. For example, the Australian Business Foundation observed that:

> While Australia has strong knowledge infrastructure through grants and tax concessions for research and development, support to universities, publicly funded research institutes and Cooperative Research Centres, it has relatively weak knowledge diffusion mechanisms. (sub 72, p. 12)

[2] These studies include the Australian Centre for Innovation et al. (2002, p. vi), the Allen Consulting Group (2004, p. ix), the Science and Innovation Mapping Task Force (2003, p. 15), and Howard Partners (2005b).

The ABS 2005 Innovation Survey (ABS 2006d) shows that most innovating firms have few connections with universities or PSRAs across several dimensions:

- 4.9 per cent of innovating businesses collaborated with institutional organisations. The highest levels of collaboration in this category occurred between innovating businesses and government agencies (3.3 per cent of innovating businesses) and universities or other higher education institutions (2.3 per cent) (p. 28);
- 2 per cent of innovating businesses acquired knowledge or abilities from higher education or research institutions through the use of patents, designs, or other IP rights (p. 29); and
- 10.4 per cent of innovating businesses acquired knowledge or abilities from these institutions by employing new graduates, 5.9 per cent by using consultants from these institutions, 3.8 per cent by using research results published by these institutions and 3.1 per cent employing academic or research staff (p. 29).

There are weaknesses in existing metrics

However, there are several problems in inferring too much from the various metrics commonly used to measure — from either the university or business perspective — the commercialisation performance of public sector research institutions. In general, attempts to measure these activities, let alone their benefits, have been hampered by a lack of data.

The most common metrics used are quite narrow (invention disclosures, such as patent applications filed and patents issued; licences executed and income arising from licensing; and start-up companies formed). These metrics miss the full range of commercial benefits flowing from publicly funded research, such as those arising from consultancy work carried out by researchers; theses on commercially relevant topics carried out by higher degree students; and the economic contributions made by people with research training who move into industry (DEST 2004d, p. 39).

Diffusion of capabilities and knowledge for business innovation can be informal, even when considering sophisticated links between firms and universities (see, for example, Biota Holdings sub. DR187; and CSL sub. DR177). And, in many cases, the ultimate commercial impacts may not be even traceable to the originating institutions. That is, ideas are footloose. The way in which clinical guidelines are connected to basic research through indirect means is an illustration (chapter 4).

The fact that firms and universities are heterogeneous also needs to be considered when evaluating commercialisation performance. For example, many firms do not need strong relationships with research institutions. This shows up in generally different rates of innovation and innovation behaviour across sectors and firm sizes — not just in relation with public research institutions — in the ABS Innovation Survey. The strongest connections to research institutions are likely to be present for businesses introducing new-to-the-world innovation, but unfortunately the sample size of the ABS Innovation Survey precludes breaking down the extent (and type) of engagement with research institutions by the novelty of innovation.

Finally, it is not clear what constitutes a 'good' performance level. As in the case of international comparisons of R&D, determining the 'optimal' commercialisation rates from overseas benchmarks is suspect.

Accordingly, the metrics available suggest, in a limited way, *what* happens between businesses and public research institutions, but by themselves say little about whether the degree or types of engagement are adequate or could be improved. Nevertheless, significant steps in improving the measurement of research commercialisation have been taken, including the development of the national survey of research commercialisation by DEST (building on previous work undertaken by the Australian Research Council, the NHMRC and CSIRO). In its submission, DEST (sub. 87, p. 61) noted that the most recent survey, covering 2003 and 2004, will be more comprehensive than past surveys.

Commercialisation performance of firms

The incentives for commercialisation by businesses are distinctively different from those of universities and public sector research agencies. The former are commercially-oriented institutions, whereas the latter are, by intention and construction, focused on broader objectives. Accordingly, unless there are systemic failures in markets and in the rules and framework conditions surrounding them, commercialisation problems are likely to be smaller in the business sector, and therefore harder to identify where they exist. The evidence that does exist is limited and suffers many of the interpretational problems raised in the previous sub-section (above all, the absence of a benchmark against which to assess good performance). However, several empirically-based observations are possible.

The ABS 2005 Innovation Survey (ABS 2006d) shows that Australian firms have roughly comparable rates of introducing significantly improved goods and services to markets as European firms (see chapter 2 in this report). Moreover, the survey confirms that innovation is occurring across the economy rather than being confined to particular sectors. This suggests that Australia's commercialisation performance — broadly defined — should not be seen as dependent on growing any particular set of knowledge-intensive industries or transformational high-tech firms.

There has been a rapid uptake and utilisation of information and communication technologies (ICT). More broadly, Catherine Livingstone (sub. 56, p. 2), a former chair of the CSIRO Board, commented that Australia had a 'world class capability as a technology integrator'.

Commercialising knowledge and technology has often occurred in areas that are close to Australia's traditional comparative advantages. Over time, the Australian mining industry has built up a competitive advantage by applying leading edge technologies, which have improved mining practices, reduced costs and increased productivity (Tedesco and Curtotti 2005, p. 5). There have been widespread similar gains in agriculture (Gans and Stern 2003), often the result of research co-funded by government (chapter 4 and appendix I describes some examples). These sectors also have a potentially broader influence on innovation through their demand for sophisticated and novel products and services from other industries (Queensland Government sub. DR203, p. 6). But the idea that successful commercial uptake must necessarily involve breakthrough technologies is questionable. As noted by the Winemakers Federation of Australia, it can often involve incremental improvements to existing practices and technologies:

> Wine industry research is in general characterised by a large number of small improvements aimed at reducing cost through either improved management practices in the vineyard and/or winery, minimising problems in viticulture and oenology and/or improving the cost per quality unit ratio. (sub. 14, p. 5)

The story for other sectors appears more complex. Service sector innovation and commercialisation is rampant (chapter 3), but linkages to public research institutions is not well researched.

Manufacturing is a heterogeneous sector with a number of high growth, globally-oriented niches — for example, manufacturing activities linked to Australia's natural endowments and products that are differentiated, and those with higher skill levels and R&D intensities (including medicinal and pharmaceutical goods, and scientific and medical equipment). The sector has a relatively high rate of innovation:

- In the two calendar years ended December 2005, 41.7 per cent of businesses in the manufacturing industry had introduced or implemented an innovation (ABS 2006d, p. 14). Only two industries had a higher proportion of innovating businesses: electricity, gas and water supply (48.8 per cent) and wholesale trade (43.4 per cent).

The Australian Electrical and Electronic Manufacturers' Association emphasised there are many positive dimensions to the recent performance of Australia's manufacturing sector and new opportunities are emerging:

> Australia, with its comparative advantages of a solid R&D capability base (particularly in the areas of new and advanced materials), its well educated skills base, its excellent research infrastructure (e.g. the Australian Synchrotron) can be viewed in a more favourable light in the emerging area of 'minimal manufacturing'. In addition, Australian designers are innovative and creative, and our engineers excel at technology integration; our contract electronics manufacturers are agile and globally competitive in small volume, complex product systems. (sub. 51, p. 10)

These are rough indicators of the extent to which Australian businesses engage in successful commercialisation of research, because much of their innovation relies on factors other than research. But, if nothing else, it appears that any weaknesses in existing business commercialisation processes are not so strong as to have large macroeconomic effects. This is evidenced by Australia's strong relative economic growth and productivity since the 1990s compared with other OECD countries (Parham 2002b; Banks 2003).

Overall, the view that Australia is poor at business commercialisation reflects too narrow a perspective of the innovation system and its performance. While some agreed with this view (Melbourne Ventures sub. DR138, p. 1), others observed that there were potential problems. GlaxoSmithKline (sub. DR154, p. 3) considered, for instance, that there were noticeable shortcomings in the commercialisation of medical research. In fact, the Commission does not see these perspectives as irreconcilable. Australia's *overall* commercialisation performance can be better than usually portrayed at the same time as specific problems affect some commercialisation functions and areas. In particular, the Commission observes that the aggregate picture:

- may mask problems in particular sectors and industries and, in such cases, there may be a role for public policy to address specific impediments to commercialisation; and
- does not indicate the extent to which Australia could be leveraging more from public investment in science and innovation.

What can we take from this picture?

Few participants identified major problems in the commercialisation activities of businesses (other than in their relations with public institutions). There is no macroeconomic evidence that weaknesses in commercialisation of research activities have widespread damaging effects on innovation or economic performance. For universities and other public institutions, any judgments about performance are made more difficult by the absence of an objective test of what would constitute a good outcome. However, knowing more about the many ways universities can influence commercial outcomes would be useful. Overall, understanding the nature and severity of impediments requires a detailed consideration of those processes where participants have identified key problems.

These are centred on three broad areas:

- impediments *within universities* including their governance and their capacity to finance commercialisation (such as ‘proof-of-concept’) (section 7.2);
- the potential weaknesses in intermediaries that could create better linkages *between* research organisations and firms (section 7.3); and
- impediments to venture finance, entrepreneurship or taxation that affect commercialisation *within firms* (section 7.4).

The issue of skill shortages is discussed in chapter 6.

As the NHMRC observed, (sub. 80, p. 14), many impediments to commercialisation may also affect non-commercial pathways of knowledge and technology development.

7.2 Perceived impediments within universities

Within Australia’s innovation system, universities play an important role in generating, transferring and diffusing knowledge and technology through their research and teaching functions. Participants raised a number of potential impediments to commercialisation within universities that they felt warranted closer scrutiny.

This section begins by considering the increasing emphasis within universities on a particular type of research commercialisation. It then goes on to canvass a number of perceived impediments to the transfer and diffusion of knowledge and technology that operate within universities, relating to:

- governance structures, incentives and culture;
- the management of IP;
- university commercialisation institutions; and
- the resourcing of knowledge-transfer activities.

The focus on research commercialisation

It has been seen as increasingly desirable for universities to secure a financial return from the research they undertake through the development and encouragement of scientific entrepreneurship. The goals of this are to:

- give universities access to additional sources of revenue; and
- sharpen the incentives for universities to focus on transferring commercialisable knowledge and technology to the business sector, ostensibly enabling greater capture of the economic and social benefits arising from public investment in R&D.

Pressure to improve research commercialisation has come from governments and from inside universities themselves (Harman and Harman 2004). As a result, some universities have devoted significant resources to developing their capabilities in this area, particularly the research-intensive universities.

> Major efforts have been made by a large number of universities to enhance technology transfer capabilities, with the allocation of additional resources to support commercialisation activities, new specialist staff appointments, and revision of institutional policies with regard to the ownership and commercialisation of intellectual property, contract research, and consultancies. Other efforts have included investment of university funds in CRCs and other research centres, and the development of research parks, either by individual universities as with Macquarie University, or by groups of universities as with the Australian Technology Park in inner Sydney, which includes three major universities. (Harman and Harman 2004, p. 159)

Like other publicly funded research organisations, the research commercialisation performance of universities has tended to be assessed against a relatively narrow range of metrics (invention disclosures, such as patent applications filed and patents issued; licences executed and income arising from licensing; and start-up companies formed). More recently, there have been attempts to develop a broader and more comprehensive framework for understanding research commercialisation and knowledge transfer (Howard Partners 2005b; PhillipsKPA 2006). Such work has usefully highlighted that the commercialisation activities of publicly funded research organisations encompass a wide range of activities (such as consultancy work and contract research, staff and students working on interchange with industry, university-appointed ‘visitors’ from industry, policy advice, seminars and conferences).

Reflecting this broader perspective, the latest national survey of research commercialisation by DEST will provide a more comprehensive survey of the commercialisation activities of research organisations by including data on research contracts and consultancies, as well as skills development and transfer (sub. 87, p. 61).

However, decision making within universities may be distorted by the objective of securing a financial return from their research activities. Too great an emphasis on capturing the financial returns from publicly funded R&D may lead to outcomes that are not in the best interests of the universities themselves, firms or the wider community.

First, it may mean that universities make poor choices about where best to allocate their research resources. For example, research relevant to non-commercial activities is also very important, such as the transfer of knowledge to the public sector and the general community (chapter 3 and 4). Griffith University cited the Pathways to Prevention Project (a community crime prevention program) as an example of research-based innovation that demonstrated economic and social benefits, but is not commercialisable (sub. 7, p. 10). Distortions in choices may affect business too. Capturing financial returns uses scarce university resources, including the time of key researchers, that have costs from forgoing other research or diffusion activities that are beneficial to business. It is notable that many businesses identify the key role of universities being their orthodox one of excellent research (for example, GlaxoSmithKline sub. DR154, p. 2).

Second, a financial preoccupation may unnecessarily slow the transfer, diffusion and utilisation of knowledge and technology if universities spend time trying to secure IP deals that are not realistic or appropriate.

Third, such a commercial drive may lock-up potentially valuable IP in small start-up ventures that lack the organisational structures, management expertise and capital needed to survive and grow.

Many participants appeared to share this concern. For example, Griffith University argued that:

> Recently all Australian governments have pressed universities to commercialise their intellectual property as a way of both further diversifying their revenue and ensuring that full economic benefit is obtained from universities' research. However, this policy may be counter-productive. First, the potential for universities to generate revenue from intellectual property may be overstated: it seems that even highly research intensive and entrepreneurial universities in Canada, the UK and the US earn no more than 3%-4% of their revenue from intellectual property sales and licensing. Secondly, it places too much emphasis on research in the innovation value chain, encouraging universities to overvalue their research. … Thirdly, it may impose obstacles to the transfer of research to application since formal legal agreements have to be negotiated and implemented. (sub. 7, p. 9)

Ultimately, in terms of community wellbeing, it is the transfer, diffusion and utilisation of knowledge and technology that matters. The social return from public investment in R&D depends on: whether knowledge and technology are transferred out of universities (that is, whether they see the light of day); how fast and widely the knowledge diffuses among potential users; whether the knowledge and technology is developed into some form of practical application (that is, whether it is taken up in some form or other that is welfare enhancing); and how widely the resulting innovation is utilised. There are multiple pathways for achieving these benefits.

Although the pursuit of financial returns from the sale or licensing of IP, and the creation of university spin-off companies, are two such important pathways in their own right, they should not be to the detriment of the overarching objective of maximising the social return.

This view was generally supported by participants (see, for example, Australian Business Foundation sub. DR170, p. 4; AusBiotech sub. DR175, p. 11). The CSIRO argued that:

> Another important feature of the […] report is that it makes explicit the diversity of pathways through which science can have impact. This puts commercialisation into perspective as only one of many possible pathways to impact, noting that too great a focus on commercialisation can divert attention from some broader and even more important outcomes of research. (sub. DR184, p. 4)

And, the Group of Eight observed that:

> Research commercialisation is but one of many ways by which universities transfer knowledge for the benefit of the wider community. While policy settings should not discourage research commercialisation *per se*, it is not the method of knowledge diffusion that matters, as much as the fact that the knowledge arising from publicly funded research is transferred for public benefit. (sub. DR158, p. 5)

The Commission emphasises that commercial pathways of knowledge transfer and diffusion — including making money for universities from such arrangements — are still important (as emphasised by GlaxoSmithKline sub. DR154, p. 2 and the AIC sub. DR136). These pathways will often not conflict with maximising the social return from publicly funded research. The Commission's argument is about ensuring that universities do not lose sight of the broader social good in pursuing financial returns from technology transfer.

FINDING 7.1

The policy framework for universities should be focused on maximising the social return from public investment in R&D through the transfer, diffusion and utilisation of knowledge and technology. The pursuit of financial returns from the sale or *licensing of intellectual property, and the creation of university spin-off companies, while important pathways in their own right, should not be to the detriment of this overarching objective.*

Governance structures, culture and incentives

Some participants argued that commercialisation may be impeded by the governance structures, incentives and culture operating within universities. To the extent that such concerns are valid, these impediments may also be relevant to the broader issue of trying to maximise the social return from the transfer, diffusion and utilisation of university research.

At an overarching level, some have questioned whether the traditional governance structures and frameworks of universities are conducive to commercialisation. For example, in a report commissioned by DEST, the Australian Centre for Innovation et al. (2002) argued that:

> One aspect of universities that may be particularly challenged by their involvement in research commercialisation is their governance. Their Acts, State Government auditing requirements, and the structure, authority, membership and practices of governing bodies may each raise, and in some cases have raised, evident inefficiencies, tensions and conflicts. (p. 48)

The governance structures and financial, legal and administrative frameworks of universities are important in shaping decision making and behaviour within these organisations and their interaction with the public and private sectors. Several participants argued that there was a need for universities to put in place governance structures and frameworks that would allow them to be more responsive. For example, the Council for the Humanities, Arts and Social Sciences argued that commercialisation was impeded by:

> … rigid university structures that prevent researchers responding in a more agile manner to the needs of industry: for instance, the rapid finalisation of contracts to conduct research, and flexibility in the conduct of these contracts. (sub. 52, p. 13)

Other study participants considered that commercialisation is still seen as lacking the legitimacy of teaching and research and claimed that incentive structures primarily rewarded researchers on the basis of their publication rate and success in securing external research grants rather than commercial development of a discovery or invention.

The CRC for Spatial Information argued that the incentive structures within universities particularly discourage researchers from engaging with SMEs because this kind of speculative/research-assisting activity does not attract adequate recognition or funding:

> … Australia operates with a reward structure for individual researchers at universities that works against engagement with SMEs. This is a fundamental structural impediment to collaboration with SMEs for the purposes of research. Moreover, the university itself is not rewarded for permitting its staff to allocate this speculative time. (sub. 32, p. 2)

There was a view from some study participants that the preferences of researchers themselves might also affect prospects for commercialisation within universities, for example, because of fears of a tradeoff between academic freedom and commercial secrecy. Further, the NHMRC claimed that there was 'a negative perception of commercialisation and research application generally among many Australian scientists working at the basic end of the spectrum' (sub. 80, p. 16).

There was also a view that, unlike some other countries, researchers working in Australian universities generally do not have experience working in the business sector with consequences for the level of understanding between the two sectors. The CSIRO observed that:

> … in Australia very few researchers or university scientists appear to have had experience working in business. This can make it more difficult to produce scientists and researchers with a broader understanding of how business works and the ways in which science can contribute to business development. It is not easy to see how to address this problem. It may in part reflect a risk averse attitude on the part of academics here compared to those in some other countries, where it can be more common for scientists to try setting up their own business and later return to research or academia. (sub. 50, p. 104)

The CSIRO also noted that effective commercial engagement has to be deliberate and continuous throughout research:

> It is generally not possible to maximise impact through a simple one-off effort at the end of the research. Managing research to achieve impact, whether commercial or otherwise, has to be a continuous process. Significant outcomes are the result of complex interactions involving continuing engagement with diverse players over a long period. Especially with major innovations, this requires engagement to start early in the research process and preferably at the planning stage. (sub. DR184, p. 4)

Early commercial engagement is likely to be more relevant for PSRAs undertaking applied research. In many cases, it is not relevant or appropriate for university research.

Nevertheless, universities offer a range of incentives to encourage research commercialisation. These incentives include: arrangements to share the financial returns from successful commercialisation between the university, the research centre or faculty and the researchers (typically, the returns are shared equally between these parties); providing business development staff and resources to help identify commercialisation opportunities and financial support in the early stage development of an invention; provision of pre-seed and seed funding for technology development, funding support for IP protection and assistance with developing a business model (Karingal Consultants 2005).

However, there have been concerns about how well such incentives work in practice. DEST commissioned an evaluation of incentives for commercialisation of research in Australian universities (Karingal Consultants 2005). The study focused on the thirteen universities comprising the Group of Eight and the Australian Technology Network. On the basis of some 'best practice' criteria, the report suggested that:

- About one third of the universities satisfied or came close to satisfying all the best practice criteria identified. …
- Around a third of the universities provided inadequate support and incentives to their researchers to get involved in the commercialisation of their research outcomes. …
- Almost all the universities had difficulty in making available adequate finance and human resources to achieve the best practice criteria identified. (pp. 10-11)

The report claimed that there was a number of structural weaknesses to the commercialisation of research within the universities surveyed:

- Many researchers were unaware what incentives were available ….
- Among researchers, there was quite widespread lack of trust in university administrations that the incentive reward would be paid as expected, particularly where changes had been made post hoc, generally to the disadvantage of the inventors or people involved in the consultancies and research contracts.
- In many universities financial commercialisation support was inadequate. There was little or no access to small amounts of pre-seed finance, often not enough to pay for intellectual property (IP) protection up to the Patent Cooperation Treaty (PCT) stage, usually about $50,000.
- The smaller research profile universities had difficulty in finding the financial and other resources needed to deploy suitably qualified and experienced business development staff, and had been unable to establish their own internal critical mass of commercialisation support. (Karingal Consultants 2005, p. 9)

A cautious approach is needed when assessing perceived impediments of this nature. Australian universities are not a homogeneous group. Each of these organisations will have its own governance structures, incentives and culture. Moreover, these governance frameworks, incentives and culture are largely removed from the influence of market forces and, thus, less amenable to the reach of market-focused policy interventions.

Nevertheless, universities should note the feedback the Commission received from academics working within universities and the business sector which suggests that there may still be issues to address in relation to governance structures, incentives and culture. Clearly, these issues affect the overall quality of university engagement with the business sector and wider community, and the potential for a greater level of socially beneficial knowledge transfer and diffusion to occur.

In addressing these types of issues it is important to ensure that an appropriate balance is struck between encouraging those working within universities to be outward looking and prepared to engage with the business sector and wider community, and maintaining the non-pecuniary benefits that researchers derive from the conduct of curiosity-driven, openly discussed and published research activities.

Intellectual property issues

The management of intellectual property

Universities have their own policies and procedures for managing IP, guided by the National Principles of Intellectual Property Management for Publicly Funded Research (ARC et al. 2001). These principles aim to ensure that researchers, research managers and their organisations have access to best practices for the identification, protection and management of IP, and therefore, to maximise the national benefits and returns from public investment in research (ARC et al. 2001, p. 2). Notwithstanding the development and application of these principles, some participants considered there was still room for improvement in the way universities manage IP.

In this study two broad concerns were raised about the management of IP by universities, namely that there is a tendency for universities to:

- overestimate the commercial value of their research; and, consequently
- seek an unrealistic financial return from the sale or licensing of IP or equity stake in commercialisation projects.

To the extent these concerns are valid, the transfer and diffusion of knowledge and technology to the business sector could be significantly impeded.

On the other hand, the Commission was advised that Australian firms do not always have realistic expectations in negotiating technology transfer deals with universities and, in this regard, universities sometimes find it easier to negotiate with foreign firms.

It is beyond the scope of this study to resolve these competing views. In part, the contradictions may reflect the marked differences in the sophistication of IP management of universities and the varying levels of support for technology transfer they receive.

The BCA has called for a review of IP arrangements, particularly as they apply to university research, to find ways of improving the sharing and transfer of IP with business and other outside organisations (sub. DR204, p. 9). But it is not clear that a formal review is required as yet, since there appears to be considerable scope for universities to continue with existing processes for improving their arrangements for managing IP and for sharing information on best practice.

To assist these processes, the Commission has provided some brief commentary on three issues:

- the need for greater sophistication, consistency and flexibility in the management of IP by universities;
- the legal framework for the ownership of IP in universities; and
- decision making by universities in relation to potentially commercialisable IP.

To some extent, these comments may also be relevant to the management of IP by other publicly funded research organisations.

Sophistication, consistency and flexibility in the management of intellectual property

Some participants considered that a lack of consistency — the same treatment in like circumstances — within and between universities in managing IP was an impediment to commercialisation. Further, there was a perception that universities could be more flexible and sophisticated in their dealings with firms on the ownership and use of IP.

Typical of participants' concerns about university management of IP were those raised by the National Committee for Mathematical Sciences, which observed that:

> … universities and academics were quoted as believing that an idea represented IP, whereas industry people see this as only the very beginning of the research and development process. Universities are seen as possessive and rigid about IP. Moreover universities have problems recruiting suitably trained people with real knowledge of R and D in industry to assist with negotiations. (sub. 25, p. 3)

Such concerns are not new. A working group convened by PMSEIC (2001) to examine the commercialisation of public sector research observed that 'our research organisations have many different approaches to knowledge and IP management.

As a result, investors are left to deal with myriad approaches to dealing with these institutions. The effort required is a serious disincentive' (p. 19).

AIC considered that inconsistency within and across research organisations in the management of IP was a significant barrier for SMEs attempting to engage with the research sector:

> Many of the 130 publicly-funded ROs [research organisations] have now set up commercialisation offices or subsidiaries to serve as 'shop fronts' for their people and technology assets. Unfortunately for SMEs, there is neither a single model for interaction with a particular institution, nor a single clearing house representing them all. Therefore, the task for SMEs in identifying, contacting, learning how to deal with and successfully negotiating collaboration or technology transfer deals with a particular RO is too time consuming for most to justify. (sub. 6, p. 3)

The Business, Industry and Higher Education Collaboration Council (BIHECC) also advocated greater consistency in approaches to managing IP:

> The Australian Research Council has defined a set of *National Principles of IP Management* for publicly funded research, however many different models of IP management are being applied by Australian research organisations with varying results. There may be value in developing more uniform national approaches to IP ownership, transactions and licensing to encourage greater technology diffusion. (sub. 55, pp. 18-19)

The National Principles of IP Management for Publicly Funded Research were developed by a working party that comprised some of the key organisations involved with, or with an interest in the outcomes from, publicly funded research in Australia. There may be value in this group commissioning further work on the costs and benefits of moving towards greater consistency in the management of IP across the various publicly funded research organisations.

However, there is a fine line between 'consistency' and excessively rigid models of engagement with businesses. The Australian Industry Group identified lack of flexibility as a more significant problem than consistency:

> Our investigations indicate that businesses recognise the importance of being able to adapt the allocation of intellectual property depending on the particular circumstances of different transactions. In our discussions, businesses are more likely to have expressed concerns with a lack of flexibility in negotiations over IP with PFRAs and universities than with a lack of consistency. (sub. DR121, p. 8)

This suggests that the transactions costs for firms in dealing with a particular institution are minimised where firms and universities are able to vary their contractual arrangements as the context suggests, but whimsical inconsistencies are eliminated.

The legal framework for the ownership of IP within universities

Some participants suggested that there may be value in formally requiring universities to undertake certain commercialisation activities. Comments along these lines usually focused on the perceived benefits of Australia adopting a legal framework for the ownership of IP within universities similar to that in force in the United States. For example, Macquarie University observed that there is 'no national mandate to undertake commercialisation activities (cf. the US *Bayh-Dole Act*)' (sub. 47, p. 5).

A key feature of the US framework is federal legislation as exemplified by the *Bayh-Dole Act* governing inventions created with project specific public funds. All research institutions that receive funding from government funding agencies are subject to this Act, the key provisions of which are that:

> … universities and government funding agencies enter into a funding agreement which grants a right of ownership to the university subject to a number of obligations. Most importantly, the university must comply with various obligations concerning disclosure of the invention, election whether to retain title, royalty sharing and preference to small business and US Industry.
>
> If the university does not comply with the above obligations or chooses not to take title, the *Bayh-Dole Act* and its implementing regulations provide for the government to receive title by giving written notice. The inventor can apply to the government for title. If the university complies with its obligations, it will be permitted to retain title and commercialise the invention. However, the government will still have certain minimum rights, including a non-exclusive irrevocable licence to use the invention throughout the world. The government will also have 'march-in rights' which allow it to make the university grant (or itself grant) a licence to a third party where the university fails to commercialise the invention, where licensing is necessary for health and safety needs, or where preference for United States industry has not been observed. (Christie et al. 2003, p. viii).

There was support from some participants for Australia adopting a similar approach. For example, the Walter and Eliza Hall Institute of Medical Research contended:

> … Federal Government clarity and endorsement equivalent to the Bayh-Dole Act in the US would provide the catalyst to greater returns from public investment in science and innovation. (sub. DR159, p. 4)

While not directly commenting on the *Bayh-Dole Act*, the AIC advocated strengthening the management of IP by publicly funded research organisations, suggesting:

> … a central tenet being 'use it or lose it'. We advocate the use of IP by the provider to achieve outcomes; and if the provider cannot achieve those outcomes on their own, they should divest it. (sub. DR136, p. 8)

Careful consideration would need to be given to the transferability of the *Bayh-Dole Act* to the Australian context. In this regard, Dr Hine observed:

> Much discussion has occurred in scholarly and industry journals, as well as at the policy formulation level, as to whether the Bayh-Dole Act is transferable to another country's context. Some have adopted similar legislation, others have adopted more informal mechanisms for encouraging technological advances out of research institutions. However beyond the discussion on the transferability of Bayh-Dole, and given that the legislation is now 26 years old, it may be more appropriate to first analyse the extent to which the technology transfer process has evolved beyond its initial manifestation. We should be seeking to assess not only the transferability of Bayh-Dole between national contexts, but to understand where technology has evolved to make more informed judgements on appropriate policies and programs. (sub. DR126, p. 4)

The Commission notes that DEST has published a detailed analysis of the legal framework for patent ownership in publicly funded research institutions (Christie et al. 2003). This analysis examined developments in the United States, the United Kingdom and Canada in relation to the ownership and management of patents resulting from publicly funded research. A key conclusion was that the adoption of a Bayh-Dole type strategy is worthy of consideration by the Australian Government, with implementation through an expansion of the National Principles approach already operating in Australia. Essentially, this would involve requiring certain Australian Government funding agencies to make grants to research institutions conditional upon the acceptance of the following:

- A responsibility to identify, and have systems in place to support the identification of, commercially valuable inventions.
- A responsibility to protect commercially valuable inventions.
- A responsibility to reward employees who create commercially valuable inventions.
- A responsibility to appropriately exploit patented inventions. (Christie et al. 2003, p. xii)

The Commission considers that it would be appropriate to adopt a cautious approach. It is questionable whether the issues confronting the United States at the time the *Bayh-Dole Act* was introduced apply as strongly to Australia. The *Bayh-Dole Act* appears to have been primarily in response to concerns that a large number of potentially valuable inventions created by universities with public funds were not being commercialised. While there is often a perception that potentially commercially valuable IP is locked away in Australian universities, convincing evidence to support this view is harder to find. For example, in research commissioned by DEST, the authors found that one of the well-established myths, which impedes understanding or effective action on commercialisation is that 'universities are a vast untapped source of intellectual property' (Australian Centre for Innovation et al. 2002, p. 48). Moreover, as outlined earlier in this chapter, the evidence suggests that in recent years publicly funded research organisations have improved their research commercialisation performance.

There are already financial incentives for Australian universities to transfer and diffuse commercialisable IP to the business sector. The most common arrangement is for Australian universities to divide the revenues from IP licensing and sales on an equal basis between the university, the inventor, and the inventor’s school or department (Vitale 2004, p. 21). While there are still apparent problems in the management of such IP, it would need to be established that adopting a Bayh-Dole stategy is the best option for addressing these issues.

In this regard, careful consideration would also need to be given to the extent to which adopting a Bayh-Dole strategy may adversely affect the incentives operating within Australian universities. One of the challenges of improving the research commercialisation performance of universities is achieving an appropriate balance between creating incentives for universities to be outward looking and commercially focused, whilst maintaining the academic traditions of openness and curiosity driven research.

Decision making in relation to potentially commercialisable IP

For the bulk of university research, centralised management of knowledge transfer and diffusion is unnecessary. Academics themselves manage this process and it appears to work quite well. Academics often have informal and formal contacts with potential users of their work that facilitate knowledge transfer and diffusion. A report commissioned by DEST from the Australian Centre for Innovation et al. (2002) on best practice processes for university research commercialisation found:

> The great majority of academics with a substantial research performance (on average about half) have a very strong interest in seeing the potential outcomes of their research being realised. This realisation may take the form of a new course, a book, a performance, a new scientific theory, or a technology, such as the computer or the Internet, which will change the world. Some can generate direct commercial returns, while from others the economic return is indirect, and the social return considerable. (p. vi)

In many cases, as already happens, the most appropriate course of action is for research to be written-up and diffused through journal articles, conference papers and seminars.

What appears more contentious is when research is potentially commercialisable. In such cases, universities need to determine: whether they should protect the IP arising from their research activities through the application of patents or some other form of IP protection or simply give the research away; how the IP should be protected; whether the IP should be transferred to an existing Australian firm or firms, a university spin-off venture or a foreign firm; and whether they should sell or license their IP. Several participants highlighted the tradeoffs between the protection of IP versus the free dissemination of knowledge for the public good (Victorian Government sub. 84, p. 13 and BIHECC sub. 55, p. 18).

As noted earlier, decision making should be guided by the overarching objective of maximising the social benefit from publicly funded research. From this perspective, there are several circumstances where it is clearly desirable for universities to seek to protect their IP.

- When protecting the IP makes it more likely the research will be picked-up by firms. This includes cases where the full commercial development of the research into a marketable product, service or process is going to be very expensive (for example, requiring highly specialised technical expertise and/or facilities) and is highly risky. In these circumstances, firms are only likely to be interested in pursuing commercialisation if they can protect their competitive position through restricted access to the IP. For example, GlaxoSmithKline noted that in the pharmaceutical industry incentives to invest are directly linked with exclusivity of rights and the strength of the IP associated with an innovation (sub. DR154, p. 3).
- The common pathway for ensuring the utilisation of research involves transferring the IP to a foreign firm. By protecting the IP, universities can ensure that Australia shares in the rents from the development of the research into a marketable product, service or process.

However, under other circumstances, it is arguably more appropriate for universities to give their research away — for example, if the knowledge or technology is generally applicable to a wide range of firms and the costs of further development and replication of the resulting innovation are low. In this case, seeking to protect the IP and sell or license it delays its transfer and diffusion, potentially imposing substantial costs on firms and the wider community.

In many cases, the tradeoffs between open availability and what BIHECC called ‘propertisation’ (sub. 55, p. 18) are less clear cut. This underscores the importance of universities having good processes in place to make a timely and accurate assessment of their potentially commercialisable research.

Of course, decision making also needs to take into account whether patents (or other forms of IP protection) are likely to be effective, and this will vary across different fields of research. The literature suggests that patents are unlikely to be effective if they can be ‘invented around’ at low cost, are unlikely to be held valid if challenged or are otherwise difficult to enforce, if the technology is moving so fast that patents are irrelevant, or if patent documents require disclosure of too much proprietary information (Shane 2002). If patents or some other form of IP protection are unlikely to effective, then again the best course may be to give the research away.

Finally, universities have to decide whether to transfer IP to an existing firm or create a spin-off company. In many cases, transferring IP to existing firms (including foreign firms) is likely to offer the best prospects for ensuring the research is commercialised. Existing firms are more likely to have: sustainable organisational structures; entrepreneurial and management skills; market knowledge; and access to the financial resources necessary for commercialisation. That said, spin-off ventures may have a role where continued involvement of university researchers or access to university research facilities is necessary for the commercial development of the research.

University commercialisation institutions

The focus of universities in recent years on research commercialisation has been reflected in the development of various institutional arrangements to facilitate the transfer of commercialisable knowledge and technology to the business sector. This has tended to involve the establishment of a specialist unit of some kind within universities (Harman and Harman 2004). These units typically identify, package and market university expertise and technology. To fulfil these functions successfully, commercialisation institutions have to draw on a wide range of skills and expertise including in the areas of contract law, IP, venture capital, spin-off development and marketing. Further, a key aim of these bodies is the development of effective linkages between universities and firms to facilitate the transfer of knowledge and technology. Generally, the literature suggests that the scale of commercialisation arms is important in terms of developing sufficient critical mass to be effective in this role (Debackere and Veugelers 2005).

Participants in this study pointed out deficiencies in existing arrangements. For example, the Commonwealth State and Territory Advisory Council on Innovation (CSTACI) considered that the ‘commercialisation arms of Australian universities, with one or two notable exceptions, may not be operating as effectively as possible’ (sub. 98, p. 2). Professor Vitale (2004, p. 18) has argued that those employed in commercialisation and associated support activities are spread relatively thinly across Australian research organisations relative to the ‘thousands of academic staff across multiple faculties’.

The AIC drew attention to a number of other issues affecting the performance of university commercialisation arms:

> Many commercialisation offices are still very much in 'start-up' mode themselves and are significantly under-resourced for the massive tasks they face. Many also complain of unclear organisational goals and policies for commercialisation, and lack of real commitment from institutional leaders. Frequently, they have limited knowledge or understanding of what IP the organisation actually has because the research may be emergent and not conveniently packaged for specific applications. IP disclosures are rarely formalised, and maintaining in-faculty development managers to seek out and understand 'hidden' IP is expensive. As such, commercialisation offices are often inefficient at being able to market their goods. (sub. 6, p. 6)

Existing institutional arrangements are not necessarily the best use of resources for all universities. In practice, this will depend on the context and capability of individual universities. Dedicated units for each university are resource-intensive to establish and maintain, and generally promote, the transfer and diffusion of only part of a university's research output. As the BIHECC noted:

> Commercialising research is a complicated and demanding process, which requires highly skilled staff with strong commercial backgrounds. Skilled commercial managers are highly sought after internationally and are expensive to both attract and keep. Unless sufficiently resourced, university knowledge transfer and commercialisation offices will struggle to employ the calibre of staff required to deliver on the commercial potential of their portfolios. (sub. 55, p. 12)

Moreover, it seems unlikely that such dedicated units can be self-sustaining for all but the large research-intensive universities. In 2003, across all universities, income from royalties, trademarks and licences was only $34.9 million or 0.3 per cent of total university income (Howard Partners 2005b, p. 17). In this regard, it is worth noting that while UniQuest Pty Limited has now grown and developed to the point where it is self financing, this has taken 10 years and required a significant investment of cash and resources by the University of Queensland.[3]

This is not surprising, since to be self-sustaining, commercialisation units would require an ongoing throughput of commercialisable IP. While universities are repositories of a great deal of knowledge, commercialisable IP is a rarer asset, shaped as it is by market opportunities and user preferences.

Reflecting these considerations, there should be no expectation that universities will each have a dedicated unit. Rather, there are strong grounds for more flexible arrangements that allow universities to draw on commercial expertise in the most efficient and cost-effective way. This could encompass:

- maintaining an in-house commercialisation capability for the large research-intensive universities; and

[3] Correspondence from Mr David Henderson (Managing Director UniQuest, 5 March 2007).

- for some universities, purchasing commercial expertise externally or collaborating with others. To some extent this is already happening such as through the commercialisation collaboration between UniQuest and the University of Wollongong. It is possible that a model might evolve in which research organisations that have built-up effective commercialisation arms spin-off these ventures, creating several independent specialist service providers.

There was general support for flexible institutional arrangements (Australian Industry Group sub. DR121, p. 8; BCA sub. DR204, p. 7; and Melbourne Ventures sub. DR138). For example, Melbourne Ventures observed the value of collaborative models:

> Certain universities in the UK have already successfully adopted this model, for example, WestFocus, which is a consortium of seven universities in South and West London and the Thames Valley that have joined forces to build critical mass for innovation support. Closer to home, Australian universities have also begun to collaborate in certain areas of commercialisation, eg through the pre-seed venture capital fund Uniseed, which is a joint venture of the Universities of Queensland, Melbourne and New South Wales. (sub. DR138, p, 2)

The resourcing of knowledge transfer

Several participants argued universities are not adequately resourced to support knowledge transfer, including their research commercialisation activities. The Australian Government has initiated a separate process to consider whether there is a business case for knowledge transfer funding. Specifically, the Minister for Education, Science and Training has requested BIHECC to undertake this work. The Commission’s understanding is that BIHECC’s report will be available to the Australian Government at around the same time as this study is completed.

In the draft report, the Commission had not reached a final view on the need to provide universities with additional funding to support knowledge transfer. Rather it adopted an open-minded approach and flagged some possible mechanisms by which increased support could be provided to promote the transfer, diffusion and utilisation of the knowledge and technology. These included:

- a separate dedicated funding stream;
- supplementation of the existing block grants; and
- no funding supplementation, but the introduction of measures that address possible impediments within universities that may frustrate the allocation of funding to such knowledge transfer activities.

It noted that each of these options has its own advantages and disadvantages.

The Commission has given further consideration to this issue, including in light of participants' comments on the draft report. The Commission also gratefully acknowledges that BIHECC provided the Commission with an embargoed copy of its report prior to finalisation.

One of the challenges of considering the adequacy of resourcing to support knowledge transfer is defining the scope of the activities for which additional resources are being sought. The debate has not been helped by the use of the term 'Third Stream Funding', which implies knowledge transfer and diffusion are somehow separate and distinct from the research and teaching functions of universities when, in fact, they are intrinsic to these functions. Thus, to the extent there are concerns about universities being able to fund the publishing and dissemination of their research, conferences, seminars, community outreach initiatives, travel for academics, student placements with industry and like activities, this should be considered in the context of the adequacy of the overall level of university funding.

However, concerns in this area appear to be primarily focused on a much narrower set of activities, specifically, those related to research commercialisation. The 'third stream' funding arrangements applied in the United Kingdom— sometimes seen as a model for Australia — concentrate largely on research commercialisation and strengthening the linkages between universities and the business sector. This dedicated funding stream was seen as building up universities capacity to (Lambert 2003, p. 43):

- engage in networking and other outreach events with business, including SMEs;
- market their research and teaching to business;
- establish business liaison and technology transfer offices to provide advice and to negotiate consultancy, contract and collaborative research and licence agreements;
- establish spinout companies;
- provide entrepreneurship training for science and engineering graduates; and
- provide work placements for students in industry.

Australian universities do not currently receive dedicated government funding to support their research commercialisation activities. BIHECC pointed out that this means 'funding for engagement, knowledge transfer, and research commercialisation activities is usually drawn from discretionary revenues and weighted against other spending priorities' (sub. 55, p. 10). This was a view reiterated by the Group of Eight (sub. 68, p. 11) and the AVCC (sub. 60, p. 34) and used as a basis for arguing for the establishment of a dedicated funding stream

(AVCC sub. DR148, p. 8; Group of Eight sub. DR158 p. 5; and FASTS sub. DR144, p. 14).

It is not clear that a dedicated third stream fund is warranted. First, there are many non-budgetary ways of improving university commercialisation processes (as discussed earlier). Second, many of the activities universities undertake to support the transfer and diffusion of commercialisable knowledge and technology are not very different from the activities by which non-commercialisable knowledge and technology are transferred and diffused — for example, teaching services, consultancy services, conferences, seminars and the publication and dissemination of research. There are three possible exceptions:

- university commercialisation arms. Some additional funding may be required on a case-by-case basis to help facilitate the development of more flexible arrangements, as discussed above;
- the creation of university spin-off companies, which in general do not provide a strong rationale for extra funding. If universities decide to invest in these commercial ventures it should be in the expectation that they will generate sufficient revenue to at least meet the associated costs; and
- funding research projects to the point of ‘proof-of-concept’. There may be a case for providing some additional support for taking research through to the point ‘proof-of-concept’ and this is discussed in more detail below.

The fact that some of these may warrant funding is still too weak a basis for a dedicated third stream fund with as broad a set of functions of the kind set out by the Lambert Review. To the extent there are concerns about the ability of universities to fund activities relating to the broader role of knowledge transfer, this should also be considered in the context of the adequacy of the overall level of university funding.

Proof-of-concept

Several participants argued that a significant impediment to commercialisation in Australia is the lack of public and private funding for taking completed research through to the early stages of commercialisation, including proof-of-concept (for example, AAMRI sub. 41, pp. 18-19).

Science Industry Australia noted that the science industry is collaborating with commercialisation intermediaries and peak bodies in the research sector to develop a set of guidelines for a proof-of-concept metric:

> These guidelines are aimed at assembling the evidence necessary to demonstrate the technical and commercial viability of a research idea to potential investors. The metric

> would, if implemented appropriately by universities and PFRAs [publicly funded research agencies], encourage researchers to develop their ideas to a stage where they are of more interest to industry, particularly Australian industry. (sub. 22, p. 7)

This is likely to be useful since investors often have to assess a large number of potential investment projects to find ones with commercial potential. For example, the latest ABS (2007) survey of venture capital and later stage private equity (LSPE) in Australia found that the 157 venture capital and LSPE managers 'reviewed 6688 potential new investments during 2005-06 and conducted further analysis on 724 of those, with 201 being sponsored for venture capital and LSPE' (p. 5). Establishing the level of evidence likely to be required by potential investors could reduce search and transaction costs and improve the level of analysis of projects.

Some participants were concerned that universities and medical research institutes find it difficult to cover the costs associated with developing their research to the point of being 'investment ready'. These costs include further research and experimental development to establish the commercial potential of a discovery and patenting the IP. This appears to be particularly an issue in areas such as the life sciences, where establishing the commercial value of a discovery can require an extended period of research and experimental development.

The 'proof of concept' stage reduces technological risk by undertaking a range of pre-commercialisation activities to validate the findings and commercial relevance of initial basic research. West (2004, p. 26) notes that:

> … like all other risk-management vehicles, venture capitalists are expert in only certain types of businesses and certain types of risk. They specialise in understanding market and managerial issues. They are rarely qualified to assess or cope with technical risk. Unlike companies, therefore, most venture capitalists attempt to remove or substantially reduce technological risk before committing to an investment. Discussions between technological entrepreneurs and venture capitalists typically begin with at least 'proof-of-concept' demonstration that the device, software program, or service will actually function as claimed.

Depending on the type of research, these pre-commercialisation activities could involve further hypothesis testing (including building a prototype), validating the potential targets of biological substances, or exploring the commercial applicability of initial research results.

Failure to develop research projects to the point of proof-of-concept can impede later stages of commercialisation that are reliant on outside funding (for example, AusBiotech sub. DR175, p. 12). The Group of Eight identified a lack of funds to support proof-of-concept activities as one of the key constraints on university research commercialisation (2006a):

- Public funding for university research typically stops at the point when the research question has been answered, or the funding runs out.
- Industry requires proof of the commercial potential of the IP before it will invest.
- This why initiatives such as the Pre-Seed Fund, run under BAA [Backing Australia's Ability], have not led to much increase in investment at the proof-of-concept stage of the process. Those in charge of the funds see it as too commercially risky to invest at this early stage.
- Universities are obliged to target their teaching and research funding on these activities — many of which promise more immediate returns on investment and are financially less risky than investment in research commercialisation.
- In Australia there exist a number of funds specifically set up to invest in technologies emerging from publicly funded research organisations (eg, UniSeed, the ANU/MTAA fund, the WestScheme Fund). However, these too tend to invest following proof-of-concept because of the risk factor (2006b, p. 1).

Reflecting these concerns, the Group of Eight has proposed a new proof-of-concept funding mechanism — the 'Innovation Stimulation Fund'. Under its proposal the Australian Government would provide $45 million over three years on a competitive basis to encourage universities to invest in research of commercial potential at the proof-of-concept stage.

The House of Representatives Standing Committee on Science and Innovation (2006) recommended the Australian Government introduce such a scheme (p. 162). Some participants supported the introduction of this type of scheme (see, for example, Melbourne Ventures sub. DR138, p. 2).

In its submission, ARC saw potential to extend the ARC's Linkage schemes to 'provide for more applied activities, including proof of concept, the development of pilot plants and extension or implementation projects in the public interest' (sub. DR167, p. 10).

A number of participants argued that MRIs face similar problems. The Australian Society for Medical Research noted that NHMRC Development Grants provide an avenue for early stage development of commercially promising projects, but argued there are limited funds beyond that (sub. 36, p. 2). The Walter and Eliza Hall Institute of Medical Research observed that '… medical research institutes face the daily reality of a gap in funds before sound 'pre-clinical' data can be established — the base line requirement for engaging Australian investors' (sub. DR159, p. 3). For its part, AAMRI argued that the funding gap is exacerbated by medical research institutes being unable to access the Pre-seed Funds (sub. 41, p. 19).

As in the case of universities, participants generally saw a need for additional government funding. The Baker Heart Research Institute argued that patent expenditure could be made an eligible expense in normal grants or the development grant system could be expanded to accommodate IP protection as well as proof-of-concept research (sub. 40, p. 7).

The introduction of a hypothecated grants program, such as the 'Innovation Stimulation Fund' proposed by the Group of Eight has several potential flaws.

First, as in the case of broader third stream funding, it is difficult to assess the need for further dedicated funding. Generally, hypothecation of government funds to universities for specific functions reduces the scope for universities to trade off the advantages and disadvantages of varying spending options — and, as discussed in chapter 12, their freedom in this area has been progressively eroded. However, there are some concerns that universities might not be able to adequately finance proof-of-concept with existing funds or that their financial decision-making priorities may be biased against such functions were their general finances to be increased.

Second, if the premise of proof-of-concept is correct, then proof-of-concept funding represents an investment by universities that should have an expected positive payoff. The implicit idea behind proof-of-concept is that it will substantially increase the value of IP held by universities, enabling them to realise higher licence fees on its sale. In that sense, proof-of-concept should be self-funding or close to it. Universities might not be able (or willing) to finance these investments from their current funding, but an upfront government grant is a relatively revenue costly instrument for overcoming such financial constraints compared with other mechanisms (such as loans – discussed below).

Third, a straight grant program would reduce the incentives for careful choice (though the requirement in the proposed program for a 25 per cent contribution by universities would partly ameliorate these). A key problem in this area is the risk of poor decision making by universities if a dedicated fund was to be provided, given that commercialisation is not a primary function for them. Universities can make multiple errors in selection and funding of proof-of-concept. They can choose projects that should not get such funding, omit projects that should, put too little or too much funding into specific projects, choose the wrong types of validation, be too slow, or fail to develop the linkages with businesses while proof-of-concept is occurring that might be necessary for the ultimate success of commercialisation. The problem is that proof-of-concept occurs at the boundaries of the usual competencies of universities and businesses. This implies that it would be important to encourage disciplines in the selection and management of proof-of-concept projects by having:

- some input of commercial expertise; and
- incentives placed on universities that penalise poor choices.

Competitive arrangements for allocating grants partly address these issues, but the experiences with the *R&D Start* program in the business sector (chapter 10 and appendix M) suggest that selection boards face significant obstacles to performing this function, are administratively costly and do not elicit appropriate incentives by applicants.

Non-contingent loan arrangements may be one alternative to straight grants as the funding mechanism. Such loans are as effective as grants in overcoming their short-term financing constraint, but have the added advantage that universities will have a greater incentive to choose a portfolio of projects with a high prospective net return for them in licence fees. This increases their prudence in project selection and management. If the average project funding is sufficiently high, then it may be possible to add the additional discipline that any loan from the Australian Government was as a last resort after private debt options have been demonstrably exhausted. This would only be feasible for large loan amounts since the transaction costs of this condition would be too high for small project cost amounts. The evidence from some other proof-of-concept programs overseas is that average project costs are relatively high.[4]

Other features of any funding arrangement could be requirements for involvement by commercial intermediaries. This could also increase the likelihood of hard-headed decision making about types of projects to be funded and their management.[5]

Given the uncertainty about the magnitude of the problems in this area and the capacity of programs to deal with them, if the Australian Government were to introduce any mechanisms for proof-of-concept funding it should be developed initially as a small pilot program. It should then be evaluated for its effectiveness before its extension is considered.

7.3 Institutional and policy responses *outside* universities

So far, this chapter has considered the direct policy and behavioural responses to potential deficiencies *within* universities (and to a much lesser extent PSRAs) that can frustrate effective links with businesses. Another way of responding to any

[4] For example, a Scottish proof-of-concept program supported 12 projects to the value of £2.1m — giving an average payment of £175,000 or about $A450 000 each — a sizeable average amount (http://www.scottish-enterprise.com/sedotcom_home/sig/academics/proofofconcept.htm?siblingtoggle=1).

[5] Again, the desirability of this would have to consider the transaction costs of such arrangements compared with the risks of poor decision making by universities.

impediment to linkages between research organisations and firms is to appraise whether institutional and policy changes *outside* universities might also be appropriate.

Participants argued that there were impediments to utilisation of research posed by inadequate linkages between research organisations and businesses, and SMEs in particular (BIHECC sub. 55, p. 15 and Engineers Australia sub. 65, p. 3). This was accentuated by the greater prominence of this size group of firms in Australia. Two broad functions for linkages are relevant for these firms. First, such linkages may encourage the broader diffusion of existing technologies, often in the adaptation of existing products or services, to the general body of all SMEs (Professor Parker sub. DR117, p. 7 and AIC sub. DR136, p. 9). Second, linkages may be the vehicle for transferring cutting edge technologies to a much smaller group of SMEs, who play a particularly distinctive role in commercialising radical or disruptive technologies (Walsh and Kirchhoff 2002) or who are early adopters of experimental technologies.

These two linkage types raise separate policy challenges. The types of policies that could be considered are different for each target group, as are the respective sizes of the target groups and the range of already existing private pathways for knowledge.

Broad diffusion of existing technologies

Potentially, the broad diffusion of existing technologies is relevant to all of Australia's more than 1.1 million businesses, including SMEs.

For incremental improvements to a firm's technology there are existing highly developed, but still expanding, pathways for knowledge acquisition. These include business associations, hiring specialised staff, trade journals, niche service providers, suppliers, customers and consultants. In many cases, these are part of a rapidly growing array of knowledge-intensive business services — that intermediate such technology acquisition (Scott-Kemmis sub. DR183, p. 3). These have often arisen from market demands, rather than in response to government policy. There is some evidence that the most effective networks are those that are sponsored and supported by industry through industry associations (Howard Partners 2005a, p. 1). Such networks and other pathways serve to provide a general awareness of technology that can then be followed up by interested firms.

Universities and research bodies play four roles in these existing pathways. First, they provide advanced human capital that is hired by firms. Second, they provide commercial services to firms on a cost-recovery basis. Third, their published research publications are sometimes used (though only a small subset of these is relevant to general diffusion). And finally, in some industries they provide technical extension services (as in agriculture). The evidence suggests that the human capital route is currently the most important.

One function sometimes suggested for such routine linkage policies is to provide information about the best existing technologies. Among innovating and non-innovating firms, this was regarded as the least important barrier to significant improvement in their products, services or processes (about 1.8 per cent and 1.7 per cent of innovating and non-innovating SMEs).[6] It actually appears more serious for innovating large businesses than innovating SMEs.

These features of the existing pathways and the absence of an evident information deficit limit the capacity for appropriate policy responses. Any public-support policies in this area would have to provide a prima facie case that they would not crowd out existing private activities, that any net costs to taxpayers were less than the benefits conferred, and that they could be administered efficiently. Of course, there is a strong rationale for reform of any inappropriate regulatory or institutional barriers to the formation of knowledge-intensive business services.

Diffusion of new and cutting edge technologies from universities and public sector research agencies

While, potentially, a large number of firms can (and a number ultimately will) benefit from currently new and cutting edge technologies, there are relatively few firms that are initial points of diffusion. These tend to be high technology-based firms that can work closely with researchers to develop immediate applications.[7] Of this sub-group, many are constrained by deficiencies in their capabilities for using technology (for example finance, access to specialised human capital) rather than in their linkages per se. If nothing else, this suggests that, to the extent warranted, linkage policies may need to be complemented by other policies (as in the venture capital case discussed in this chapter).

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[6] ABS Innovation Survey 2005 (cat. 8158.0).

[7] Survey evidence suggests that 6 per cent of SMEs perceive themselves to be high-technology *based* businesses (PMSEIC Working Group 2005, p. 74). This would imply around 70 000 high technology SMEs in Australia (of 1.16 million enterprises) at the time of the survey (2004). The latter figure is likely to significantly exaggerate the target group, which are not only high-technology *based*, but have the capabilities for assimilating cutting edge technologies into their businesses. Such introduction and their subsequent use in commercial applications would often be categorised as a first-to-the-world innovation in its own right — which is rare even among innovating firms (chapter 1).

For the receptive firms that remain, existing private options are developing for commercialisation and diffusion of new technologies, often through sophisticated intermediary services, such as the emergence of knowledge brokers and technology advisers (Howard Partners 2005a, p. 25). However, there are less developed existing private or public policy arrangements for diffusing new and cutting-edge technologies than for existing technologies. This is likely to reflect the small target group, difficulties in matching appropriate firms to technologies; and the relatively high costs and scarce expertise associated with specialist unique advice in high technology areas. This may mean it is uneconomic to provide such services, or it may mean that the evolution of their commercial provision is slower and more uncertain.

Participants in this study generally raised concerns about the depth of such services (AEEMA sub. 51, p. 5; DITR sub. DR185, p. 15; and DCITA sub. DR180, p. 7) and sought approaches that strengthened intermediation or that would better promote linkages in these areas. Various possibilities are explored as follows.

Research linkages using existing institutions

One general approach is to use existing institutions (intermediaries or research bodies), but change the nature of demand by SMEs for them. In this vein, the Commission has suggested the development of a flexible collaborative R&D program (chapter 10) to encourage collaborative smaller-scale R&D, and reforms to university commercial arms and IP arrangements (this chapter) to lower transaction costs for businesses engaging with universities.

Another suggested approach is the *Australian Growth Partnerships Model*, developed by CSIRO, and widened by the House of Representatives Standing Committee on Science and Innovation (2006). This aims to encourage demand-driven collaborative commercialisation arrangements between SMEs and PSRAs. The proposal includes several features:

- provision of funds to SMEs with a track record of commercialisation to acquire technologies and technical advice; and
- repayment of funds if the project is successful.

This has some overlaps with the Commission’s suggestion of flexible collaborative arrangements and a significant overlap with some of the suggested intermediated services below. Given that they are to some extent substitutes, not all models should be adopted in fully scaled up versions, though initial experiments in their effectiveness may be worth adopting.

The AIC suggested the possible introduction of a subsidy for SMEs to reduce the cost and risk faced by SMEs in identifying and assessing new opportunities arising from the research sector (sub. 6, p. 9). It considered that providing funding to help SMEs cover the costs of essential external services to undertake opportunity identification, assessment, negotiation and commercialisation planning would have two benefits:

> Firstly, it encourages SMEs to look to the research sector as a catalyst for innovation and growth. If SMEs were left to fully fund this activity themselves it is likely many would just see this as an additional cost of research sector engagement and would simply avoid it. Given the significant investment in the public research sector, many SMEs rightly expect that appropriate mechanisms are also provided to help them engage with the entire research sector without employing experts to help them access this public asset.
>
> Secondly, it can assist SMEs to follow best practice in undertaking due diligence and subsequent commercialisation, as the costs in doing so is more affordable. It is the failure to adequately undertake such due diligence and commercialisation planning that currently leads to sub-optimal technology transfer outcomes by SMEs. (sub. 6, p. 9)

The Queensland Government (sub. DR203) noted a novel Dutch example of a ‘demand-pull’ mechanism for engaging SMEs, that, like the AIC suggestion, uses explicit subsidies to promote change. Aston University launched a similar, but more targeted voucher pilot scheme for SMEs in the English midlands in late 2006.[8]

The Dutch pilot program provided voucher-based subsidies to SMEs to acquire technological knowledge or to help identify relevant research problems for commercialisation (Cornet et al. 2006). The vouchers could only be used with universities and other public research agencies. The program was intended to overcome information problems that SMEs have when dealing with research agencies, help them formulate better research questions relevant to commercialisation, stimulate general engagement with research agencies by SMEs and engender changes in the cultures of the research agencies when dealing with SMEs.

Since the first Dutch pilot of the voucher scheme has been partly evaluated, it has interesting insights into (certain) demand-pull mechanisms (box 7.3). While novel, this program has several major potential deficiencies, highlighting some possible obstacles to the design of well-functioning ‘demand-pull’ mechanisms. While most of the new assignments were new (high additionality), it stimulated very little privately-financed spending by firms. The risk of such high effective subsidy rates is that the projects may have produced a value to the firm below the cost of the subsidy (similar to the risks posed by all hypothecated subsidies). The evaluation

[8] http://www.aston.ac.uk/about/news/061228.jsp accessed 7 March 2007.

indicates that the value of the vouchers has not been confirmed. But the fact that, despite the large subsidy, about one third of the firms were dissatisfied with the price/quality ratio of the services received is revealing. From a public policy perspective, the conditions for a net return from this voucher design look poor. Every voucher loses a certain €1500 (the inefficiency costs of taxes times the voucher value), must involve additional administrative and compliance costs, and looks likely to produce benefits to its users that are below its costs.

This program was a trial of particular kind of demand-pull arrangement. It does not mean that other programs would share its features or its distinctive disadvantages. But in all such schemes, consideration has to be given to the demanding requirements of sufficient additionality and marginal benefits to meet program costs.

New intermediaries

The creation of new intermediaries represents another approach to encouraging interactions with research institutions and the diffusion of technologies. There were many suggestions about the form of such intermediaries.

- The Australian Academy of Technological Sciences and Engineering argued that was a need ‘to provide substantially increased funding to support ‘outreach’ programs, based on the establishment of ‘Knowledge Exchange Networks’ (sub. DR169, p. 10)
- AusBiotech recommended it ‘work with the Federal Government to explore new and expanded intermediary concepts, such as the AUTM [Association of University Technology Managers] model (sub. DR175, p. 15).
- Howard Partners (2005a, p. 30) argued there was a strong case for supporting the development of technology brokers, who are knowledgeable about university and business research and can work with business in an independent intermediary role. The report argued that this should not displace the market oriented role of a growing industry of professional technology advisers.

Box 7.3 **A Dutch pilot voucher program**

Other than its restriction to SMEs, the Dutch Government applied few restrictions to applicants or the nature of activities supported by the vouchers, and did not require that an applying SME provide any details of what it wished to do or with which institution.[9] Only one voucher (worth €7500 each[10]) could be used per applicant (though firms could aggregate their vouchers, up to a maximum of ten). Vouchers were non-transferable. SMEs were not required to co-fund the subsidised activity, so that projects could receive a 100 per cent subsidy.

As interested applicants outnumbered the limited available vouchers (100 in the first round), vouchers were allocated on a random basis to applicants. This random assignation allowed a much more rigorous appraisal of additionality than is usually the case with programs of this kind. Comparing the extent of engagement with public research institutions by lottery losers and winners provides an estimate of additionality that is not tainted by the selection biases often biasing evaluations (appendix M).

The evaluation study (Cornet et al. 2006) found that around 80 per cent of the assignments with the research agencies were additional in the year of the voucher, but that the long-run additionality was likely to be less given that the voucher also brought a significant number of future projects forward. Mostly the subsidy induced no private expenditure. Three quarters of voucher users contributed none of their own funds, receiving a 100 per cent subsidy in their ‘purchases’ from the research institutions. (The only winners that spent less than the voucher value spent nothing.) Of those firms that did spend more than the voucher value, it is not yet certain whether this was induced by the subsidy, or might have happened in its absence. Overall, using figures from Cornet et al. (2006), the Commission estimates that induced *private* expenditure per €1.0 of subsidy is bounded between €0 and €0.20, with the average figure the most likely.[11]

Despite the fact that most firms received a 100 per cent subsidy, 30 per cent of total voucher users indicated that they were dissatisfied with the price/quality ratio of their arrangement with the research agency. This is not consistent with the subsidy generating high value outcomes for SMEs.

Source: Cornet et al. (2006).

[9] A second round of the voucher pilot allowed more advantageous bundling arrangements, increased the span of participating research institutions, and introduced a few conditions, such as exclusion of training courses and the supply of software.

[10] Some universities doubled the voucher amount with their own funds, so that the voucher was more lucrative to SMEs.

[11] Based on conservative assumptions about the behaviour of lottery losers, which is scant in the evaluation study.

The AIC drew attention to the *TechFast* model (which is already running as a small-scale program), an intermediary that links SMEs and research organisations. It summarised the program as involving:

> … firstly identifying established, technology-receptive SMEs that have a track record in a particular sector and are eager to grow via innovation, and then sourcing technologies, intellectual property (IP) and know-how with potential market impact, from research organisations that can be matched to the needs of the SME. The AIC provides a variety of services to facilitate the knowledge identification and exchange, including IP searches, market research, technical feasibility and project management needed to 'de-risk' the technology and facilitate successful knowledge diffusion and collaboration between PFROs and SMEs. (sub. DR133, p. 3)

TechFast provides a useful trial of the extent to which there is an untapped demand on the part of SMEs to either enter into collaborative relationships with research organisations or to adopt such technologies for their own purposes. If the program is successful in achieving its stated objectives, the firms that benefit from these services should capture sufficient commercial benefit to pay for the provision of these services, suggesting that the program may be able to be self-funding in the longer run.

The Commission notes the Australian Government has already decided to provide further funding to support firms in accessing intermediary services (DITR, sub. DR185, p. 15). DITR has recently finalised two contracts for provision of a pilot *Intermediary Access Program* with InnovationXchange and TechFast. Funding of $4 million has been provided for the pilot over 12 months to assist SMEs access the services of TechFast and InnovationXchange. The pilot should provide a useful experiment of the effectiveness and efficiency of such intermediation arrangements, and should be carefully evaluated in this context.

7.4 Policies aimed at businesses alone

This chapter focuses on constraints within universities because this is where the main concerns about commercialisation failures arise. As discussed in chapter 10, businesses have more appropriate incentives than universities for undertaking commercialisation of R&D, and that is one of their key routes to maximising business value. Ex ante, a firm that commits to R&D has already signalled its intention to commercialise. So if there is a systemic impediment to commercialisation, it will generally be revealed as an absence of R&D, not a failure to commercialise pre-existing R&D (the commonly claimed failure).

Nevertheless, several impediments relating to business commercialisation were identified by participants in this study that warrant brief discussion.

Entrepreneurial, management and leadership skills

Participants had various concerns about the availability and quality of entrepreneurial, management and leadership skills in Australia. DITR pointed to the implications of the Global Entrepreneurship Monitor (sub. DR185, p. 10). A comparison of the innovative propensity of Australian private business owners with other global entrepreneurship monitor high-income nations, suggests that:

> … the findings portray the generality of Australian owner-operated businesses as those that do not tend to introduce new knowledge and technologies into the market unless prompted by the need to gain a distinction — potentially a shallow and short-term and low value distinction — from a competitor. In essence this suggests Australian businesses adopt strategies that follow, not lead. (O'Connor 2006, p. 7).

Others have also suggested deficiencies:

- Jonson (2002, p. 80) asserted that Australia lacks a base of 'serial' entrepreneurs — that is, people who have a track record of successfully commercialising knowledge and technology.
- The Australian Business Leadership Survey (a joint research project undertaken by the Australian Institute of Management and Monash University) found that the least extensive culture for Australian organisations was innovation (Sarros et al. 2005, p. 43).[12] The survey also found that in terms of the climate for innovation within organisations, Australian managers are most supportive of creativity, but least supportive of providing sufficient resources for innovation (p. 59).[13]
- D'Netto and Bakas (2005) found that the effectiveness of management development within Australian organisations is mediocre. The study makes a number of recommendations on how Australian organisations could improve the effectiveness of management development (pp. 3–4).

But gauging the quality of 'entrepreneurship' is highly subjective. Some other indicators suggest that corporate leadership in Australia is not as poor as some suggest. The World Economic Forum's Global Competitiveness Report 2006-2007 rated Australia third in the world in the efficacy of its corporate boards and eighth in terms of its capacity to manage effectively through its auditing and accounting standards. Since the Karpin Report (Industry Task Force on Leadership and Management Skills) in 1995 the number and range of management-development

[12] Seven descriptors of organisational culture were used in the survey: social responsibility; competitiveness; performance orientation; supportiveness; emphasis on rewards; stability; and innovation.

[13] The dimensions of climate for innovation were support for creativity, non-conformity, support for innovation, and resource supply.

programs offered by tertiary, industry and professional bodies has expanded considerably (often financed partly by government through HECS). However, management schools in Australia are rated at the bottom end (17th) of developed countries by the World Economic Forum.

In considering any policy response to what is an uncertain problem, it should be noted that Governments already provide a range of information and programs to assist business, including the development of entrepreneurial and management skills. For example:

- Schools often now include education in entrepreneurial activities (and the BCA suggested additional possible elements of this; attachment to sub. DR204, p. 14).
- The Building Entrepreneurship in Small Business program, which is a suite of four competitive merit-based grant initiatives aims to support the development of 'a new culture of entrepreneurship by providing grants focusing on the ongoing improvement of Australia's small business operating skills' (AusIndustry 2007).
- The Australian Government also provides a range of information through the business.gov.au portal.

The grounds for any further significant initiatives are weak on several grounds. First, there is strong scope for the business community to engage directly with higher education institutions on the relevance of current management courses. Second, an active role by government in the provision or financing of management advisory services risks crowding out existing privately financed arrangements. Third, some of the problems identified by participants could not readily be overcome by government. For example, DITR (sub. DR185, p. 11) observed that many firms consulted during the current development of the Industry Statement 'recognised the need to upgrade their capabilities [but] were mistrustful of the consultancy industry and were looking for an 'honest broker' approach to assist them'. To the extent this is true, it is unclear why government is better placed to play this 'honest broker' role than their own industry and professional bodies.

Access to capital by start-up and early stage firms

There is a perception that inadequacies in access to capital for start-up and early stage firms — primarily from the venture capital industry — acts as an impediment to effective commercialisation of risky technologies. It is claimed that sources of risk capital in Australia are much poorer than in the US (CSL sub. DR177, p. 11).

Venture capital is a subset of the private equity market. Private equity covers professionally managed pools of funds seeking investment in high risk/high return opportunities in unlisted companies or situations. Venture capital covers seed, early stage and expansion stage investment in emerging businesses, usually IP based, with prospects for rapid growth, and with a higher risk/higher return profile than later stage private equity investment.

Venture capital brings with it not only access to finance but management expertise and contacts as well. Firms can also benefit from being able to tap into the established network of relationships that venture capitalists have built up over time. In these ways, venture capitalists may significantly improve the probability that start-up and early stage firms succeed in commercialising their IP.

The Australian Government has provided considerable support to the development of the venture capital sector (box 7.4). However, despite considerable government assistance over the last decade, there is a strong perception that the venture capital market in Australia remains relatively shallow and still an emerging market:

> … the venture capital sector of the venture capital and private equity [market] in Australia is under-developed. The seed, early stage and expansion stage investment in young business with rapid growth potential is characterised by low investment levels, a lack of capital formation and scale and relatively few investment managers with a proven track record. This is likely to be an impediment to the commercialisation of Australian innovation. In contrast, the later stage private equity sector is mature and receiving significant investor support. (DITR sub. DR185, p. 15)

The size of the private equity market in Australia is continuing to expand. The 2005-06 ABS survey (ABS 2007) of venture capital and later stage private equity in Australia reveals that, as at 30 June 2006, investors had commitments of $10.9 billion in 229 venture capital and later stage private equity investment vehicles. This is compared with commitments of $10 billion as at 30 June 2005 and around $8 billion as at 30 June 2004. The ABS survey reveals that in the five years to 30 June 2006, the level of commitments by investors in the private equity market has doubled ($5.3 billion to $10.9 billion).

However, the commitment figures include both the venture capital market and the later stage private equity market. In that sense, the overall picture could be misleading in terms of the strength of the venture capital sector. It appears that in the wake of the dot.com boom, most of the growth in the private equity market has occurred in the later stage private equity segment of the market.

In terms of investments in investee companies, the 2005-06 ABS survey reveals that, as at 30 June 2006, $4.3 billion was invested in 902 investee companies. This is compared with investments of $3.5 billion as at 30 June 2005 and $3.1 billion as at 30 June 2004. Figure 7.1 shows investment in investee companies, by stage of investee company. For the last five years, expansion capital comprised on average 65 per cent of venture capital (defined as seed, early and expansion). Thus even within the venture capital segment of the private equity market, a significant proportion of funds goes to the expansion of existing ventures rather than emerging commercialisation ventures.

Box 7.4 **Government support for the venture capital sector**

The main Australian Government initiatives in this area include:

- Innovation Investment Fund (IIF): a competitive investment program with the Government investing funds alongside funds from private investors up to a maximum ratio of two to one. Licensed private sector fund managers administer the pool of investment capital. An important aim of the fund is to develop fund managers with experience in the early-stage venture capital industry.
- Pre-Seed Fund program: a portfolio of four venture capital funds that invest in projects or companies spinning out from universities or Australian Government research agencies. The fund managers acquire an equity interest in each project or company, and provide management and technical advice to develop the commercial potential of the technology. Once the project has reached maturity, the managers divest their interest in the project or company to later stage investors.
- Venture Capital Limited Partnerships (VCLP): this vehicle is intended to attract certain non-resident tax exempt funds for investment in high risk start-up and expanding Australian businesses. VCLP registration provides flow-through taxation treatment for gains made on eligible venture capital investments. For an eligible partner of a VCLP, these tax gains are exempt from capital gains tax.
- Pooled Development Fund (PDF): PDFs raise capital and make equity investments in Australian SMEs. PDFs and their shareholders receive tax benefits on the income derived from their equity investments.

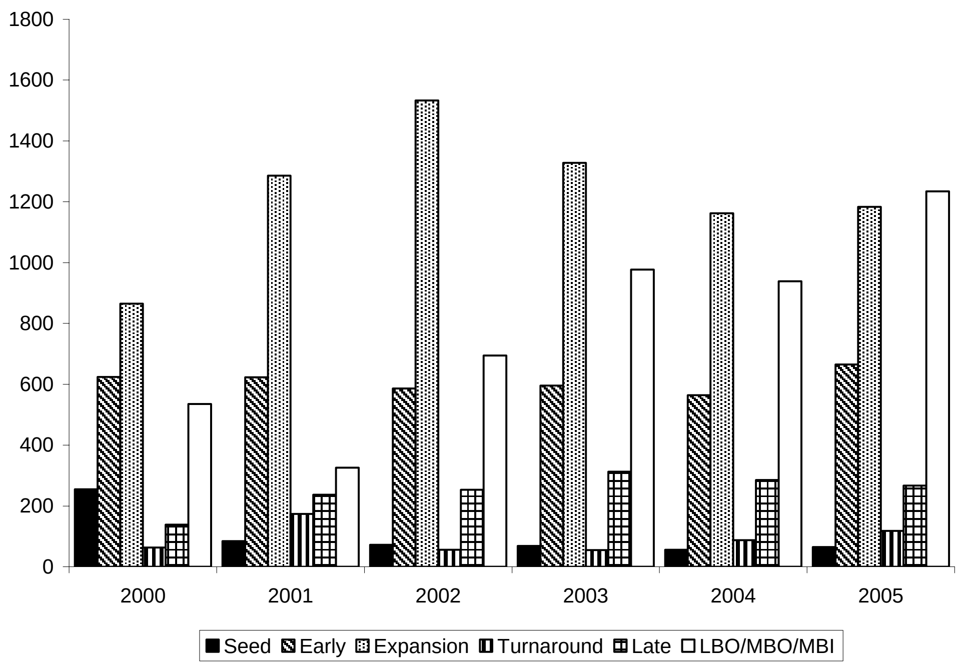
In the 2006-07 Budget, the Australian Government announced a number of further measures to stimulate activity in the venture capital sector.

- The establishment of an Early Stage Venture Capital Limited Partnership investment vehicle providing flow-through tax treatment and a complete tax exemption for income, both revenue and capital, received by its domestic and foreign partners. This initiative will progressively replace the exiting PDF program (which will be closed to new registrations after 31 December 2006).
- The operation of the existing VCLPs will be enhanced by: removing a range of restrictions including allowing investment in unit trusts and convertible notes as well as shares; relaxing the requirement that 50 per cent of assets and employees must be in Australia for 12 months after making the investment; and removing restrictions on the country of residence of investors.
- The Australian Government has committed $200 million for a further round of funding of the IIF program.

This is in the context of a broader suite of government programs at both the Commonwealth and State and Territory level that support the early stages of commercialisation. For example, the Commercial Ready Program; Commercialising Emerging Technologies; and the Renewable Energy Equity Fund.

Indeed, several participants argued the funds that are available in the Australian private equity market tend to be skewed towards later stage development. For example, AAMRI contended that one of the reasons the funding of venture capital consortia to identify commercial opportunities in academia has not worked well is because 'such consortia necessarily take a very short term approach to liquidity and therefore identify only late stage projects' (sub. 41, p. 5).

Figure 7.1 **Investment in investee companies, by stage of investee company, 2000 to 2005[a]**
(as at 30 June, $million)



Data source: ABS (2005d, *Venture Capital Australia 2004-05*, Cat. No. 5678.0).

a Data for 2006, while now available, are not shown in this figure. 2006 data include new categories of finance (pre-seed, start-up, early expansion and late expansion) and exclude three former categories (early, expansion and late). Clearly some of these are overlapping. Overall, the latest data show an increase in total funding of 22 per cent over 2005, but may be affected by these compositional and definitional changes.

Moreover, it is claimed that limited access to venture capital seriously constrains the ability of start-up and early stage firms to commercialise knowledge and technology (Research Australia sub. 33, p. 3; TGR BioSciences sub. DR140, p. 1). It is often suggested that lack of funding leads to other undesirable outcomes as well, such as firms issuing public offerings earlier than similar firms overseas; seeking to license their knowledge and technology relatively early (which can mean the value of the IP is heavily discounted); and adopting a cautious approach to patenting because of the difficulty of covering the cost of protecting their IP.

In sum, participants generally considered there was a strong case for supporting the venture capital market. For example, GlaxoSmithKline argued that:

> … the case for providing support to small and medium sized companies to access finance in order to grow has been well made. This is particularly important for the biopharmaceutical value chain in Australia where many small biotechnology firms, including those spun out of universities, would not have access to start up finance without some public support. (sub. DR154, p. 2)

A well functioning and self-sustaining venture capital market potentially provides a relatively efficient mechanism for identifying, screening and funding the most promising early stage commercialisation ventures. However, the general consensus appears to be that Australia still has some way to go in achieving this goal. The most significant impediments to the development of the venture capital sector in Australia are considered to be the scale of the existing venture capital industry, the relatively small pool of investment managers and the lack of a strong track record in delivering the kind of returns needed to attract major institutional investors to this high risk market.

It is also important to recognise that while the Australian venture capital market may be relatively shallow, Australian firms have developed a number of strategies for working within this constraint. For example, in the biotechnology sector, firms are raising money and/or establishing commercial presences in foreign capital markets; developing a revenue stream by leveraging aligned products and services; and merging with or partnering a foreign company (Herpin et al. 2005).

Some participants argued for further public policies to develop the venture capital market in Australia. AIC (sub. 28, p. 2) proposed that superannuation funds be required to invest 0.1 per cent of their assets in early stage venture capital. Mandated arrangements of this kind act as an effective tax on super companies, if they do not voluntarily wish to assume these venture capital risks. They would also establish a problematic precedent that could extend to expanded assumption of such risk or mandating of other apparently desirable portfolio investments.

The Queensland Government (sub. DR203, p. 4) suggested broader strategies for addressing early stage business finance, including:

- the skills of fund managers and inventors. However, it is notable that the Australian Government has already announced a Commercialisation Training Scheme to fund around 250 awards for research students undertaking higher degrees to study full-time for a semester to obtain graduate qualifications in areas relevant to the commercialisation of research and the management of IP (DEST 2006d); and

- the informal and ad hoc manner in which business angels and other non-equity market sources of business finance invest in early-stage businesses. However, it is hard to see what role government could seriously play in this part of the market.

A major obstacle facing more government initiatives in this area is that though it is possible that there may be market failures underlying shallow venture capital markets, these are hard to substantiate (chapter 3). It is not the role of government to ‘de-risk’ highly risky commercial ventures. This is also an area where good program design is hard to achieve (chapter 10). Quite apart from the usual business program risks for government of potential crowding out of private finance and administration costs, governments may also face the risk of subsidising projects with poor commercial prospects.

The Commission notes the current suite of programs in this area and considers that they should be subject to periodic independent review to ensure they have their intended effects, to learn and improve on any of their design features, and to increase the likelihood of net benefits.

Tax issues

Tax constraints to commercialisation were raised by several participants (for example, Group of Eight sub. 104). A recent report, released by the Intellectual Property Research Institute of Australia, examines the tax treatment of the commercialisation of IP with a particular focus on spin-off companies (Rider et al. 2006). The general conclusion of this paper is that the ‘current tax law presents considerable obstacles to the efficient commercialisation of intellectual property, and these obstacles will also negate the effect of the R&D concessions and the CGT concessions which are intended to encourage increased investment in intellectual property’ (p. 105).

Based on their examination of the Australian income tax system, the authors argue that the income tax law reveals an excessive tendency to impose taxation of unrealised gains, and double taxation of realised gains, from IP commercialisation. Areas the authors identified as causing problems include:

(a) up-front tax liabilities imposed on the initial contribution of intellectual property to commercialisation vehicles such as spin-off companies;

(b) inappropriate tax liabilities imposed on employee shares in start-up companies;

(c) unfavourable tax treatment of start-up losses where the commercialisation vehicle is a limited liability company;

(d) denial of tax deductions for many intellectual property commercialisation cost items, such as confidential information, trade secrets, trade marks, brands and good will;

(e) features of the general tax law which negate the intended benefits of specific concessions such as deductions for research and development and the venture capital and pooled development fund concessions;

(f) tendencies in the tax law to encourage relocation of intellectual property ownership and control to more favourable overseas jurisdictions; and

(g) tendencies in the tax law to discourage investment in entrepreneurial risk activity as an alternative to passive low-risk investment activity. (pp. 2-3)

The report makes some suggestions on how the tax treatment of the commercialisation of IP could be improved through amendments to the Income Tax Act. The authors acknowledge that considerable additional work is required to evaluate these reform options, including further investigation of the options of the US tax law provisions.

Tax issues relating to the commercialisation of IP or the commercialisation activities of wholly-owned university companies requires more detailed analysis than is possible in the context of this study.

7.5 An overall assessment of the impediments to commercialisation

There is evidence of widespread successful commercialisation in Australia in all sectors of the economy, which belies a commonly expressed pessimistic view of Australia’s capabilities. Indeed, there is a danger in tilting the activities of institutions whose role is not primarily commercial — universities and PSRAs — into greater commercial exploitation for financial gain.

But the Commission has identified a range of potential impediments to commercialisation and diffusion, particularly in universities, that may merit action:

- Greater consistency in the management of IP could reduce transactions costs for businesses dealing with them.
- Some universities have poor governance structures and incentives for facilitating commercialisation.
- Only the largest research universities are likely to be able to develop dedicated commercialisation arms of sufficient scale and expertise to operate effectively. More flexible arrangements — including the use of private sector

intermediaries — may allow universities to draw on the commercial expertise they need in a more efficient and cost-effective way.

- Universities can sometimes find it difficult to sell commercialisable IP to business because the concepts have not been adequately demonstrated (‘proof of concept’) and this may warrant some public funding.
- There is likely to be some scope for universities to improve their linkages with firms in other ways, but this does not necessitate a dedicated new funding stream, such as third stream funding. Current metrics used to identify problems in such linkages tend to accentuate only specific kinds of mechanisms, such as company spinoffs or IP licensing, and fail to recognise the importance of diffusion arrangements that already work well, such as informal networks, conferences and publications. But new intermediary arrangements aimed at better diffusion are being trialed and will provide a useful experiment.

Claims that public support are required for a whole range of other apparent problems in the commercial exploitation of know-how — such as inadequate venture finance and poor entrepreneurship and management skills — are either ill-founded or overlook programs that already exist.

8 Performance evaluation and benchmarking

Key points

- Performance evaluation and benchmarking is a vital tool in the allocation of public (and private) funds firstly to programs and, secondly, to projects within those programs.
- Effectiveness measures assess a program's outputs and outcomes in terms of its defined objectives, and efficiency measures assess resource use.
  – Measures can be usefully applied in three ways: backwards looking evaluation of results; monitoring of current progress; and estimation of future performance.
- With some activity, for example basic research, suitable output measures can often be used as helpful proxies for measures of outcomes.
- Performance evaluation is enhanced by: specifying desired outputs and outcomes consistently; factoring performance measurement into initial program design; considering how best to assess quality and impact; providing appropriate independence and transparency of assessment; and ensuring that measurement results feed back into program design.
  – Isolating the effects of public support from the many other factors which can affect outputs and outcomes is important but difficult.
  – Performance measurement system design should trade off the advantages of greater precision against additional administrative and compliance costs.
- The adequacy of existing performance evaluation and benchmarking is mixed.
  – There are some shortcomings, particularly in relation to business and rural programs.
  – The outcomes from higher education block funding are not transparent and thus are difficult to assess.
  – Some arrangements appear very sound in principle, but scope remains for further improvement.

Previous chapters have explored the evidence relating to the nature and extent of the economic, social and environmental impacts of public support for science and innovation. This chapter is more concerned with *frameworks* for performance evaluation and benchmarking. In particular, there is a focus on assembling information relevant to whether public support returns a net community benefit.

The terms of reference request the Commission to report on 'whether there are adequate arrangements to benchmark outcomes from publicly supported science and innovation and to report on those outcomes as measured by the benchmarks'. The chapter assesses the extent to which, in an individual program context, adequate arrangements have been established to monitor, measure and report on the effectiveness and efficiency of public support for science and innovation. 'Benchmarking' can also be interpreted in a 'best practice' framework — through comparing, for example, the performance of a firm with others or, at a broader level, in comparing the performance of countries (chapter 9).

The relevant terms of reference focus on 'outcomes' from publicly supported science and innovation. As discussed further below, however, much performance evaluation will beneficially be, or necessarily have to be, related to program and project 'outputs'.

The outputs of research programs and the outcomes that result from that research should ideally be assessed in the context of relevant objectives. These can be set at various levels, for instance: at an economywide or community-wide level; for broad programs such as Backing Australia's Ability; for narrower programs such as the business R&D tax concession; and for individual projects. Given this, performance evaluation should take account of the level at which the objectives are pitched.

- The broader the level, the more necessary it will be for evaluation to trace the direct and indirect positive and negative flow-through impacts of public support on economic, social and environmental outcomes, including the opportunity costs of providing that support.
- At the narrower level, it will be more appropriate for evaluation to concentrate on the direct and immediate positives and negatives of a particular form of support for a particular program or project, leaving aside many of the more indirect and wider impacts. (In the terminology used in this chapter, funding for the CSIRO, for example, would be considered as *program* funding, which that organisation itself would then allocate as *project* funding.)

The following discussion proceeds largely, but not entirely, in the context of performance evaluation for the more narrowly defined programs and projects.

Given that public support is extended in the belief that it will influence outputs and achieve outcomes, a central issue concerns how to establish useful performance measures that isolate, as far as possible, the effects of such public support from the many other factors which can also affect those outputs and outcomes.

8.1 The importance of evaluation

Economic theory can provide rationales for the provision of public support to science and innovation activity in general (chapter 3) and, at a more detailed level, to particular programs and projects. However, theory provides little if any practical guidance about how much support is appropriate in aggregate and how that support should be distributed across programs (chapter 9). Assessment of these matters can be facilitated by performance evaluation and benchmarking.

Indeed, appropriate and effective performance evaluation of the outputs and outcomes from public support can help to achieve a number of goals.

- It provides a guide to the success, or otherwise, of public support in achieving the objectives sought.
  - In turn, this allows evaluation of whether support for particular objectives could profitably be increased, or should be reduced.
- Where comparable data for other countries is available, guidance can be given about whether Australia is achieving 'best value for money' from available funding and whether there is scope for improvement in outcomes.
- Comparisons between programs within a country are facilitated, thus guiding the allocation of funding between them.
- At a project level, benchmarking of expected outcomes could guide the initial allocation of funds to projects by recipients of public support. Setting performance indicators and targets can provide impetus to researchers to perform well. Evaluation of actual project outcomes could then assess whether expected outcomes had, in fact, been achieved and whether funding should be reallocated within the program.

Performance measures can be most useful when they can be used to infer information about the marginal impacts of public support — the change in net benefit that is, or would be, occasioned by a change in the level of public support. Then, theoretically, public support could be allocated in such a manner as to maximise the overall net benefit from its provision (chapter 9). But although measurements over time can sometimes proxy for marginal effects, in practice, measurement of marginal impacts, either for public support in aggregate (chapter 4) or through performance measurement of particular programs, is very difficult. Nevertheless, much useful information can be garnered from average measures.

8.2 A conceptual framework

A simple conceptual framework is useful: a science and innovation program is established in response to a set of objectives; the program transforms a set of inputs (including public support) into a range of outputs; and these influence outcomes. Outputs and outcomes may also be affected by a range of influences 'external' to the science and innovation program in general, and to the public support component in particular. (In this chapter, the term 'impact' can usually be used interchangeably with the term 'outcome'.)

Although this model separates 'outputs' and 'outcomes', the Steering Committee for the Review of Government Service Provision (SCRGSP 2006) notes:

> Outcome indicators provide information on the impact of a service … and on the success of the service area in achieving its objectives. Outputs, on the other hand, are the services delivered.
>
> While the … focus [is] on outcomes, they are often difficult to measure. The Report therefore includes measures of outputs, with an understanding that there is a correlation between some outputs and outcomes, and that measures of outputs can be proxies for measures of outcomes. (p. 1.13)

Two broad categories of performance measure are defined.

- Effectiveness measures assess how well the outputs and outcomes achieved meet program objectives. Of course, the weaker the links the less meaningful effectiveness measures will be.
- Efficiency measures assess how well resource inputs are used.

Each category can be applied in three separate ways: backwards looking evaluation of results; monitoring of current progress; and estimation of future performance. (And, conceptually, each could be targeted at average or marginal impacts.)

These detailed performance measures need to be supplemented by high level review of the rationales for public support and their translation into objectives for particular programs.

A significant criticism of the way such frameworks are applied to performance evaluation and benchmarking centres on the narrow interpretations often given to the concepts of outputs and outcomes. They may, for example, focus on measurable outputs and economic outcomes such as papers produced and their quality, patents registered, students trained, conferences attended, new products developed, and the extent of cost reduction and productivity growth, to the exclusion of wider relevant social and environmental influences, which may be more difficult to measure. Graeme Pearman Consulting, for instance, considered that in the context of science, ‘the concept of wealth needs to include such components as public scientist/technological literacy, international awareness, policy sophistication and inclusiveness …’ (sub. 86, p. 11).

In the Commission’s view, the evaluation framework should embrace, where relevant, social and environmental outcomes, reduction of risk, preparedness to meet uncertainty, and the maintenance of strategic capability and infrastructure.

8.3 Improving evaluation

This section briefly discusses a number of criteria useful to the assessment of the adequacy of current performance evaluation arrangements and how they might be improved.

Given the rationales for public support for science and innovation (chapter 3), program and project objectives should focus on such things as overcoming market failures, capturing spillover benefits, dealing with social and environmental risks (including preparedness), serving the research needs of government agencies, and making a contribution as a global citizen. As well, public support can help to build the human capital and infrastructure bases necessary to pursue these objectives. In turn, effectiveness measures and key performance indicators should be developed in accordance with those rationales and objectives.

As an example, an objective of *increasing expenditure on R&D by business* has no merit in itself. This is because it does not reflect the rationales for public support and thus obscures important evaluation issues, such as causality/inducement. An alternative objective of *increasing net positive spillover benefits available to the community through enhancing levels of business R&D* would be more useful. This would serve to focus evaluation on the net community benefits of public support, while treating enhanced business R&D expenditure as just an output which contributes to the underlying goal.

Further, the nature of activity accorded public support and the form in which that support is provided should also influence performance evaluation.

Basic research, for example, focuses on investigation for the sake of curiosity, improving the community’s stock of knowledge and the development of new experimental techniques. Outcomes from such work are not necessarily expected in the short to medium term and its practical usefulness can sometimes be manifested in unforeseen and serendipitous ways. Indeed, often such basic research is undertaken on the understanding that there may well be no apparent impact from a short to medium term viewpoint. When evaluating such activities, the focus is more appropriately on outputs, including quality, rather than outcomes, as well as, of course, assessing the efficiency of the use of resource inputs to achieve those outputs.

With applied research, in contrast, practical outcomes are usually expected in a reasonable timeframe. Evaluation should focus more on achieved outcomes, rather than outputs. It should specifically attempt to address the causality issue — in effect, to demonstrate that public support has 'caused' the desired outcome. Support for BERD, rural research, the CRCs and such programs as ACIS provide examples of where, after appropriately defining objectives, it is reasonable to focus more on outcomes than outputs — and, in particular, on the extent to which public support has been a factor in enhancing outcomes.

Assessing causality

According to the OECD, four basic problems affect the relationship between research outputs and its outcome effects (box 8.1) — these can be broadly summarised under the term 'causality'. Dealing with this issue is central to appropriate and useful effectiveness measurement.

Box 8.1 **Complexity of relationship between research and its effects**

According to the OECD, exploring why the relationship between research and its effects is complex highlights four 'basic' problems.

- *Timing* — the effects of research are often manifested long after the research has been completed and the connections obscured.
- *Attribution* — a given innovation may draw upon multiple research projects and a given research project may impact upon multiple innovations. In drawing pathways between them it is also the case that an innovation depends upon many inputs other than research before market or social effects are realised.
- *Appropriability* — the beneficiaries of research may not be the same people or organisations who performed it so it may not be obvious where to look for effects.
- *Inequality* — the distribution of impacts in a given project portfolio is typically highly skewed. A small number of projects ('blockbusters') may account for the majority of effects, while around half often do no more than advance knowledge in a general way. This has implications for sampling strategies.

Source: OECD 2006a, p. 4.

Ideally, it would be preferable to develop a range of effectiveness measures that can directly measure the effect of public support on outputs and achieved outcomes.

However, a range of influences can make it difficult to assign attribution to public support (or, indeed, to any other factor(s)). Using business R&D as an example:

- an increase in total R&D activity (with enhanced spillovers) might reflect an underlying trend, developing technological opportunities, more favourable economic conditions, or an improvement in profitability and the ability of firms to invest, just as much as greater public support; whereas
- a decrease in total R&D activity might disguise a situation of even lower such activity in the absence of public support.

Further, achieved outcomes depend not only on the effects of immediate public support, but also on such influences as the existing 'stock' of relevant R&D (domestic and/or foreign), the competitive environment, and institutional and regulatory factors. Elapsed time between program inputs and achieved outcomes can be lengthy. For example, it has been estimated that in the CRC program there is an average lag of some 9 years between funding support and achieved outcomes (Allen Consultancy 2005a, p. ix). Some basic research may only pay dividends in the form of measurable impacts after many years, if at all.

In commenting on such issues, the New South Wales Government considered that:

> Performance measures must recognise the long-term nature of the impacts from research, and that many benefits, especially environmental and social impacts, are difficult to track and measure. A measurement system will also have to resolve the issue of attribution and the broad span of the commercialisation or adoption pathways. (sub. 91, p. 15)

Indeed, some forms of outcomes may not be apparent to external observers, being internalised within the individuals, firms or institutions receiving public support. This does not mean that such outcomes are not valuable — they can form the building blocks to future gains for particular groups or for the community generally — but just that they cannot be reliably measured or estimated.

Given this attribution difficulty, there can be incentives for recipients of funding to ascribe changed outcomes almost 'automatically' to the support program, thus falling for what is described by the OECD as the 'project fallacy' (OECD 2006a, p. 42). However, this leads to inaccurate and misleading performance measurement and assessment.

The causality problem is less intractable that it might first appear, however.

- Appropriate professional judgment such as peer review can shed some light on output quality and impact. Similar professional judgment is drawn on in many fields, including education and medicine. Appropriate ground rules for such judgment, including moderation where appropriate, can build confidence in the rigorousness of the process.

- Some categories of science and innovation activity are predominantly funded by government — for example, some public sector research agencies (PSRAs) and much of the basic research of tertiary institutions. Of course, this does not necessarily make the identification and measurement of particular outcomes much easier nor eliminate the causality problem entirely — external factors would still need to be accounted for.
- Similarly, much research undertaken to maintain scientific capability and to address defence and environmental risks may simply not be undertaken without public support.
- Finally, as discussed in more detail below and in chapter 10, another approach is to provide public support in a form which inherently evokes additionality of outcomes — for instance, if the program objective is to encourage useful additional spillovers for the community, then support could be conditional on recipients demonstrating that such additional spillovers had been or would be gained.

Assessing quality

The assessment of 'quality' has assumed greater importance in the evaluation of many programs of support for science and innovation in Australia. Quality evaluation may become even more central in future, through developments such as the proposed Research Quality Framework (RQF), for example (see below and chapter 12).

Although quality, of course, is relevant to both outputs and outcomes, it is best to regard it primarily as an output characteristic. Even though there will always be legitimate interest in promoting research efficiency and quality, good outcomes may sometimes be obtained almost irrespective of the quality of program activity through serendipitous discovery, for example. Further, treating quality as an outcome characteristic could lead to this important dimension of activity being overlooked in performance evaluation in basic and strategic research where no particular short or medium term outcomes are targeted (see below) and where the focus is thus on outputs.

A cost–benefit framework

As discussed in chapter 12 in relation to funding for higher education research, performance evaluation and measurement systems themselves need to be considered in a cost–benefit framework, assessed against a number of possibly conflicting criteria.

To put it simply, it would be counterproductive to establish detailed and expansive systems to assess quality and impact if the gains compared to simpler systems were to be outweighed by extra administrative and compliance costs, greater opportunities for gaming or even more intrusiveness.

Forms of assistance

In many cases, choosing forms of support which most directly target assistance rationales not only improves program outcomes but also facilitates useful performance evaluation. For example, as the 175 per cent tax expenditure deduction for additional R&D relates more directly to the underlying rationales for public support than the 125 per cent deduction for *base* R&D, performance evaluation measures can more readily deal with the causality issue.

Further, evaluation will be enhanced if program rules are structured to maximise the incentives for participants to contribute to the intended outputs and outcomes while minimising their opportunities to manipulate the funding allocation rules to the detriment of program objectives. For example, assistance simply based on the number of research publications produced would overlook the more important quality and efficiency dimensions.

These issues are discussed more in chapters 10 and 12.

The role of project case studies

Many programs, including for example the CSIRO, the RRDCs and the CRCs, include case study evaluations of the impacts of selected projects as part of their performance evaluation arrangements. As summarised in box 8.2 (also see chapter 4 and appendix I), however, there are significant issues in using such analyses as indicators of the community benefits of public support. Indeed, in that context, they may well only be useful as a supplement to more focused program-wide evaluation.

Aggregation and weighting issues

As noted, performance evaluation can proceed at various levels, including review of the rationales for public support, prospective and/or retrospective evaluation of broad funding mechanisms, the programs themselves and for individual projects within programs.

Box 8.2 **Relevance of selective project case studies**

A number of agencies measure the economic impacts of particular projects in terms of such measures as the social rate of return, net present value and/or benefit–cost ratios. Essentially, although their expression varies, all such measures attempt to measure benefits net of costs.

But there are a number of problems in using such measures as indicators of the *net community benefits of public support*.

- If measurement focuses on those projects with the highest net returns it gives a misleading picture of program impacts. Most programs could be expected to have a share of 'failures' or low/negative return projects ex post.
- Such measures may not address the impacts of the marginal dollar either — that is, the net benefits of extra spending at the program level.
- They often measure the impact of total project funding, rather than just those impacts consequent on public support. That is, they often fail to deal adequately with causality/additionality issues.
- Often, they do not factor in opportunity costs, including the efficiency costs of taxation.

Even as indicators of the net benefits of *particular* projects, such measures can have problems.

- Benefits are difficult to judge and measure, particularly those for future years. The time for which an outcome will be inherently useful — for example, before it is overtaken by outcomes from other projects or 'depreciates' in some other way — is often uncertain. Choice of a discount rate will be important. Difficult judgments need to be made about how much of an outcome to attribute to the project, how much to attribute to forerunner projects and how much to attribute to external factors. There can be a tendency to over-attribute benefits to the project (the 'project fallacy') — for example, to attribute all profit arising from the production and sale of a new product to its R&D genesis, ignoring the contribution of other factors of production. The bottom line is that benefits can be easily overestimated.
- Cost issues arise as well — for example, in judging which overhead and indirect costs to include.

In summary, selective economic impact evaluations can be quite useful as indicators of the net benefits from particular projects, if done well. But they must be used with considerable care as indicators of the net community benefits of public support provided to particular programs.

Often, questions of aggregation and weighting will arise. For instance, higher education institutions and research agencies such as the CSIRO may literally have hundreds of projects proceeding at any given time. Further, with business programs, each firm could be considered a separate 'project' in a sense. How should performance in relation to such individual projects be aggregated to give a measure of overall program performance, particularly where occasional 'failure' at a project level can be expected and where separate but concurrent projects often deliver their outputs and achieve outcomes at different periods of time?

The answer partly depends on the nature of activity undertaken. In some cases, simple counts of successful outcomes falling within range (possibly against pre-specified targets) may suffice. In others, more sophisticated summation and weighting measures may be appropriate. Frequently, however, informed professional judgment will be required.

Performance assessment of programs which receive funding from more than one source can be complex — particularly where a variety of funding criteria are used with different conditions attached — as it will not always be possible to ascribe outcomes to particular funding sources.

Retrospective or prospective assessment

As noted, performance assessment and evaluation can take place in three different timeframes — looking back, looking forward, and current monitoring. There is a role for all three forms.

Much evaluation is ex post evaluation. As noted, this can then be used to inform such decisions as future funding levels, revisions to assistance mechanisms and changes in administrative and compliance rules. As such, ex post evaluation is critically important.

However, there is also a place for ex ante evaluation/estimation, particularly in the allocation of funds to projects. For example, the ARC/NHMRC processes assess likely outputs/outcomes in advance through peer review of proposals and allocate funding accordingly. Similarly, some business programs also use an evaluation of likely outputs and outcomes in allocating funds to particular firms.

Further, there is a critical role for monitoring work in progress, especially in large organisations such as higher education institutions and the CSIRO, where there is a multiplicity of projects under way at any one time. Where progress is unsatisfactory, an informed decision can then be made about whether to proceed or not.

Frequency

While it is reasonable to expect that efficiency of resource use should be kept under annual or more frequent review, a number of considerations will need to be balanced in considering how often comprehensive effectiveness evaluation should be undertaken.

- Outcomes may take years to emerge (even though outputs should be observable more frequently).
- Evaluation can be expensive, particularly where extensive data has to be collected, special methodologies need to be employed or the review workload is otherwise likely to be high, for example when extensive peer review might be required.
- Comprehensive review itself can take considerable time.

In some circumstances, effectiveness evaluation can be relatively simple and quick, especially where forms of public support are compatible with outcomes sought; and where substantial reliance can be placed on output measures rather than outcomes.

The New South Wales Government stated that it:

> … recognises that the recipients of public sector research funds should be required to undertake submission and reporting activities that demonstrate prudent management of funds, and outcomes from the investment. However, the quantity and frequency of reporting should be in step with the funding levels, and the projects' scale. (sub. 91, p. 13)

In summary, it is difficult to be prescriptive about the optimum frequency of performance evaluation, especially for effectiveness measures of outcomes. However:

- the evaluation of a program's past performance, objectives, future desired outputs and outcomes, and future levels of public support, should be undertaken periodically — consistent with the costs and benefits involved. Major programs, for example, should be reviewed every three to five years;
- individual projects should be monitored with sufficient frequency to reassure the program sponsors that satisfactory progress is being made; as well, they should be assessed after completion for their effectiveness and efficiency; and
- relevant institutions should report on their own performance at least annually.

Independence and transparency

A major purpose of performance evaluation is to assess the net returns to the community as a whole of public support provided for science and innovation. Thus, there is a strong case that performance evaluation, at least at the program level and above, should be conducted independently with reports and recommendations being made available to the public.

Independence of evaluation is not always easy to achieve in practice. Terms of reference, or non-transparent 'riding instructions', may favour the status quo or seek to protect the interests of a program's sponsoring agency. Sometimes evaluation will necessarily have to draw on the experience of program participants or rely on the assessments of expert peer reviewers, for example. While review procedures can help to reduce bias, it is hard to eliminate completely. This makes transparency all the more important. (Of course, it is recognised that in particular instances questions of privacy/security, commercial confidentiality, and so on, may arise.)

The quality and transparency of program evaluation can be reinforced through such procedures as establishing independent steering committees to guide evaluators, agreement up front on a timetable for publication of the evaluation, and through independent third party peer review of the evaluation report. Inter-departmental working groups could also be useful.

A further possibility is to take responsibility for program review completely away from program operators and their sponsoring agencies. For example, an outside body — such as the Auditor General, or a small agency established specifically for the purpose — could be given responsibility for program review. Such a body would set relevant terms of reference, engage appropriate independent reviewers, and establish appropriate review procedures. This would enhance the quality of program evaluation and benchmarking, with minimal, if any, additional cost. (See also section 10.5.)

Feeding assessment back into improvement

Finally, performance evaluation and benchmarking will only be useful if the findings are drawn on to enhance the future benefits of public support for science and innovation. With major reviews, this requires governments to commit to a public response to any relevant recommendations for change. And at a lower level, the results of performance evaluation can be used for fine tuning program arrangements.

8.4 Adequacy of current arrangements

This section responds to the terms of reference which request the Commission to report on whether the benchmarking and reporting arrangements for the outcomes from public support are adequate. (Some of the programs discussed below are described in more detail elsewhere in this report.)

Broad level programs and arrangements

National Research Priorities (NRPs)

Australia's NRPs and their associated priority goals, developed in 2002 and enhanced and refined in 2003, are listed in chapter 9.

The priorities and priority goals are not ranked in importance in any way. Neither are they prescriptive, nor do they provide quantitative goals in measurable terms (for example, in terms of expenditure targets). Further, they do not apply to industry R&D programs or to university block grants.

However, 'all Australian Government research and research funding bodies are expected to contribute to the national research priorities, within their existing mandates and missions'. Each of these bodies was expected to prepare an implementation plan to 'describe how they propose to implement national research priorities'. Each plan in turn was required to 'identify performance measures to enable the impact of the national research priorities initiative to be assessed. Performance measures should include outcomes, outputs and inputs components' (quoted from DEST website).

Research and research funding bodies are required to report progress against these plans in appropriate documents, including in the annual *Innovation Report*, and to report annually to the Government. These reports typically assess how the funding body's activities line up in broad qualitative terms against the national priorities. As well, they usually objectively report expenditure and trends in expenditure classified by research priority and also, sometimes, by simple measures such as numbers of projects.

Given the purpose and nature of the current NRPs it is not surprising that performance reporting against them is relatively simple. This is all the more so given their current non-prescriptive nature, their lack of specification of the expected public benefits arising, and their non-quantitative expression (in the broad and at an agency level).

As discussed in chapter 9, the Commission considers that NRPs should continue to be expressed as high level direction statements of the areas in which the Australian Government considers science and innovation activity in Australia should be focused. In the Commission’s view, there are advantages in avoiding the added prescription that a move towards greater specificity in Australia’s NRPs would bring. Accordingly, there is little to be gained from attempting to enhance the ‘sophistication’ of performance evaluation and reporting associated with them.

Backing Australia’s Ability

The terms of reference refer to the Backing Australia’s Ability (BAA) program, established in 2001. Funding levels under the BAA umbrella were boosted in 2004 — the original program provided some $3 billion over a five-year period from 2001, while the revised arrangements provide for some $8.3 billion over the 10 years to end 2010-11. In total, BAA now annually accounts for some 20 per cent of Australian Government funding for science and innovation.

BAA was implemented in a number of ways, including by the establishment of new programs with associated funding allocations, the cessation of, or significant revisions to, some existing programs, and by augmenting funding for many existing arrangements.

The Government’s objective has been to ‘support … innovation by boosting funding to key areas and introducing significant new initiatives’ (BAA 2001, p. 14). According to the initial strategy document:

> *Backing Australia’s Ability* has been developed with full understanding of our current strengths and weaknesses, recognition of relevant national and international factors and a comprehensive assessment of likely conditions in the future. … This strategy supports the essential ingredients for a dynamic and productive innovation system. It focuses on the Government’s commitment to three key elements in the innovation process: strengthening our ability to generate ideas and undertake research; accelerating the commercial application of these ideas; and developing and retaining Australian skills. (BAA 2001, p. 14)

However, while the 2001 plan, and its 2004 successor, draw on previous reports and studies, the plan documents themselves do not explicitly link funding provision, either for individual programs or in total, to those general goals.

The terms of reference note that the Commission’s research study ‘will complement the ongoing and planned reviews of BAA programs’. The Commission understands that this refers to a planned review of BAA as a whole, following the Commission’s report, as well as to ongoing reviews of the individual programs that are supported, at least in part, by BAA funding. Current BAA progress is commented on in general terms in the annual Innovation Report.

The general nature of BAA's objectives, and the lack of any linkage between these objectives and specific programs and funding allocations, make a useful review of BAA as a whole very difficult. Nevertheless, such a broad level review could consider whether there would be merit in rebalancing the BAA's various components and revising funding levels accordingly.

In practice, such broad review, however, would have to draw heavily on more detailed reviews of each component program. This emphasises the importance of working towards overcoming the present inadequacies in performance evaluation in several of those programs (see below).

Public sector research agencies

As with higher education institutions (see below), public sector research agencies (PSRAs) operate under a 'hybrid' funding model, involving block grants from governments together with monies attracted on the basis of performance, or likely performance, both from governments and private sources. The extent of funding that is directly based on performance varies over time and among agencies.

It could be expected that a PSRA should focus on work likely to have wide community benefit. However, a focus on such work is necessary but not sufficient for the ongoing maintenance of such a public sector organisation — this depends on the particular nature of the research issues addressed as well as how it performs relative to the possible alternatives (such as contracting out). Hence, continuing performance evaluation of effectiveness and efficiency is crucial for such an organisation, especially for the publicly funded component.

The following discussion draws on, as one example, the CSIRO, which is Australia's major PSRA, and which in 2005-06 received public funding of some $600 million from the Australian Government. Such appropriations make up about two-thirds of the organisation's revenue. A second illustration concerns the DSTO, the R&D arm of the Australian Defence Organisation. In 2005-06, its government funding, delivered as an integral part of the defence budget, totalled some $350 million. (Further information about both these organisations is presented in chapter 11.)

CSIRO

CSIRO has a performance measurement framework which is based on a number of performance indicators under 24 objectives clustered under 6 strategic goals (see CSIRO 2003, 2005b). Targets are set for many, but not all, of the performance indicators. Five elements of performance are distinguished: strategy implementation; program performance; science highlights; organisational health; and outcomes.

In the CSIRO context, program performance relates to the achievement of annual performance goals detailed for each of its many 'programs' (these are better described as 'sub programs' in the terminology used throughout this chapter, with the organisation itself being the 'program'). Input and output measures are generally reported under the organisational health element, whereas outcomes are reported under its own heading. The organisation conducts a 'science assessment review' process, aimed at assessing the quality of its scientific capabilities and the impact of its research performance (box 8.3) — there are similarities between this process and the proposed RQF (see below and chapter 12). It also assesses the 'economic impacts' of selected research projects. Collectively, this performance framework guides the CSIRO in setting strategies and priorities, allocating funds to sub-programs and to projects, monitoring progress of research and measuring outputs and outcomes. Much of the resulting information is reported publicly.

DSTO

As noted, DSTO is the R&D branch of Australia's defence organisation (ADO) and is funded through it. Indeed, about 90 per cent of DSTO's income comes from the ADO. The nature of its work is somewhat different from that of a PSRA such as the CSIRO. Such a direct ownership relationship has implications for performance assessment.

A recent external review of DSTO commented that:

> DSTO's role in securing Australia cost effectively means its primary output is a more cost effective defence capability — not the supply of public good-based research outcomes of direct value to the wider community. Accordingly, this output should be its primary basis for accountability. (Trenberth 2004, p. 99)

The review considered that as it is 'intimately connected to the ADO', DSTO 'is more like an industry research group than a university' (Trenberth 2004, p. 1).

As a result of that review, recent changes have been made to promote greater interaction with industry to diffuse and commercialise DSTO research.

Nevertheless, it still remains true that the DSTO's prime focus remains on serving the ADO.

Box 8.3 The CSIRO's Science Assessment Review process

As part of its 2004-07 triennium funding agreement, the CSIRO undertakes reviews of the quality of its scientific capabilities and the impact of its research performance. These are currently done on a divisional basis, with each division to be assessed once over the three year period. To an extent, the proposed RQF mirrors processes already undertaken in these reviews — however, in contrast to the proposed RQF, these existing CSIRO reviews have no immediate broad funding implications, although they do inform internal resourcing allocation decisions.

In brief:

- the relevant division provides information on the basis of which assessments can be made, grouped by appropriate subdivisional units (groups);
- the assessments are undertaken by panels of 3–5 external (to the CSIRO) experts, predominantly from overseas, including at least one member from an end-user organisation, plus the CSIRO's executive director of science planning; and
- groups are assessed on two criteria — research community impact, and industry/community impact — each against a five point scale.

A range of other processes are used by the CSIRO in monitoring and assessing its research quality and impact. These include citation based analysis, benchmarking performance against other organisations, and formal cost–benefit evaluations.

Source: Information provided by the CSIRO.

The nature of the relationship throws considerable onus on the ADO to ensure that it is getting good value for money from DSTO and that it cannot do better, taking its security and strategic concerns into account, from contracting scientific work to outside organisations, either directly or through the DSTO itself (chapter 11).

Adequacy

Although the Commission has not made a detailed evaluation of each PSRA, there is no evidence that the performance evaluation and measurement processes used by those bodies are not broadly conceptually appropriate. Considerable improvement has been made in recent years, particularly through bringing reporting into an output/outcomes framework. Some arrangements — for example, those of the CSIRO — are particularly notable for their structure and breadth. Improvement can be expected as programs and institutions develop their performance evaluation frameworks and their ability to specify and measure relevant key performance indicators, particularly in relation to the rationales and objectives for public support.

Even further improvement, however, could be gained by enhancing the independence and transparency of assessment, where appropriate.

Another safeguard is the requirement under the Triennium Funding Agreements for 2004-07 for the Australian Institute of Marine Science, the Australian Nuclear Science and Technology Organisation and the CSIRO to undertake a continuous process for assessment of research performance consistent with the objectives of the RQF process (sub. 87, p. 30).

Higher education institutions and programs (including the ARC and the NHMRC)

Science and innovation activity, including R&D activity, in higher education institutions is often part of a broader functional responsibility which includes undergraduate and postgraduate teaching. Given this, and the basic research focus of much of their activity, defining expected outcomes in other than very general terms becomes difficult, even allowing for the relatively recent emphasis on increasing commercialisation (chapter 7). For this reason, much of the past and current performance evaluation of higher education institutions relies on output measures, rather than on the assessment of outcomes.

Each higher education institution has its own internal procedures for allocating funds (including block grants) to research, for monitoring research in progress and for assessing outputs and outcomes. These arrangements are reported by the institutions to DEST in Research and Research Training Management Reports. The latest publicly available are for 2005. But as far as the Commission is aware, there is currently no published comprehensive retrospective evaluation of the quality and impact of higher education research, nor of that funded specifically from block grants (see chapter 12).

Funding institutions such as the ARC and the NHMRC have their own performance measurement frameworks. As an illustration, that of the NHMRC is briefly summarised in box 8.4. The NHMRC indicated that it is still developing its methodology, but that it has:

> … made considerable efforts to demonstrate practically the benefits of health and medical research. The NHMRC has directed significant resources towards developing and implementing its Performance Measurement Framework and developing protocols to evaluate the impact and the benefits of the Australian Government’s investment in health and medical research. (sub. 80, p. 12)

Box 8.4 The NHMRC's performance measurement arrangements

Performance measurement arrangements for the NHMRC ultimately stem from its strategic plan (NHMRC 2003). This defines seven 'strategic objectives' for the 2003-06 period, each with one associated 'outcome'. In the terminology generally used in this chapter, these objectives and outcomes, however, appear to relate variously to inputs, outputs and outcomes.

A number of 'strategies' are associated with each 'outcome' and, in turn, a non-exhaustive list of performance 'measures' are listed in the strategic plan. These also relate variously to inputs, outputs and outcomes.

The formal performance measurement framework (NHMRC 2004a) takes each strategic plan 'outcome' and defines a number of performance measures called 'indicators' arranged under subheadings. Each measure has an associated target although many of these are described as 'new' with targets 'to be benchmarked and reported'. The NHMRC has described this framework as including 'a balance of inputs, processes, outputs and outcomes' (NHMRC 2004a).

Included in the indicators and associated targets are some measures of efficiency as well as effectiveness measures. However, many indicators and targets are expressed as simple input and output measures.

According to the NHMRC, a 'key initiative' has been the establishment of its Evaluation and Outcomes Working Committee to steer peer review of final project reports and to 'evaluate and disseminate the outcomes arising from NHMRC funded research' (sub. 80, p. 13).

Similarly, the ARC is making considerable effort to demonstrate the net benefits to the community from ARC-funded research (see sub. 73 from page 34), although it commented that:

> Conceptual and practical difficulties plague any attempt to measure research impact in any aggregated way, and are exacerbated in the case of research undertaken by or for government agencies, whose focus tends to be on research with diffuse benefit streams and/or longer time horizons than that of the private sector. (sub. 73, p. 20)

Adequacy

A major perceived current deficiency in performance evaluation and measurement is the lack of comprehensive retrospective information about the quality and impact of higher education research. Part of the rationale for the development of the RQF is to address this issue, particularly in regard to block funding.

In regard to competitive funding, both the ARC and the NHMRC are enhancing their efforts to promote research with good quality and impact and to measure the outcomes of research they fund. While, at this stage, some performance measures appear 'soft' and/or unquantified, both organisations are constantly refining and improving their performance evaluation methodology.

Business and similar programs

Grants and tax concessions for BERD

As discussed in chapter 3, economic theory suggests that businesses are likely to underinvest in R&D. It is argued that public support would induce more R&D from business, providing beneficial spillovers for the community and thus increasing net social returns.

However, this theoretical argument leaves two central points to establish in practice. That is, to what extent does public support, in the forms in which it is provided, actually engender additional BERD and spillovers; and how much public support should be provided (beyond a certain point it could be expected that additional public support would also come at a net cost). Both these questions necessitate performance measurement and evaluation.

Although individual businesses will monitor and assess the benefits and costs of their R&D expenditure, from a public policy point of view what is of most relevance is the extent to which the level of public support for that R&D engenders net benefits for the community.

The Industry Research and Development Board provides annual registration data, together with some information on eligible R&D expenditure and its nature, and information about its administrative processes. A performance evaluation of 'the effectiveness, appropriateness and efficiency of the 125 per cent R&D Tax Concession' (DITR web site) was conducted for the Department of Industry, Tourism and Resources by the CIE in 2003; similar reviews were conducted by the CIE that year on the R&D Start Program (section 10.5). As yet, their adverse findings have not been fed back into program redesign. Further, there is no publicly available evaluation of the performance of the (relatively recently introduced) 175 per cent element of the R&D tax concession or the R&D tax offset.

In response the Commission's draft report, the Department of Industry, Tourism and Resources noted that it evaluates programs every three years. A common set of key performance indicators is used to 'provide some consistency across programs and Australian Government departments in the collection of key output data' (sub. DR185, p. 31). The Department further noted that:

A substantial upgrade of Departmental program data management systems for monitoring and evaluation purposes of the R&D Tax Concession program will begin in 2007 and allow the Department to measure accurately the performance of the program. (sub. DR185, p. 31)

Agriculture R&D

Government-industry funding arrangements for rural R&D have been in place for more than 50 years. In broad summary, under current arrangements a number of industry based rural research and development corporations and companies (collectively known as RRDCs) act as funding agencies in channelling research to major agencies such as CSIRO, state departments of agriculture, universities and other research centres. Available funds arise from two main sources: levies on producers; and the Australian Government (chapter 10). But support to primary industries and producers for R&D is not limited to the government's matching contribution, however, as other federal and state/territory government monies find their way in through research agencies such as the CSIRO, higher education institutions, CRCs and state departments of agriculture.

As with other programs and institutions, performance evaluation can take place at several levels. Individual RRDCs monitor their own performance as well as that of the projects they support. The Grape and Wine R&D Corporation's Annual Operational Plan, for example, includes information about its overall objectives and its R&D development strategies and priorities; includes more detailed information for its programs and sub programs relating to objectives, outcomes, strategies and performance information; and lists expected program outcomes, associated relevant outputs and 'measures of success'. (Box 10.5 gives some detail about RRDC priority setting, management and evaluation criteria.)

As well, RRDCs have published information about many 'successful' projects which illustrate worthwhile benefits for producers and, in some cases, for the community more broadly (see, for example, the submission from the Council of Rural Research and Development Corporation Chairs — sub. 96). Success, of course, depends on more than just the appropriateness of a RRDC's project selection — it also reflects the abilities of the funded agency, be it the CSIRO, a CRC or whatever, in undertaking the actual work.

With programs of this nature, it is important that review of their broad objectives as well as the justification for the levels of public support provided should be undertaken from time to time. However, no such broad level independent evaluations appear to have been undertaken in recent years.

A submission from the Australian Centre for International Agricultural Research (ACIAR) noted that it has 'a long standing program of quantitative evaluation of the impact of its activities' (sub. 81, p. 25), and that it is continuing to develop its evaluation methodologies.

CRC program

In effect, the CRC program is a funding arrangement directed at encouraging public sector agencies and private interests to work cooperatively together to 'match the technology push provided by [Australia's] strong research base with the demand pull of industry and other research users' (Howard Partners 2003, p. i).

Australian Government funding for 2005-06 was about $208 million. This is expected to have made up about 30 per cent of total CRC funds available in that year, with the rest contributed (in cash or kind) by other partners including business, universities, the CSIRO and State and Territory Governments.

As with the above programs, performance evaluation of the CRC program can proceed at a number of levels: the program funding level; the level of each individual CRC; and that for individual projects sponsored by a particular CRC.

The latest program evaluation was published in July 2003. Howard Partners commented that:

> The arguments for public involvement in industrial research are well rehearsed and it is not proposed to restate them in this Evaluation. … The CRC Programme also addresses a market failure, particularly in environmental research, but also in agricultural research … (Howard Partners 2003, p. i)

A 2005 report by the Allen Consulting Group for the Cooperative Research Centres Association assessed the 'economic impacts' of the program. Its key finding was that:

> … over the 1992 to 2010 period the Australian economy's overall performance has been considerably enhanced when compared to the performance that would have occurred in the absence of the Commonwealth Government investment in the round one to seven CRCs that was provided between 1992 and 2005. (Allen Consultancy 2005a, p. vi)

One particular interesting aspect of this study is that it found, on average, a nine-year period from initial expenditure to reaping of benefit — illustrating the difficulty of linking public support for science and innovation in a causal way to outcomes.

Individual CRCs adopt a range of processes for allocating funds to projects, monitoring quality and impacts, and measuring their own effectiveness and efficiency. The emphasis on such activities is likely to have been enhanced with the relatively recent usual requirement for CRCs to be established as corporate entities, with governance through boards of directors.

Adequacy

Although the Commission has not undertaken a detailed examination of the performance evaluation and measurement undertaken by individual RRDCs and CRCs, there was no evidence presented to suggest there are any inadequacies at that level.

However, these programs and the other business programs have a number of shortfalls in terms of the considerations set out in section 8.3. These relate mainly to a lack of regular, transparent, and independent reviews of the objectives for assisting business in the forms and at the levels provided and of the detailed program arrangements. More specifically, in a number of these programs:

- desired outputs and outcomes may not be linked back to the rationales and objectives for public support;
- levels of support may not be clearly related to those rationales and/or objectives, nor to science and innovation objectives more generally;
- causality and additionality issues may be overlooked or inadequately addressed;
- forms of support may be inconsistent with rationales and objectives;
- there may be inappropriate reliance on selective case studies; and
- comprehensive evaluation may be infrequent, and may be lacking in transparency and independence.

And where evaluations have been undertaken, their findings have not always been drawn on in program review and redesign.

State/Territory programs

Although this report primarily focuses on federal programs, State and Territory Governments are significant players in science and innovation in Australia (appendix S). Their involvement ranges across many areas including rural industry, other primary industries, manufacturing and industrial development, health, technology and environmental and social issues.

A traditional area of involvement at this level of government has been in respect of agriculture. Indeed, this remains the case with, for example, the NSW Department of Primary Industries Division of Science and Research employing over 900 staff, managing over 700 projects, with a budget of over $130 million. Similarly, the Victorian Department of Primary Industries has a scientific strength of some 950 staff.

Some States have formalised activity through science and innovation plans or initiatives. For example, Victoria has made a total of $620 million available over the 1999 to 2005 period for strengthening the science and technology infrastructure and support base in the State, and for promoting commercialisation. South Australia, also, has a '10 year vision for science, technology and innovation' (sub. 92, p. 1). And the Queensland Government has a Smart State Strategy:

> … focused on supporting our industries in maintaining and enhancing international competitiveness through research and innovation, in addition to providing strong economic foundations and developing Queensland's workforce. (sub. DR203, covering letter)

Submissions from State Governments generally recognised the importance of adequate performance evaluation and monitoring. Some examples were provided which illustrated the evaluation methodology used. These examples, however, concentrated on the evaluation of projects, rather than on higher level evaluation of the reasons for public support, and the forms and levels in which it is provided at the state level. The extent to which such evaluations exist, whether they are public and whether they are undertaken independently, has not been comprehensively investigated by the Commission in this study.

Summary

The Commission is not in a position to undertake detailed assessments of the performance evaluation arrangements of individual programs — nor would it be worthwhile attempting to do so in a study of this nature. However, there are examples of inadequacies in performance evaluation in relation to some existing programs and arrangements when assessed against the range of criteria spelt out above. And even where existing arrangements are reasonable, scope remains for further improvement. As the Department of Industry, Tourism and Resources noted, 'the ongoing strengthening of performance evaluation mechanisms [would help] to ensure accurate and appropriate targeting of Government support' (sub. DR185, p. 31).

In the Commission's view, performance evaluation and reporting arrangements for every relevant science and innovation program should be reviewed against criteria such as those detailed in the previous section. If applied consistently, this should lead to a marked improvement in performance evaluation and reporting overall and thus, ultimately, to enhancing the returns to the community for its support for science and innovation.

FINDING 8.1

Performance evaluation and reporting arrangements have developed significantly in recent years, particularly through the adoption of an outputs/outcomes focus. There are, however, examples of deficiencies. Arrangements should be reviewed against the following criteria.

- *Outputs and intended outcomes should be defined in relation to the rationales for public support and to the community benefits expected from that support.*
- *Evaluation should be developed in a cost–benefit framework, balancing greater precision against administrative and compliance costs.*
- *Where undertaken, selective case studies of impacts should be placed in a supplementary rather than central evaluation role.*
- *Assessment should be undertaken with adequate frequency — this might vary between different types of measure.*
- *Assessment should be as independent and transparent as reasonably possible (also see finding 10.10).*
- *Feedback mechanisms should be implemented to ensure that performance evaluation findings are drawn on to enhance the future benefits of public support for science and innovation.*

9 Funding levels, allocation and coordination issues

Key points

- Any science and innovation spending targets for Australia should be expressed in relation to Australia's aspirations and needs, rather than in relation to overseas levels or targets. International benchmarking should only serve an informative, not prescriptive, role.
- Australia's levels of *government financed* R&D spending have remained consistently at, or above, the average for OECD countries over the past decade.
- When intercountry differences in industry structure and other factors are taken into account, Australia's *business* R&D expenditure is broadly in line with that of other OECD countries.
- The available evidence suggests that the level of public support for science and innovation is neither notably inadequate nor excessive in terms of Australia's own science and innovation aspirations and needs.
  – There are, nevertheless, likely to be benefits from changing public support levels, up or down, in particular program areas. However, these are matters for political judgment in a budgetary context, supported by Australia's existing bureaucratic, institutional and regulatory processes and structures, and informed by the available evidence.
- There are concerns from continuing to divert public funding to applied science and innovation activity, at the expense of basic and strategic science and innovation.
- The existing policy and budgetary processes of government provide a reasonably satisfactory mechanism through which information flows and advice can be integrated to facilitate decision making.
  – These processes generally support an incremental approach to change — with a reliance on diversity and devolution. However, they also allow more radical change when this is considered necessary.
  – Program evaluation and feedback are critically important. They are in need of improvement (as discussed in chapter 8).
- There is no need to markedly strengthen existing coordination mechanisms, or create new ones, in relation to the high level institutional arrangements for funding of science and innovation programs.
- The disadvantages of greater specification and quantification of National Research Priorities would outweigh the advantages.

As discussed elsewhere in the report, there are sound rationales for public support for science and innovation. But determining how much funding the government should provide, and how it should be allocated among competing objectives, is not easy.

This chapter examines different factors that need to be considered in addressing these issues. The question of whether there is a useful role for international comparisons and targets is discussed first. This is followed by an examination of the practical problems in determining the optimal scale and allocation of public funding. The mechanisms currently used to determine funding levels for the different parts of Australia's public science and innovation system are then discussed along with their strengths and weaknesses. A discussion of two key issues stemming from Australia's pluralistic system follows — namely the importance of effective coordination mechanisms and the role of the National Research Priorities (NRPs).

9.1 The role for international comparisons and targets

Calls for greater public support for science and innovation are often accompanied by comparisons of Australia's R&D spending levels with those of other countries. Many participants in this study drew on such comparisons when arguing for greater domestic spending on science and innovation in general, or on R&D in particular, or for specific target levels of expenditure. For instance, the Australian Vice-Chancellors' Committee and the Business, Industry, and Higher Education Collaborative Council (BIHECC) proposed that Australia should aim to spend on R&D the equivalent of 2 per cent of GDP by 2010 and 3 per cent by 2020. According to BIHECC:

> This would keep Australia apace with global competitors such as China, which has set a target of increasing research and development to 2.5 per cent of GDP by 2020, and the EU and Canada which have recently committed to spending to 3 per cent of GDP by 2010 to compete with similar levels in Sweden, the United States and Japan. (sub. 55, p. 17)

Several participants considered that Australia's performance relative to that of other countries should not be judged only in terms of spending levels but also in relation to research quality and impact, research focus, funding allocation systems, and human capital formation. For example, the Walter and Eliza Hall Institute of Medical Research commented that:

> International benchmarking is vital to enhancing competitiveness in research outcomes since knowledge generation and associated translation and commercialisation are international activities. (sub. 31, p. 7)

But others warned about the inherent difficulty of international comparison. Innovative Research Universities Australia commented that:

> Due to Australia's unique mix of economic, demographic, geographic, historic, and other factors it is almost impossible to identify a reliable comparator nation to benchmark research and development performance against. (sub. 54, p. 4)

Similarly, the CSIRO stated that:

> Benchmarking against other countries does not always provide a useful indicator, given the differences that inevitably exist between countries and the importance of local factors and capabilities. (sub. 50, p. 96)

And Macquarie University considered that:

> … international benchmarking is difficult … as there is a wide diversity in the way publicly funded institutions contribute to different countries' economies. (sub. 47, p. 3)

In the Commission's view, international comparisons can have merit, but only if interpreted carefully. Although they cannot directly provide an answer to the question of 'how much' Australia should spend, *major* disparities in public or business R&D spending levels relative to GDP between Australia and other developed countries would raise questions about whether Australia was spending too much or too little. International comparisons and benchmarking can also provide information about the relative quality and impact of Australian research. In this way, impetus can be provided for the improvement and development of science and innovation in Australia, and of the various programs and institutions. Essentially, such comparisons can indicate areas for more detailed examination, rather than being prescriptive about funding levels and allocation.

Such comparisons, however, need to distinguish between the actual achievements of other countries and any targets they may have set. As noted in appendix C, almost all other OECD countries have employed targets for international benchmarking and goal setting for science and innovation policy in recent years. But, as that appendix also notes, those targets often far exceed actual achievements. The following analysis addresses the latter.

The key indicators that commentators most often draw on are Australia's gross expenditure on R&D (GERD) and business expenditure on R&D (BERD) to GDP ratios relative to OECD countries. Indeed, despite strong real increases in R&D spending over the past two decades (discussed in chapter 2), Australia's GERD to GDP ratio, at 1.77 per cent in 2004, remains well below the OECD average. Overall, on this measure, Australia ranked 15th out of 30 OECD countries — 0.5 percentage points below the OECD average of 2.25 per cent.

Breaking down GERD into its component parts shows a much lower business financed R&D intensity (BERD:GDP) which, at just under 1 per cent, was 0.6 percentage points below the OECD average in 2004.

This was counteracted to some extent by Australia's slightly above average government-financed R&D spending, which was 0.7 per cent of GDP compared with an OECD average of 0.68 per cent in 2004.

A common interpretation of these international data is that Australia is underperforming in terms of R&D spending, in particular on business R&D spending. However, this cannot be supported on detailed examination.

First, the OECD averages are skewed heavily by a few key players — when spending by the United States and Japan is excluded, for example, the OECD average (weighted) for the remaining countries drops sharply from 2.25 per cent to just 1.75 per cent for 2004. This is marginally below the figure of 1.77 per cent for Australia (appendix C).

Second, differences between countries, particularly in industry structure, are important when comparing business R&D expenditure. This arises because some industries (including computers, communications equipment, pharmaceuticals and transportation equipment) are significantly more R&D intensive than others. When the BERD intensities of OECD countries are adjusted based on a standardised (OECD average) industry structure, Australia's BERD intensity increases from 1.2 to 2.1 per cent, close to the OECD average of 2.3 per cent in 2002 (figure 9.1).

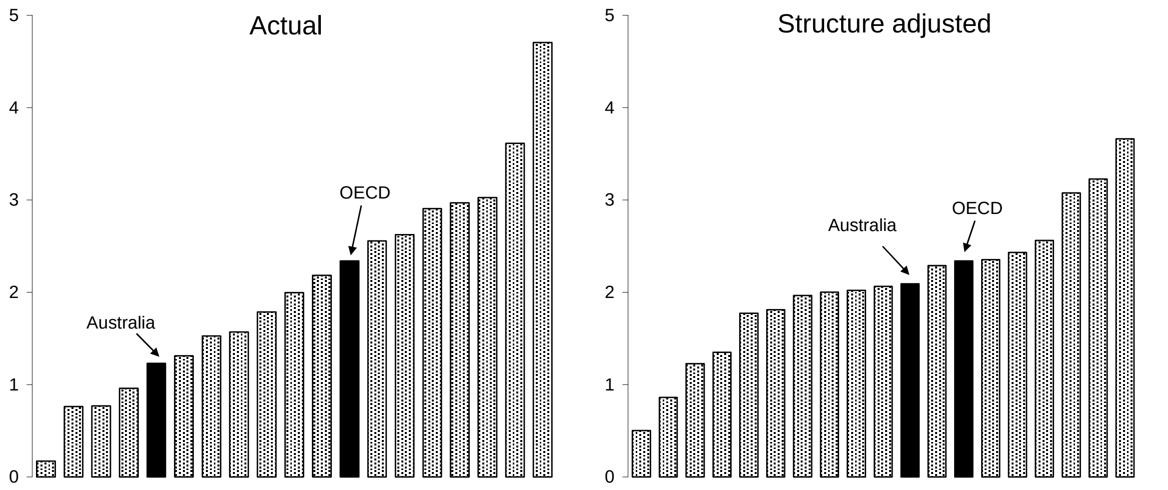
A number of participants commented on the analysis that the Commission undertook and presented in its draft report in relation to international comparisons. Many acknowledged the role of structural factors in comparing Australian BERD intensities and those of other countries, although interpretation of the results varied (box 9.1).

Having reviewed its analysis, the Commission remains of the view that, when differences in country size, industry structure, firm size and wage rates are taken into account (appendix C), Australia's business R&D expenditure is broadly in line with that of other OECD countries.

The question of whether government should encourage higher levels of business R&D, or indeed higher levels of expenditure on science and innovation more generally, is discussed below. In examining such issues, however, it is necessary to acknowledge that such expenditure is essentially a cost to business, government and, ultimately, the community generally. Of greater importance than its mere level, therefore, is whether that investment is used productively to generate positive net private and social outcomes, taking account of the opportunity costs.

Figure 9.1 **Comparison of actual and structure adjusted[a] BERD intensities across OECD countries**

BERD/value-added ratio (per cent), 2002



a The structure-adjusted estimates use the OECD average industry structure and are based on the total structure effect — the sum of the direct structural effect and an estimate of the structural component of the mix effect which includes both structural and intensity effects.

Data source: Appendix C.

In this regard, expenditure on science and innovation, including on R&D, can contribute to a wide range of economic, social and environmental outcomes. Some of these are captured through macro indicators such as multifactor productivity growth, the world competitiveness index, and business innovation propensities. While fairly broad, all of these indicators show that Australian businesses are performing well with their current R&D investments compared with other countries (appendix C and chapter 2).

Indeed, Australia has also consistently performed strongly in international comparisons of non-economic indicators. For example, Australia was ranked third by the United Nations Human Development Index in 2005 — a composite indicator that includes life expectancy, adult literacy, and enrolment ratios for primary, secondary and tertiary education (UN 2005). Moreover, the 2005 Environmental Sustainability Index (Yale Center for Environmental Law and Policy 2005) placed Australia 13th in the world (of 146 countries) and eighth in the OECD.

Clearly, while Australia will rank differently for these various outcomes, depending on the methodology employed, the key point from a policy perspective is that Australia performs strongly relative to other developed countries across a wide range of economic, social and environmental indicators. However, these indicators can provide no more than a broad feel for the appropriateness of the level and allocation of expenditure on science and innovation.

Box 9.1 **Participants' views on the role of structural factors**

Adjusting for structure

> The Queensland Government supports the analysis undertaken by the Productivity Commission in adjusting Australia's BERD intensity for industry structure and other factors. The Queensland Government believes this analysis provides a more accurate and relevant representation of Australia's BERD intensity in comparison to other countries, allowing for more effective policy options to be identified and implemented to further improve BERD in Australia. (Queensland Government, sub. DR203, p. 1)

Interpreting the results

> FASTS do not share the Commission's rather sanguine position on 'benign differences' between Australia and other nations on BERD as a percentage of GDP. FASTS are familiar with the structure argument but note the Commission's own estimate that Australia is still below the OECD average once BERD is adjusted for structure … . (FASTS, sub. DR144, p. 11)

The need to transform Australia's industry structure

> The draft report indicated that once adjusted for research intensities and industry structure, Australia's BERD was just below the OECD average. Given the importance of a strong science sector and high private R&D for economic competitiveness this appears to reflect a worrying complacency. It would appear important to respond to the relatively low levels of R&D expenditure amongst Australian business and to acknowledge that the structure of Australia's industry is not necessarily conducive to long term economic competitiveness. (Tasmanian Government Department of Economic Development, sub. DR181, p. 2)

> The draft report seems hesitant to use public support for science and innovation as a vehicle for strategically repositioning Australia's industry outlook. By contrast, the [BCA] New Pathways report is enthusiastic about research and innovation as drivers of industry overhaul. … If BERD is a consequence of industry sector mix, for example, is it desirable that GOVERD be used as a vehicle to transform that mix? (CHASS, sub. DR171, p. 7)

Public support for BERD

Some participants drew a link between the proportion of business R&D which is funded by government and Australia's industry structure. This is reflected in claims that Australia's current industry structure is in part the result of a lack of public support for BERD in the past (see, for example, AVCC, sub. 60).

The Commission has examined structural change in Australian industries in a range of studies and found that the key drivers of changes in Australia's industry structure in past decades have been changes in consumer demand and income-related preferences, shifting trade patterns and changes in relative prices (see for example, PC 1998, 2003b and 2005 and Maclachlan et al. 2002). There is no evidence that Australia's present industry structure has been affected to any appreciable extent by the levels of public support accorded business R&D.

The pitfalls of directing publicly funded R&D to achieve transformation of industrial structure are discussed in chapter 3.

Moreover, it is not even clear that Australia currently provides less public support for BERD when compared with OECD countries. Although latest OECD data on government financed BERD indicate that public financed BERD in Australia was well below the OECD average (see appendix C), this indicator does not provide a complete picture of intercountry differences in support for BERD as it excludes assistance via tax concessions. Indeed, over the five years to 2003-04, Australia provided more than twice as much assistance to BERD via the tax concession than in direct assistance (as measured by the OECD).

It is difficult to pinpoint exactly how Australia measures up with other countries in terms of the level of support for BERD via tax measures. The OECD confirms that such comparisons are difficult, as detailed data on tax expenditures from public budgetary accounts are available only for a few countries (OECD 2006b). Nevertheless, a comparison of the relative inducement effects of R&D tax measures across countries suggests that Australia's public support for BERD is around the mid point for the OECD (Warda 2006; appendix C).

A role for targets?

Do the expenditure levels achieved in other countries, or their specific expenditure targets, offer any prescriptive guidance to how much Australia itself should spend on science and innovation (and on R&D), either in total or from public support in particular? In the Commission's view, the answer is 'no'

The targets in many countries are fundamentally aspirational in character and best viewed as policy tools to assist in generating and maintaining the will to achieve desirable goals in the context of their particular science and innovation systems. Australia's policy responses to international comparisons need to be carefully assessed in the light of Australia's own aspirations, its science and innovation needs, and its institutional and regulatory environment.

When put in that context, targets set specifically for Australia can play a useful role. For example, by locking in future expenditure levels in a number of program areas, Backing Australia's Ability has set a number of targets to be achieved over the years ahead. This provides focus and certainty over a number of years. In line with the discussion below, however, any overall target should only represent the sum of desired expenditures in particular program areas.

9.2 How much to spend in total?

Many participants emphasised the benefits of increased public support for science and innovation, without acknowledging the costs. However, the funding of any such increase would have to be raised from the community through higher taxes, or diverted from other public expenditure areas.

Apart from their administrative and compliance costs, taxes also impose an efficiency cost. In general, the efficiency cost increases more than proportionately to increases in tax rates and thus, at some point, the increase in efficiency cost resulting from a higher rate of tax will almost certainly outweigh the benefit of additional government expenditure. *In effect, a budget constraint applies and thus not all otherwise desirable projects can be funded.*

Governments therefore have to make tradeoffs between such projects across the full range of spending possibilities — be they in education, health, public housing, aged care, the arts, defence, and other areas where government has a significant role as a funder. If there is too little public support for science and innovation, Australia misses out on beneficial economic, social and environmental outcomes, and fails to contribute its share as an international citizen. If, on the other hand, there is too much, funds are used that could be better devoted to other expenditure areas, or simply not collected from taxpayers (businesses and individuals). Similarly, misallocation of funding within science and innovation would reduce the net benefits of public support.

A further factor to consider is that the community's expectations of government are not static. For example, the expected ageing of the population will necessitate growing public expenditure in such areas as health, while others argue for greater public investment in infrastructure. Accordingly, any additional public support for science and innovation should be evaluated against those growing needs, and the higher tax rates necessary to fund them, rather than those tax rates that presently apply. As noted, higher tax rates raise the hurdle rate for acceptable benefits.

Given adequate data, it would be theoretically possible to optimise the allocation of funds among all possible expenditure options or projects, with public support for science and innovation competing with all the other possible uses for government funds. In essence, public funds would be allocated to science and innovation whenever:

- the net social benefit of additional government spending is positive, taking into account the costs of raising tax revenue, including the efficiency cost; and
- the returns from additional spending on science and innovation exceed the benefit from the next best alternative use.

On this basis, the optimal level of expenditure on science and innovation would be determined by summing the components — rather than determined in aggregate up front. Such a theoretical approach is virtually impossible to apply in practice, however. Not only would it require detailed knowledge about the benefits and costs of all possible spending options on science and innovation but also knowledge about the benefits and costs of all other possible areas of public spending, including some knowledge about the possible returns from future spending options. In the final analysis, informed judgment is required.

In practice, policy decisions have to be, and are continually being, made about the level of public resources allocated to science and innovation for each component (and thus in total), within the context of other demands for public funds. Such judgments are, of course, supported by Australia's existing political, bureaucratic, institutional and regulatory structures.

As discussed above, the necessary judgments can be informed by, but not prescribed by, international comparisons, not just of expenditure levels but also in terms of a range of socio-economic indicators influenced by the contributions of science and innovation. The judgments are also informed by a host of indicators of the degree of 'stress' within the innovation system, in relation to such questions as:

- Are the needs of business users for quality human capital being met?
- Is there a brain drain of the most talented people?
- Are research quality standards high?
- Is Australia performing well in its capacity for solving its own environmental and social problems?
- What does evaluation evidence of particular science and innovation programs suggest about their impacts and net returns?

Other chapters in this report examine these and similar questions in the context of the policy and funding framework discussed above. At an aggregate level, the most important implication of the available evidence is that Australia's public support of science and innovation is not in the danger zone of demonstrable over or under-funding. While it is apparent that there would be benefits from changes in particular program areas, the final judgments on these matters need to be made in the detailed budgetary and bureaucratic processes.

FINDING 9.1

Any science and innovation spending targets for Australia should be expressed in relation to Australia's aspirations and needs, rather than in relation to overseas levels or targets.

- *Even so, Australia's levels of government financed R&D spending have remained consistently at, or above, the average for OECD countries over the past decade.*
- *When intercountry differences in industry structure and other factors are taken into account, Australia's business R&D expenditure is broadly in line with that of other OECD countries.*
- *Australia performs strongly relative to other developed countries across a wide range of economic, social and environmental indicators.*

FINDING 9.2

The available evidence suggests that the level of public support for science and innovation is neither notably inadequate nor excessive in terms of Australia's own science and innovation aspirations and needs.

- *There are, nevertheless, likely to be benefits from changing public support levels, up or down, in particular program areas. These are matters for judgment in a budgetary context, supported by Australia's existing institutional and regulatory processes and structures, and informed by the available evidence.*

9.3 The balance between basic and applied R&D

While curiosity-driven research has its own intrinsic worth, governments fund science and innovation to achieve a whole range of specific outcomes linked to the rationales and objectives discussed in chapter 3. Thus, a mix of spending is necessary. But as noted above, there is no practical rule about how to allocate public support to achieve the optimum.

There are many dimensions to the form, purpose and delivery of funding. These include the various functional objectives (basic (pure and strategic), applied, experimental development); socio-economic objectives (health, environment, defence, and industry); funding agencies; funding recipients; and types of funding (such as block versus competitive).

Issues relating to many of these dimensions are discussed throughout the report. The following sections of this chapter specifically focus on the decision making environment, coordination and the NRPs. The rest of this section concentrates on the balance of funding by functional objective — examples of participants' views are given in box 9.2 (also see box 12.2).

Several participants considered that the balance of public support had shifted inappropriately towards applied science and innovation at the expense of basic and strategic science and innovation. This, however, was not the universal view (box 9.2). Nevertheless, there appears to have been some such shift, as evidenced by the recent emphasis by research organisations on pursuing returns from technology transfer (chapter 7), the assessment of CRCs according to the commercial benefits they generate rather than the overall public benefit that they deliver (chapter 10), the increasing external funding of PSRAs such as the CSIRO (chapter 11) and the reducing proportion of block funding for higher education institutions (chapter 12).

While there is no absolute standard against which to judge the appropriateness of this shifting balance, it is clear that, when assessed against the rationales for public support for science and innovation, there are consequences if the trend goes too far. These include:

- providing public support for commercially-oriented expenditure, the benefits of which will largely be captured privately;
- focusing on short term impacts at the expense of valuable medium and longer term outcomes;
- losing research capacity across a number of disciplines, including the ability to absorb R&D undertaken in other countries;
- losing strategic capacity and preparedness to shift focus and emphasis if events dictate; and
- downgrading the fundamental importance of basic research and knowledge generation.

FINDING 9.3

There are risks associated with the continuing diversion of public funding to applied science and innovation activity at the expense of basic and strategic science and innovation.

9.4 The decision making environment

While the ultimate decisions about the appropriate tradeoffs between various objectives are political ones, the existing budgetary and non-budgetary bureaucratic processes provide a framework that supplies and organises the information on which these decisions are based.

Box 9.2 Participants' views on the balance of public support

It is important to strike the correct balance between pure, strategic research and applied research driven by contemporary community and market needs. This will always remain a role for government. (Western Australian Department of Industry and Resources, sub. 82, p. 11)

[Recent work] emphasises the uncertainty that surrounds future states of the world and the value of possessing options for responding to those uncertainties. It focuses on the need to protect as well as generate wealth, and on the value of having the capacity to do both. In the ARC's view, this constitutes an important additional objective for the science and innovation system. (ARC, sub. 73, p. 14)

… [there is] lack of appreciation of the pluralistic nature of the outcomes of [the CSIRO's] investment and thus the value proposition for maintaining or growing the investment. Australia's commitment to publicly funded science is based on, at best, a poorly constructed view of what the investment is for, and at worst, a short term, ideological and narrow view of the role of science in modern societies. (Graeme Pearman, sub. 86, p. 2)

… we should move to introduce the concept of 'preparedness' to complement the more familiar concepts of science and innovation — resulting in a policy framework that focuses on science, innovation and preparedness (SIP) policy. (Mark Matthews, in sub. 83, p. vi)

The system has to encompass all varieties of research: short term and long term; high risk and low risk; curiosity driven, investigator led research and experimental development; research in different fields and across different sectors. Achieving the right balance is not easy but a complete system that includes all varieties of research provides the best means of retaining and developing the capability that maintains preparedness. In an uncertain world, this ability to keep open Australia's options for action and to create new options has a value beyond the direct impact of the research itself. (CSIRO, sub. 50, pp. 37–8)

A significant proportion of publicly supported R&D is concerned with improved levels of preparedness and contingency options for handling unwanted and unexpected events … While 'preparedness' is an outcome that the general community has come to expect from public R&D it does not currently feature with comparable weight in considerations about how public funded research benefits society. (Group of Eight, sub. 68, pp. 7–8)

… there is still a tendency in the sector to undervalue the potential social and environmental impacts of public R&D funding, particularly with rigid outcome based funding models. (CSIRO Staff Association, sub. 78, p. 23)

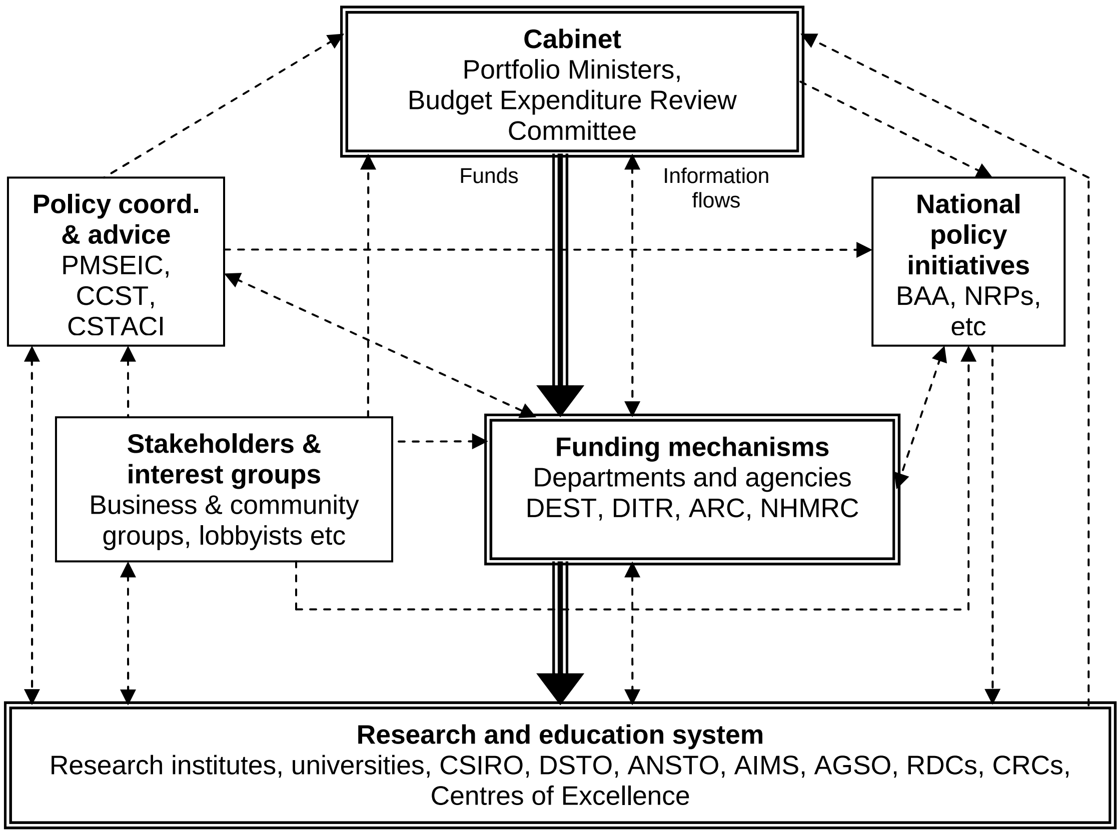
… GSKA is highly supportive of public funds being made available for strong basic research, however, the company would submit that no clear evidence exists supporting the claim of an emerging trend towards greater funding being invested in applied scientific research. (GlaxoSmithKline Australia, sub. DR154, p. 3)

…the [draft report] implies that there is an inadequate level of basic research being undertaken and that this trend is increasing. The ATN disagrees with this finding as basic research often dominates competitive grant funding. (ATN, sub. DR153, p. 8)

The AVCC concurs with the draft report's cautions regarding basic and strategic science and innovation …; while applied research should be supported, shifting the focus too far away from basic research will be detrimental to innovation. (AVCC, sub. DR148, p. 2).

In effect, public science and innovation has to compete for funds with all other areas of public spending and thus is subject to the same justification and substantiation processes for ongoing programs and for new policy proposals. The process draws on a wide array of information from a diverse range of stakeholders including government departments, R&D performers, funding bodies, facilitators and regulators (figure 9.2). Research stakeholders, such as universities and publicly funded research agencies, have well organised processes that enable them to engage effectively with departments and Ministers on policy and funding debates. In addition, the funding outcomes are influenced by key science and innovation players such as industry lobby groups as well as information and advisory bodies such as the Office of the Chief Scientist, the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) and the Coordination Committee on Science and Technology (CCST). Within Government, proposals also receive scrutiny from the Expenditure Review Committee of Cabinet supported by key central departments such as Prime Minister & Cabinet, Treasury and Finance.

Figure 9.2 **Science and innovation public funding and information flows at the federal level**



While these processes provide a reasonably satisfactory mechanism through which information flows and advice can be integrated to facilitate decision making by government, this does not mean that they cannot be improved. The next section examines the advantages and disadvantages of two key features of the current arrangements, before the remainder of the chapter goes on to consider coordination issues and the role of the NRPs.

Key features: incremental change; diversity and devolution

There are two key characteristics of Australia's approach to allocating funding for science and innovation:

- *incremental change* — change is generally made gradually, with an emphasis on adaptation based on learning from experience; and
- *diversity and devolution* — there is a number of funding bodies, spending bodies, funding instruments, priorities and programs. In some, there is an emphasis on devolved decision making.

Incremental change

Australia's science and innovation funding allocation mechanisms accord a reasonably strong weight to past practice and generally rely on incremental change to improve outcomes. In this respect, they are similar to many other processes of government and program funding. But even so, there can be quite large changes made from one year to the next. In relation to business programs, for example, public support declined by some $300 million from 1995-96 to the following year. And there have been some significant short lived programs such as the one-year $200 million funding of the NHMRC for medical support infrastructure in 2005-06. As well, over time, even relatively small annual changes compound, such as with the increased share of funding for higher education research going to the ARC and NHMRC competitive funding streams, away from direct block funding of universities.

Benefits of incremental approaches

Incremental approaches may be appropriate in the presence of uncertainty about the relative benefits of spending, where science and innovation funding can be influenced by 'fashions' whose benefits are not established, and where there are costs of adjustment from shifting program funds from year to year.

First, if returns from programs are uncertain, then a reasonable approach is to have a portfolio of programs, with reasonably stable funding from year to year. Such gradualism allows policy learning via 'intelligent trial and error'. Clearly, this is highly dependent on the quality of the evaluation and feedback mechanisms.

Second, gradualism also provides protection for science and innovation funding agencies from changes in government policy and in fashionable fields of research. The OECD (2003a, p. 8), for example, notes the importance of insulating public science and innovation systems from 'rapid shifts in funding or interests' to ensure long-term sustainability.[1]

Third, adjustment costs are reduced and the scope for capability development is enhanced if there is some inertia in funding arrangements. In bureaucracies, it takes time to develop operational procedures, train staff, and collect and assimilate information. These are the fixed costs of developing these program-specific capabilities. Firms and other research agencies face similar difficulties in environments where policy is always changing. It takes time for them to shift resources to the given research area, and to develop efficient compliance and information systems. Firms prefer certainty and often will not respond much to short-lived programs because of the costs of learning and adjustment.

Costs of incremental approaches

Some commentators attribute the appeal of incrementalism to risk aversion on the part of decision makers, noting that it increases the ability of incumbents to control the agenda, limits the scope of alternatives, shuts out unsympathetic voices, and skews decision making in favour of vested interests and past practice (Hayes 2002).

Incremental systems can pose problems for science and innovation policy in instances where the appropriate policy response to new information about particular research opportunities and challenges requires substantial changes to funding allocation among institutions and fields of work.

Another concern — not of high relevance in the current Australian context — is that incremental approaches pose particular challenges in a context of declining total funding. For instance, Smith and McGeary (1997) note that in regard to US science and innovation spending, although experience shows incremental budgeting to be preferable to 'comprehensive' budgeting schemes, its virtues are far more apparent when budgets are increasing than in a period of 'decremental' budgeting. Problems with the latter include: the tendency to spread cuts across the board rather than in the areas that are underperforming, deferring infrastructure and other investments to

[1] Sarewitz (2003, p. 3), also notes that the high degree of 'embeddedness' of public science in the US budget process offers 'significant protection against major disturbances in overall funding commitments for R&D activities'.

protect staff, increasing cost sharing, and avoiding risky projects. Experience in OECD countries has also shown that achieving change in science and innovation policies is much easier with new money and when budgets are increasing (OECD 2003a).

Policy implications

There is really no practical alternative to incremental approaches for the vast majority of science and innovation spending. This, however, does not mean that support should be continued for existing policies and programs uncritically. Nor does it suggest that alternative funding arrangements that could better meet the objectives for support should not be considered. Occasional 'foresight' exercises could be valuable in this respect — their outcome could, of course, feed into policy frameworks such as national research priorities (see below). Bougias and Kulkarni considered that:

> LRP [long range planning] and foresighting are areas that require further attention in Australia. LRP involves identifying the opportunities and challenges we face as a nation in the long term. The process would be systematic and significant in size and scope and involve a coordinated approach across a range of stakeholders including Government, business and the academic community. (sub. 59, p. 25)

An important implication stemming from Australia's reliance on incremental approaches in allocating public funds for science and innovation is the crucial role of drawing on the lessons of experience via program and performance evaluation. Unless these systems work effectively, the risks of the negative consequences of incrementalism and locking in the status quo are high.

As discussed in chapter 8, there are significant deficiencies in some current program evaluation arrangements. That chapter (and chapter 10) suggests ways of improving their relevance, quality, independence and transparency, so that evaluation results can feed more directly into funding decisions.

Diversity and devolution

Benefits

In a number of respects, there are advantages to diversity and devolution of decision making.

- *Instruments.* A combination of interventions will generally be appropriate — (such as tax concessions, public research institutes, competitive grants, block funding for university researchers) — not only because some may better meet particular objectives than others but also because their relative efficacy is somewhat uncertain.

- *Funders.* Selecting the best research is a difficult task and even the most competent assessors inevitably make mistakes. Having more than one potential funder available to a given researcher or research institution reduces the risk of rejecting projects that should have been accepted ('Type II errors'). As the then Chief Scientist noted in his *Review of Science and Technology Arrangements* (Stocker 1997, p. 3), 'overlaps in science and technology effort need to be recognised as a necessary and desirable part of the science and technology system'.
- *A mix of centralised and decentralised decision making.* Centralised decisions can have the advantage of breadth of perspective and broad tradeoffs can be made. But decentralised decision makers may have the advantage of more complete and cheaply acquired information about the merits of the researcher and the local infrastructural and other circumstances of the proposed project.
- *Different levels of government*. While the Australian Government takes the lead in science and innovation policy, different levels of government all play important roles.
- *Research performers.* Size can be very important to the success of some research projects, but others can benefit from being small and focused. It is important that funding arrangements promote the best research and research institutions, regardless of their size (IC 1995).

The recent *Pathways to Technology Innovation* report (House of Representatives Standing Committee on Science and Innovation, June 2006, pp. 55–6) concluded that 'the plurality of programs, while posing some difficulties, is a necessary feature of a comprehensive suite of innovation support to address different innovation needs'. Diversity can also play an important role in strengthening a country's capability to respond to challenges (and opportunities) as they arise.

Costs and policy implications

The most obvious costs of diversity and devolution is that funds could be wasted on ineffective programs, merely for diversity's sake, rather than better spent elsewhere. This again highlights the importance of well functioning evaluation processes in ensuring Australia's science and innovation system operates effectively and efficiently.

Another cost relates to the potential risk of gaps, inefficiencies, overlaps and duplication in funding arrangements that a pluralistic system entails. For example, an investigator whose proposal is turned down by one agency might find another one that will provide support. Although this can be advantageous (as noted above), it can also create additional administrative costs, magnify compliance costs and provide gaming and lobbying opportunities. Devolution of decision making can add to problems of setting meaningful national priorities, if agencies make decisions without full regard to the impact on the broader system.

The policy challenge is how to retain the positive features of incrementalism, diversity and devolution while minimising the negative downsides. This is discussed below in the context of coordination.

9.5 Coordination

Some countries have endeavoured to deal with the problems associated with incrementalism and diversity through greater centralisation of funding decisions. Examples include the use of central coordinating bodies (Japan), rationalised/amalgamated science ministries (Denmark), fewer funding councils and one source of R&D funds (Sweden).

However, as discussed above, incrementalism, diversity and devolution bring advantages. Should problems exist in terms of overlaps, duplication, coordination or divergent or inconsistent priorities, another strategy is to address them within the existing institutional context through improving or strengthening coordination and liaison mechanisms. As the Department of Industry, Tourism and Resources noted ‘the governance framework for Australia’s innovation system is important to its overall effectiveness’ (sub. DR185, p. 18).

In Australia, a number of formal and informal coordination arrangements already exist, including the budgetary/policy arrangements described above. Three particular arrangements —the Prime Minister’s Science, Engineering and Innovation Council, the Coordination Committee on Science and Technology and the Office of the Chief Scientist — are described in box 9.3. On occasion, formal coordination arrangements have been established for such programs as Backing Australia’s Ability. In addition, there is a mechanism for regular interaction with State and Territory Government bodies involved in innovation policy development (see below).

Less formal mechanisms include ongoing peer-to-peer interactions across agencies, and taskforces. The latter can undertake across-government activities, as occurred for the mapping of Australian science and innovation exercise in 2003.

Box 9.3 **Coordination and advisory mechanisms**

Prime Minister's Science, Engineering and Innovation Council (PMSEIC)

PMSEIC is the Australian Government's principal source of independent advice on issues in science, engineering and innovation and relevant aspects of education and training. The Council meets twice a year to discuss major national issues in science, engineering and technology and their contribution to the economic and social development of Australia. To underpin its advisory role, the Council has resources to examine Australia's science and engineering capabilities and the effectiveness of their organisation and utilisation. The non-ministerial members constitute the Standing Committee of the Council, and oversee and contribute to studies and research aimed at improving understanding of the major science, engineering and innovation issues.

Coordination Committee on Science and Technology (CCST)

The CCST brings together deputy secretaries and heads of Australian Government agencies with an interest in science and technology. It facilitates networking, information exchange, strategic thinking and coordination of activities in areas of science and technology, and complements the work of PMSEIC. CCST meetings are primarily to provide an up-to-date and broad information base to feed into well coordinated advice to Government on science and technology matters. There is also scope in CCST for initiating cooperation between departments and agencies on specific science and technology issues, problems or identified opportunities. CCST can examine major cross-portfolio issues and hence assist policy development through an early 'whole of government' discussion of issues. CCST may also address the specific portfolio issues raised by its members.

Office of the Chief Scientist

The Office of the Chief Scientist provides information and advice on policy issues, research and administrative support for the Chief Scientist, PMSEIC and CCST. The Office supports the Chief Scientist in engagement with the research and industry communities, learned societies, and other portfolios and governments, which informs advice to Government on a wide range of scientific and technological issues of importance to Australia.

Coordinating funding allocations to programs

The issue of funding coordination within the Australian Government science and innovation portfolio has long been debated (Stocker 1997). Participants' views differed on such issues. On one side, the Australian Vice-Chancellors' Committee commented favourably on existing mechanisms, advising that many programs 'are free standing and require relatively little government coordination' (sub. 60, p. 38). It considered that:

> The key point is not whether there are too many programs, but rather that there is not enough funding to support the breadth and depth of university research activity. (sub. 60, p. 38)

In contrast, the Western Australian Department of Agriculture and Food commented that:

> To facilitate R&D activity across the private-public good spectrum and the basic to applied continuum the Commonwealth needs to support a coordinated approach to building innovation pipelines from research to commercialisation. (sub. 44, p. 14)

And the Cooperative Research Centre for Spatial Information argued that:

> Australia would be well served if it were to establish a peak body to oversee the investment of public funding of science and innovation. (sub. 32, p. 4)

In particular regard to PMSEIC, the Australian Academy of Technological Sciences and Engineering recommended that:

> … PMSEIC ensure that mechanisms are implemented to achieve the coordinated development of policies and strategies related to innovation. (sub. 27, p. 16)

However, there is no certainty that centralised allocation of funding, or even an increase in high level coordination, would offer a net advantage over current processes. Some of the strengths of a more devolved decision making system, such as allowing those with the best working knowledge of particular science and innovation aspects to make decisions, would also be watered down or lost.

In relation to the high level institutional arrangements for coordination across the funding of programs, the Commission considers there is no evident case to markedly strengthen existing mechanisms or create new ones.

Coordination between programs

A related issue is whether at a program and project level, there may be scope for better coordination. Clearly there is already considerable coordination and consultation — for instance, the ARC and the NHMRC liaise and coordinate on appropriate matters, with each other and with higher education institutions. The Department of Agriculture, Fisheries and Forestry noted that improved collaboration and coordination between the RRDCs is being led by the Council of RDC Chairs (sub. 100, p. 32). And many programs actively aim to leverage additional funding from other funding sources — obviously requiring a degree of coordination. Further, there is evidence that coordination can work well when planning major infrastructure, such as for the Australian synchrotron project.

Nevertheless, it would be surprising if, given the diversity of current arrangements, there were not some coordination problems.

Participants offered only few comments specifically directed at such issues, however. GlaxoSmithKline Australia submitted that:

> … better coordination between … programs [such as CRCs and PIIP/P3] could enable the objectives of increased collaboration and more effective commercialisation to come together. (sub. 38, p. 30)

The Commission notes that Australia’s diverse set of programs and funding arrangements are likely to result in costs due to coordination problems. This is also likely to be the case where a diverse range of programs are brought together in a high level program such as Backing Australia’s Ability. But while it supports efforts to improve coordination between programs, care should be taken to ensure that such efforts do not fundamentally change existing funding arrangements to the detriment of the advantages of diversity, devolution and policy experimentation.

Coordination across levels of government

A number of institutional arrangements facilitate discussion and coordination between the various State and Territories and between them and the Australian Government in relation to science and innovation policy and programs.

These include the Commonwealth State and Territory Advisory Council on Innovation (CSTACI), which was established in February 2000. The Council comprises senior representatives of each Commonwealth, State and Territory industry department, as well as each State and Territory innovation council or equivalent. Various Chief Scientists also attend its meetings. According to CSTACI, its role is:

> … to enhance innovative activity across Australia by adopting a targeted and strategic approach to innovation issues to improve the effectiveness, integration and coordination of the National Innovation System. (sub. 98, p. 1)

As well, for example, a National Collaborative Research Infrastructure Strategy has been developed (box 5.5).

There was no evidence presented which suggested such mechanisms have not served a positive role. Nevertheless, the increased involvement of the various levels of government in science and innovation policy in recent years together with a multiplicity of programs increases the risk of coordination problems. Further, costs can arise when programs focus on competitive industry or state development rather than on the rationales for public support for science and innovation. In regard to such issues, CSTACI commented, however, that:

> While the number of programs available may be criticised as too large and/or confusing, they are a response by Australian and New Zealand governments seeking to address particular market failures. Several states and territories have been through their own review processes over the last year in the innovation research and policy area, with rationalisation and restructuring resulting in some instances. CSTACI does, however, support the view that very large programs may not be appropriate when particular target outcomes are being sought — for example, for a particular sector or size of firm. (sub. 98, p. 3)

In its initial submission, the Victorian Government noted that it had begun consultations with Victorian and national stakeholders to identify collective and individual actions to progress a ‘National Innovation Agenda’. It commented that, from its initial consultations, there:

> … emerged a strong impetus for a coordinated national approach to innovation that more clearly defined the respective roles for Federal and State Governments and addressed linkages across the innovation system. (sub. 84, p. 10)

The New South Wales Government argued that:

> Developing programs in isolation is unlikely to deliver the best results for either the Commonwealth or State Governments to achieve their respective policy objectives. The NSW Government would like to see a greater commitment to consultation with the States at the design stage of funding programs for science and innovation. (sub. 91, p. 11)

And the South Australian Government also expressed some concern:

> The general policy thrust of the Backing Australia’s Ability packages has been to improve collaboration at all levels, set national priority areas, accelerate the commercialisation of ideas and invest in people and skills. These goals are commendable; however, the South Australian Government believes that there are continuing impediments and obstacles to these goals. (sub. 92, p. 5)

Although the Commission supports current initiatives to improve collaboration across jurisdictions, it has not given specific consideration to what further measures might be appropriate.

9.6 National research priorities

Australia has generally avoided high level direction of the research sector, with a preference for allowing funding organisations, research bodies and individual researchers to exercise considerable autonomy in deciding what research to pursue.

In recent years, though, there have been changes of emphasis — for example, in encouraging efforts towards greater commercialisation (chapter 7). Also, the share of 'competitive' funding has grown somewhat relative to general purpose institutional funding, for example in higher education research (chapter 12).

Further, there has been a number of national initiatives aimed at providing greater guidance to funding agencies. For example, the Australian Government's January 2001 statement on innovation, Backing Australia's Ability, flagged the desire for an emphasis on research in areas in which Australia enjoys or wants to build competitive advantage. Subsequently, in January 2002, the Government announced four areas of priority for the ARC's National Competitive Grants Program — nano- and biomaterials, genome/phenome research, complex/intelligent systems, and photon science and technology — and specified an investment target for these areas of at least 33 per cent of funds in the ARC's 2003 funding round.

Then, in December 2002, the Prime Minister announced four NRPs for Commonwealth-funded research (box 9.4):

- an environmentally sustainable Australia;
- promoting and maintaining good health;
- frontier technologies for building and transforming Australian industries; and
- safeguarding Australia.

These priority areas, and associated priority goals, were further developed in 2003.

The NRPs are an attempt at a comprehensive explicit articulation of where national science and innovation effort should be directed. The Government announced that, as a general principle, all Commonwealth research and research funding bodies that can contribute to a national research priority would participate in the national research priorities initiative to the extent that this is consistent with their mandate or mission. The NRPs do not apply to industry R&D programs or to university block grants, however.

The priorities, and priority goals, are not ranked in importance, nor are they quantified, nor is funding earmarked for particular priorities. Further, a cursory examination of the different national priorities adopted across OECD countries indicates Australia's NRPs are pitched at a considerably broader level that in many other countries. Many countries have identified a limited number of priority sectors to receive above-average amounts of new funding because of their anticipated leverage in terms of future economic growth, employment and overall social value. While there are variations, the broad areas receiving the most attention are ICT, biotechnology and nanotechnology (table 9.1).

Box 9.4 **National Research Priorities**

In 2002, the Government announced four NRPs to focus research in specified areas. These NRPs, and their associated priority goals, revised and enhanced in 2003, are:

1. An environmentally sustainable Australia

- *Water* — Sustainable ways of improving water productivity, using less water in agriculture and other industries, providing increased protection of rivers and groundwater and the re-use of urban and industrial waste waters.
- *Transforming existing industries* — New technologies for resource-based industries to deliver substantial increases in national wealth while minimising environmental impacts on land and sea.
- *Overcoming soil loss and acidity* — Identifying causes and solutions to land degradation using a multidisciplinary approach to restore land surfaces.
- *Reducing and capturing emissions in transport and energy generation* — Alternative transport technologies and clean combustion and efficient new power generation systems and capture and sequestration of carbon dioxide.
- *Sustainable use of Australia's biodiversity* — Managing and protecting Australia's terrestrial and marine biodiversity both for its own value and to develop long term use of ecosystem goods and services ranging from fisheries to ecotourism.
- *Developing deep earth resources* — Smart high-technology exploration methodologies, including imaging and mapping the deep earth and ocean floors, and novel efficient ways of commodity extraction and processing (examples include minerals, oil and gas) while minimising negative ecological and social impacts.
- *Responding to climate change and variability* — Increasing our understanding of the impact of climate change and variability at the regional level across Australia, and addressing the consequences of these factors on the environment and on communities.

2. Promoting and maintaining good health

- *A healthy start to life* — Counteracting the impact of genetic, social and environmental factors which predispose infants and children to ill health and reduce their well being and life potential.

(Continued next page)

Box 9.4 (continued)

- *Ageing well, ageing productively* — Developing better social, medical and population health strategies to improve the mental and physical capacities of ageing people.
- *Strengthening Australia's social and economic fabric* — Understanding and strengthening key elements of Australia's social and economic fabric to help families and individuals live healthy, productive and fulfilling lives.

3. Frontier technologies for building and transforming Australian industries

- *Breakthrough science* — Better understanding of the fundamental processes that will advance knowledge and facilitate the development of technological innovations.
- *Frontier technologies* — Enhanced capacity in frontier technologies to power world-class industries of the future and build on Australia's strengths in research and innovation.
- *Advanced Materials* — Advanced materials for applications in construction, communications, transport, agriculture and medicine.
- *Smart information use* — Improved data management for existing and new business applications and creative applications for digital technologies.
- *Promoting an innovation culture and economy* — Maximising Australia's creative and technological capability by understanding the factors conducive to innovation and its acceptance.

4. Safeguarding Australia

- *Critical infrastructure* — Protecting Australia's critical infrastructure including our financial, energy, communications and transport systems.
- *Understanding our region and our world* — Enhancing Australia's capacity to interpret and engage with its regional and global environment through a greater understanding of languages, societies, politics and cultures.
- *Protecting Australia from invasive pests and diseases* — Counteract the impact of invasive species through the application of new technologies and by integrating approaches across agencies and jurisdictions.
- *Protecting Australia from terrorism and crime* — By promoting a healthy and diverse research and development system that anticipates threats and supports core competencies in modern and rapid identification techniques.
- *Transformational defence technologies* — Transform military operations for the defence of Australia by providing superior technologies, better information and improved ways of operation.

Source: DEST (2003a).

Table 9.1 **Science and technology priorities in OECD countries**

Country	*Priority fields of science and technology*
Australia	Environmentally sustainable Australia; promoting and maintaining good health; frontier technologies for building and transforming Australian industries; safeguarding Australia.
Austria	Life sciences; ICT; nanosciences and micro technologies; mobility, transport, space and aeronautics; environment, energy and sustainability; social sciences, humanities, cultural studies.
Czech Republic	Embryonic cell research.
Denmark	Biotechnology; nanotechnology; ICT.
France	Research for health; development of renewable energy; resource management (water and food); diffusion of knowledge and promotion of scientific culture.
Germany	ICT; microsystems engineering; optical technology; materials research; clean processes and production technologies; biotechnology; nanotechnology.
Hungary	Material science, production engineering and equipment; energy; transport; electronics, measurement and control technology; biotechnology; environmental protection; ICT and its applications.
Iceland	Environment; ICT; nanotechnology.
Ireland	Biotechnology; ICT.
Japan	Life sciences; ICT; environment; nanotechnology and materials.
Korea	Digital TV and broadcasting; displays; intelligent robots; new-generation automobiles (intelligent car, clean car, etc.); next-generation semiconductors, next-generation mobile communication; intelligent home-networks; digital content and solutions; next-generation batteries; biomedicine (bio-chips, artificial organs, etc.).
Mexico	ICT; biotechnology; materials; design; and manufacturing processes. In addition, sectoral funds have been established for applied research and technology development in areas such as health, communications, environment, housing, agriculture.
Netherlands	Life sciences and genomics; nanotechnology; ICT.
New Zealand	Biotechnology; ICT; creative industries.
Norway	Marine research; medical and health research; ICT; energy and environment; functional genomics; new materials (i.e. nanotechnology).
Spain	Chemistry; materials (including nanotechnology); industrial design; quality of life (including biomedicine and biotechnology); space; physics; information society; social sciences and humanities; security.
United Kingdom	Stem cells; sustainable energy; post-genomics and proteomics; e-science; basic technologies.
United States	Inter-agency priorities include: homeland security; networking and information technology; nanotechnology; priority areas of the physical sciences; biology of complex systems; climate, water and hydrogen.

Source: OECD (2004c).

As part of the implementation process for NRPs, Commonwealth research agencies and funding bodies were asked to submit implementation plans indicating, among other things, the current level of investment in priority areas and projected changes over a two to five year timespan. At first glance, an overview sample of these plans indicates that even though the priorities are very broad in nature, their establishment has had an impact on the directions of research activity. For instance, several agencies have reported increases in alignment of their funding allocation to NRPs.

Nevertheless, their effect should not be overestimated. DEST (2003c) examined the reported alignment between expenditure and the NRPs for six agencies, programs and funding bodies (CSIRO, ARC, DSTO, NHMRC, CRCs and Antarctic Division), accounting for just over three-quarters of all expenditure by those subject to the NRPs for 2002-03. While some of the spending in these agencies reflected more specific priorities set by the Commonwealth and other stakeholders, a strong alignment between allocations and the NRPs was already evident at that early stage. As DEST commented, 'the NRPs are intended to be a light touch approach to priority setting' (sub. 87, p. 29).

Leaving aside issues of their coverage, and the processes for their formulation — the Victorian Government, for instance, called for State and Territory involvement (sub. 84, p. 54) — a point of debate is whether the NRPs should be specified in greater detail or quantified.

Some participants did not support tightening of the NRPs. For instance, the Australian Vice-Chancellors' Committee considered that 'the NRPs are satisfactory in their current form and would not want to see them more narrowly defined (sub. 60, p. 36). And CHASS commented:

> Recent suggestions that the Government may seek to have the NRPs applied less flexibly raise concerns that this may result in funding for some forms of research, and for some fields, being reduced. (sub. 52, p. 11)

Nevertheless, it went on to argue that the NRPs needed to offer 'a better match between Australian needs and Australian expertise' (sub. 52, p. 14).

And the Western Australian Department of Agriculture and Food said:

> There is a need for objective determination of national R&D priorities linked to areas with prospective high return and strategic importance. (sub. 44, p. iii)

Building greater detail into the NRPs would bring both potential advantages as well as disadvantages. On the advantage side, the Government would be able to more precisely specify the outcomes sought from the spending of public funds based on its judgment of where community benefits are most likely to occur. Moreover, more tightly specified NRPs would result in more focused guidance to agencies as to what their expected outcomes should be, which, in turn, could make performance evaluation more meaningful.

However, such a prescriptive approach would raise a number of problems. Essentially, it would detract from the advantages of incrementalism, diversity and devolution discussed above. Governments would be making decisions about the details of funding allocation which are possibly best left to expert funding agencies, research institutions and individual researchers. A focus on quantifiable inputs or outcomes could bias funding towards the applied end of the research spectrum at the expense of basic and applied research. And it would add to uncertainty through exposing individual projects and researchers more directly to political direction and research ‘fashions’.

Clearly there will always be tradeoffs between maintaining stability in science systems and shifting resources in response to emerging technologies, opportunities and societal needs. The OECD, for example, notes that achieving the right balance between ‘top-down’ and ‘bottom-up’ approaches to priority setting is (2003a, p. 75) ‘… the fundamental tension in priority setting and is likely to continue’.

On balance, the Commission is of the view that the disadvantages of greater specification and quantification of NRPs would outweigh the advantages.

10 Business programs

Key points

- Australia's current suite of business programs do not target the rationales for public support (additionality and spillovers) effectively and, as a consequence, involve substantial transfers from taxpayers to firms without attendant net benefits.
  - the need to raise taxation revenue to fund these transfers creates large efficiency losses.
- In particular, the basic 125% R&D tax concession:
  - is available to all eligible firms whether or not the R&D would have been performed anyway; and
  - it assists R&D that has low levels of spillover.

  The effectiveness of the program could be improved by tightening the definition of eligible R&D and maintaining access to the concession for small firms only.
- The premium 175% component of the R&D tax concession could also be improved by moving to a scheme based on changes in R&D intensity from a fixed base period. Selective modifications to the beneficial ownership requirement and access to the premium component by start-up firms could also be made.
- There is robust evidence that the Commercial Ready program supports too many programs that would have proceeded without public support, and that the national benefits from the program are, at best, uncertain. This is unsatisfactory given the quantum of funding involved.
- The Commission has strong concerns regarding governance arrangements for business programs in general. Institutional change is required to ensure such programs are managed more effectively and the lessons from their evaluation are fed back into program design.
- There are grounds for public support of RRDCs that provide spillover benefits beyond industry members where R&D would not proceed in the absence of support. But there is only a weak rationale for the present substantial co-funding of industry-centred RRDCs. Changes to current arrangements should be announced well in advance of their implementation.
- Although assistance to automotive R&D is generous in comparison to other sectors, this needs to be viewed in light of the transition to a lower tariff environment.
- The complete shift to industry-focused CRCs is inappropriate. In addition, current cost-sharing arrangements do not appear to reflect the distribution of benefits from the program, with potentially large subsidies available to business partners. Given high associated compliance costs under current arrangements, a complementary arrangement to support smaller-scale and short-term collaborations between groups of firms either independently or with universities and public sector research agencies should be introduced.

10.1 Introduction

Science and innovation programs should provide support to firms, public sector research agencies (PSRAs) and higher education research providers in order to undertake socially valuable research. These programs, while potentially valuable if properly designed, face particular challenges because of the uncertainty regarding the outcomes of support and the behaviour of the agents chosen to pursue those outcomes.

Research is an inherently risky endeavour. As such, policy makers (and in many cases the agents themselves) cannot know in advance which projects will deliver the greatest (if any) private and social benefits. Moreover, the agents (firms and researchers) given support by the government to produce and diffuse knowledge have information that could improve policy decisions, but that may not be in their own interests to reveal (such as whether a firm would undertake a research project without the aid of a public subsidy).

Accordingly, program designers must use eligibility criteria and incentives as a means of selecting the research performers and projects that will produce the most socially valuable outcomes from any given level of public support, even while recognising that the inherent absence of relevant information makes such a task problematic.

10.2 Elements of good program design

Where programs have the capacity to improve economic, social and environmental outcomes, the focus of policy and program design should be on getting the maximum benefit for the funding involved. This will be supported by adhering to a range of desirable design principles (box 10.1). While there will inevitably be tradeoffs between some of these principles, the relative importance of each will depend on the objective being targeted (for example, whether the aim is to increase business R&D or raise the quality and impact of higher education and public sector research).

Targeting and inducement

Effective programs are based on sound rationales and target appropriate objectives rather than particular firms, sectors or activities. The ultimate objective of science and innovation programs must be to encourage a higher level of socially valuable activity than would be undertaken in the absence of public support.

Box 10.1 **Design principles**

- Target the source of the problem (objectives/rationales)
- Inducement (additionality)
- Contestability
- Consistency
- Funding duration
- Avoidance of risks
– Adverse interactions with other programs
– Unforseen liabilities for government
– Strategic behaviour by firms
- Administrative and compliance efficiency
- Accountability and transparency
- Cost effectiveness
- Compliance with international obligations
- Evaluation, monitoring and reporting

Source: Lattimore (1998).

Any gains from such support have to be weighed against alternative options for spending by government (opportunity costs) or the distortionary cost associated with the need to raise taxation revenue (the marginal excess burden of taxation). The importance of targeting activity that would not otherwise proceed was recognised by the Australian Research Council:

> The potential for government funding to replace, rather than complement, the efforts of private investors is now widely canvassed. Such substitution, if substantial, could undermine returns to public investment by subsidising research that would otherwise be undertaken by those most likely to capture its benefits (creating little or no 'additional' research) and diverting funds from areas where the public return is likely to be greater. (sub. 73, p. 23)

Although various design tools are available to help meet program goals, such tools all have problems. For example, while eligibility criteria can restrict support for business R&D activity to that above a base level, there is no guarantee that public support itself induced the expansion. Similarly, incentive mechanisms that aim to ensure that only genuinely new research proposals are put forward to receive support can be problematic in their implementation (see below).

Contestability

Where possible, funding arrangements should provide an incentive structure that maximises the economic and social value of expenditure on science and innovation activity to the community. One important design tool is to make public support open to all potential providers on a competitive basis as this encourages merit-based project selection and efficiency in resource use. The Association of Australian Medical Research Institutes (AAMRI), for example, acknowledged these benefits in its submission:

> … competition for funding — is of course necessary to ensure that the limited funds available are delivered to the projects most likely to produce the desired outcomes. The only disadvantages are that this increases the time delay between the idea and its initiation and it requires considerable effort on the part of policy makers to get the judging criteria right and on the reviewers to do their job diligently. These are opportunity costs but the alternative of not formally assessing and ranking proposals would make it difficult to justify that the expended funds were used in the best interests of taxpayers. (sub. 41, p. 6)

Competitive funding arrangements are a feature of science and innovation systems in most countries. In Australia, for example, many business programs have this feature as does a significant stream of funding for higher education. But there are also major elements of Australia's innovation system (such as public sector research agencies) where public funding is not directly contestable except through the budget process. The R&D tax concession is similarly not a contestable program. As discussed below, there may be some reasons for not always relying on contestability, including the need for strategic capability building, infrastructure provision and on the grounds of administrative efficiency. The appropriate balance between contestable and non-contestable funding mechanisms is a key issue.

Contestable funding arrangements can be applied at different levels, from individual projects to research institutions. As noted in the Commission's earlier report on R&D (IC 1995), the choice between contestable and other forms of funding will depend on a range of issues including:

- the ability to define appropriate objectives in terms of community benefits;
- the ability to evaluate the merits of competing proposals against those objectives;
- the administrative and compliance costs involved in the application and evaluation of funding proposals; and
- the potential for strategic behaviour by stakeholders to obtain preferential treatment.

Importantly, contestable funding arrangements need not be inconsistent with the promotion of cooperation and collaboration between research providers. Perhaps the most visible example in an Australian context is the funding basis for the Cooperative Research Centres (CRC) program. The success of that program in fostering cooperation was cited in a number of submissions to this study. The Department of Agriculture and Food Western Australia (DAFWA) specifically used the CRC initiative as a model against which other programs should be compared:

> Although some funding programs (eg Cooperative Research Centre funding) facilitate cooperation between research institutions to deliver focused research outcomes, many other programs promote organisational or regional competition for funds. This competitive approach can improve efficiencies and may stimulate innovative research approaches. However, the experience of many R&D staff is that competition for funds and competition over products from research can be counterproductive, especially where research providers feel under duress due to funding uncertainties, rationalisation pressures and asset fixity (be that physical or human capital). (sub. 44, p. ii)

Administrative and compliance efficiency

All programs involve administrative costs for government and compliance costs for participants. While efficient program design should aim to minimise such costs, the extent of the burden imposed needs to be weighed against the level of program effectiveness. Similarly, program evaluation and monitoring improve program outcomes but require additional administrative resources. In a different context, a threshold level of compliance costs can be useful in deterring lower quality project proposals (although it may also deter smaller socially valuable project proposals) and some projects that would have been conducted anyway.

This latter point was acknowledged with respect to the operation of the R&D tax concession in the submission by the Corporate Tax Association:

> We have had reports from more than a few corporate groups that the 7.5% cash incentive associated with the current base rate concession does not warrant the significant compliance work associated with registering projects and maintaining records of relevant expenditure. This may not altogether be a bad thing, and may in itself go some way to filtering out non-incremental expenditure claims. (sub. DR197, p. 1)

Centralised decision making can involve high administration and compliance costs. Competitive grant schemes, for example, often require detailed information to be provided on individual projects and involve resource-intensive review and assessment processes to select the most meritorious proposal. At the same time, however, the distribution of block funding within public sector research agencies and higher education institutions can also involve internal resource intensive decision-making processes. An example is provided by CSIRO's approach to project selection (chapter 11).

As a final point, coordinating and rationalising programs and delivery agencies is an important means of avoiding duplication and minimising administrative and compliance costs. A number of submissions pointed to coordination problems associated with the multiplicity of programs and delivery networks in Australia's science and innovation policy space. Engineers Australia, in particular, highlighted the issue and proffered an example of the potential consequences:

> … because control of programs and funds is decentralised within and between Commonwealth and State and Territory government and research organisations, and because there are inadequate coordination mechanisms, government expenditure on R&D is still fragmented, complicated and often unaccountable.
>
> …
>
> One of the consequences of the lack of coordination is that there may be insufficient funds to take advantage of major opportunities or address major challenges. (sub. 65, pp. 13–14)

Coordination issues are also covered in chapter 9.

Transparency and simplicity

Transparent and simple program design minimises compliance and administrative costs, provides for greater accountability and is more readily amenable to evaluation and refinement. Straightforward and well-specified criteria for providing support reduce the level of administrative discretion, the uncertainty faced by participants regarding eligibility and also the incentive to reorient activities inappropriately in order to qualify for support. Moreover, simple and broadly-based rules can reduce the absorption of resources devoted to wasteful lobbying and litigation.

That said, allowing greater administrative discretion in decisions regarding funding support may be justified in some cases. This is because the extent of social benefits and/or the responsiveness to financial support will vary from one research proposal and provider to another. While accurate information regarding the net social benefits of public support (whether in university-based basic research or private sector R&D) can be difficult, if not impossible to obtain, proxies do exist. Examples include academic merit or excellence in a higher education context and the risk profile (perhaps related to project size), potential breadth of utilisation and scope for appropriability of a new product or process invention.

This serves to highlight the inherent tradeoffs involved in program design. For example, in a business program context, while discretionary grant schemes involve higher administration and compliance costs than the entitlement-based R&D tax concession, they also offer *potentially* greater scope to target projects with high social benefits because competing project proposals are thoroughly scrutinised and ranked on the basis of merit.

Funding duration

Program duration needs to be aligned with the objectives that underlie public support. Where a program is intended to change culture regarding the value of undertaking a particular activity or provide a demonstration of better practices, the program should have a fixed life with the objective that the better practices will continue once public support has ceased (Lattimore et al. 1998).

While the characteristics of science and innovation activity mean that under-provision is a permanent feature of the market for knowledge and ongoing public support will be warranted, there are examples of Australian programs introduced specifically to change attitudes to innovation (including collaboration), but that appear to have achieved a degree of permanency. Examples range across the business, higher education and public research agency spectrum and are discussed in the following sections.

Avoidance of risks

Interactions among programs

Public support for science and innovation in Australia is spread across a multiplicity of different programs that aim to meet a number of (sometimes conflicting) objectives. Some of these programs can overlap, compensate for, complement or adversely affect each other. Effective program design needs to take account of these interactions. Where support is provided for different activities and in different sectors it is important that the combined level of support is consistent, as far as practicable, with the net social benefits associated with the research undertaken.

In this context, the potential for (and impact of) ‘double-dipping’ needs to be closely scrutinised. For example, although ‘clawback’ arrangements are in place to prevent this in specific circumstances, current arrangements do provide scope for subsidised sectoral research bodies to participate in collaborative arrangements that are partly publicly funded and, under certain conditions, also access the R&D taxation concession. As a second example, some industries enjoy specific public program funding and also benefit from prioritisation in the R&D activities of public sector research agencies. Instances such as these have the potential to increase significantly the subsidy rate provided to certain types of research or to certain sectors and lead to a less effective allocation of overall public support.[1]

Avoiding excessive financial risks

Excessive risks to government revenue should be avoided, preferably through a formal risk-management strategy that efficiently limits sizeable risks (including legal or taxation liabilities). While the simplest approach involves placing a cap on potential liabilities (a feature of most but not all science and innovation program funding in Australia) this involves an implicit and arbitrary judgment about the net social benefits available to support provided above and below the cap.

This issue is especially relevant where program funding is provided via the taxation system as revenue foregone (such as in the case of the R&D tax concession) and where the complexity of that system makes it difficult to accurately estimate in advance a program's actual cost to revenue. In this context, there is some uncertainty regarding the impact of the dividend imputation system on the value of concessions associated with, for example, accelerated depreciation of plant and equipment and R&D expenditures (section 10.4). For the same reasons, the robustness of any program (in terms of the constancy of the benefits provided and the program's cost) needs to be re-assessed in line with changes to other policies and the economic environment.

Strategic behaviour

The higher the proportionate level of public support provided to a business research project the greater the chance of encouraging an unwanted behavioural response because the financial consequences of project failure are reduced. In turn, this could lead to potentially poor project management and project selection as well as a desire to find loopholes that allow non-R&D activity to pose as genuine R&D (as occurred in the case of core technology, feedstock and interest deductions in the R&D tax concession during the 1990s). Accordingly, programs should aim to build on market incentives wherever possible.

For certain types of activity (for example, applied research) an involvement by commercial stakeholders (either on a collaborative or contractual basis) can reduce

1 The complexity associated with some aspects of Australia's science and innovation funding arrangements means that care should be exercised in judging what constitutes double-dipping. In the higher education sector, for example, block-funding is partly determined by an institution's success in securing ARC grants. But project overheads (such as infrastructure) are generally not covered by ARC grants and therefore require supplementary funding from other sources.

the potential for inappropriate behaviour by directing research to areas more likely to have practical applications. And in most areas (notably in funding arrangements for higher education and public sector research agencies), contestability can provide an effective discipline on researchers as it raises the potential for funding to be reallocated to higher quality and more efficient providers.

Evaluation, monitoring and reporting

As discussed in chapter 8, proper evaluation of research programs and research proposals is critical to transparency, accountability, achievement of program objectives and policy learning. Program evaluations should be conducted on both an ex ante and ex post basis — the former in order to assess and rank the potential social returns from the provision of support and the latter to facilitate accountability and improvements to program design.

The cornerstone of program evaluation should be thorough formal cost-benefit analysis where possible, and initiation or continuation of a program should be dependent on the results of that analysis. Science and innovation activity is inherently risky and uncertain with the specific outcomes from research difficult to specify in advance and also measure in hindsight (especially for basic research). But this is no reason to dispense with systematic and consistent analysis.

Public reporting of the results of program evaluations should be a mandatory requirement as it increases transparency, reinforces the accountability of those designing and managing programs to act in the community’s best interests. Such reporting can also provide useful information to potential program participants. As noted below, some program administrators have serially failed to release the results of program evaluations in a timely manner. This raises questions regarding their findings. The level of detail in reports should reflect the amount of public support provided. Core requirements should include program objectives, selection criteria, and evidence of the net social impacts of the program or project.

Finally, many decisions about program delivery will be quite difficult in practice. This highlights the importance of administrative innovation and learning, as the initial program design or other features may need to be modified in the light of experience. It also reinforces the need for effective program evaluation to provide feedback about program performance.

One participant, Don Scott-Kemmis, highlighted some concerns associated with current program evaluation practices:

> Program evaluations are too often not carried out as a mechanism for policy ‘learning’, but rather as quickly and cheaply as possible. Indeed in some cases the evaluations of

significant innovation programs are not made publicly available, due to a veto by some departments. This is unacceptable not only because of the lack of accountability, but also due to the lost opportunities for learning. (sub. DR183, p. 1)

Assessment of current arrangements

The following sections provide a sketch of the main elements of Australian Government support to business for science and innovation in Australia. Their purpose is to highlight the key program design strengths and weaknesses in current science and innovation arrangements and to offer some insights into potential improvements. While they draw on the material in this section, that material is not used as a checklist against which to assess every feature of those arrangements.

Two broad funding approaches are used by governments to support business involvement in science and innovation — intellectual property regimes may be considered another element (with funding provided by the users of the resulting knowledge) but these are discussed elsewhere in this report:

- direct fiscal incentives to firms to subsidise the cost of R&D; and
- hybrid arrangements involving public-private partnerships aimed at encouraging collaboration and the utilisation of research outputs (such as the CRC program).

These approaches can be viewed as complementary in the sense that they target different objectives and this highlights the need for diversity in policy design. But none of these mechanisms is a perfect solution to the underlying problems they seek to address as they each create incentives that are, to varying degrees, incompatible with ideal community outcomes. Nor are they costless to implement. Accordingly, the most appropriate form of policy intervention will depend on the nature of the activity and the market incentives for its supply. This also implies that, in certain cases, the most effective response may be to do nothing as there is a net cost associated with intervening. An important (though difficult) policy question is the appropriate funding allocation across business and other science and innovation programs. This issue was discussed in chapter 9.

10.3 Overview of business sector support

Direct support for business sector science and innovation activity by the Australian Government was around $1.2 billion in 2004-05 (or 22 per cent of total federal funding for science and innovation). That support is delivered through a range of programs distinguished according to: whether they are sector-specific or generally available; the stage of business development for which they are intended; and whether the funds are allocated on a competitive or entitlement basis (DITR sub. 93, p. 5).

The main programs are: the R&D Tax Concession (which accounts for about 50 per cent of total business support); Rural Research and Development Corporations; grant funding under the Commercial Ready Program (which replaced R&D Start and several other smaller programs); and the Automotive Competitiveness and Investment Scheme (table 10.1). A number of smaller programs (many of which target small- and medium-sized enterprises) make up the remainder. The level of support provided by these arrangements — defined in this chapter as the level of the Australian Government's contribution for every $100 of business spending on R&D — varies considerably across programs (table 10.1).

10.4 R&D tax concession

Key features

The R&D Tax Concession Scheme was introduced in 1985 (originally at a uniform rate of 150 per cent) as a temporary measure to '… encourage Australian industry to undertake increased levels of systematic R&D' (IR&D Board 2005). Program objectives have been variously modified since that time (in line with trends in general policy thinking) with the current stated goals being much wider than the original motivation and now include improving competitiveness and export-orientation.

The scheme is broadly-based, provides for decentralised decision-making on the type of activity undertaken (subject to eligibility criteria) and is open-ended in that it is not subject to either sunset provisions or to a funding cap. Since its introduction, it has been reviewed and refined on several occasions — primarily to deal with unforeseen problems in its operation. It currently involves the following three components:

- a basic 125% R&D Tax Concession — allowing all companies incorporated in Australia and undertaking eligible R&D activities to claim a deduction of 125% of R&D expenditure;

Table 10.1 **Government contribution to major business support programs in 2004-05**

Program	*Government contribution for every $100 of business spending*	*Program cost*
	Dollars	$ million
R&D Taxation Concession[a]		
Basic 125 per cent	7.5	490
Premium 175 per cent	22.5	90
Rural Research & Development Corporations[b]	76.8	214
Commercial Ready	100.0	152
Automotive Competitiveness and Investment Scheme (R&D component)	45.0	128
Cooperative Research Centres[c]	125.0	195

a The notional subsidy rate to a firm on an after-tax basis will be higher than that implied by the government contribution rate. However, the operation of the dividend imputation system will act to clawback part of the Government contribution (see the text below). **b** Based on average industry contribution across industry-focused RRDCs (table 10.4). **c** Maximum potential support based on average industry contribution to CRC program since 1991. Ignores additional support provided by the R&D taxation concession and other programs where relevant. Payments to Cooperative Research Centres (CRCs) for the purpose of eligible R&D may also be eligible for the R&D Tax Concession.

Sources: Australian Government 2006d; IR&D Board 2005 and PC estimates.

- an incremental 175% Premium R&D Tax Concession — introduced in June 2001 to provide a higher level deduction for eligible expenditure on labour[2] and for that part of a company's claim that is greater than its average R&D expenditure over the previous three years; and
- an R&D Tax Offset — to assist small companies, especially those in tax loss, by providing an immediate benefit from the basic and incremental components by allowing benefits to be 'cashed out'. The offset is available to companies with an annual group turnover up to $5 million subject to an R&D expenditure threshold of less than $1 million.

At a 30 per cent company tax rate, the level of the Australian Government's contribution for every $100 of business R&D varies between $7.50 for the basic concession and $22.50 for the incremental component. While this is in the mid-tier of support provided by other OECD countries (appendix C), a number of participants called for an increase in the subsidy rate (see below).

There were around 5500 companies registered for the program at 30 June 2006 with total eligible expenditure of just over $7.7 billion in 2004-05. Firms eligible for the

2 In 2004-05, around 43 per cent of business expenditure on R&D was accounted for by labour. Other current expenditure accounted for a further 50 per cent and capital items about 6 per cent (ABS 2006b).

premium tax concession (including the Tax Offset) reported R&D expenditure of about $3.7 billion in that year (although the majority of this activity would attract the lower concession rate because it is not additional R&D).[3]

The definition of R&D

The definition of eligible R&D is based, in principle, on the widely-recognised OECD *Frascati Manual* (OECD 2002) classification covering all types of activity from basic research to experimental development, but is broader in scope (see below). Eligible R&D is defined as systematic, investigative and experimental activity that involves innovation *or* high levels of technical risk conducted for the purpose of acquiring new knowledge (whether or not with a specific practical application) or creating new or improved materials, products, devices, processes or services. To ensure there is a scientific or technological basis to eligible expenditure, a range of activities are excluded. Among these are the making of cosmetic modifications to products, processes or production methods (this is relevant to the discussion later regarding ACIS).

In the draft report, the Commission commented that much of the R&D undertaken in Australia was not radical in nature and mainly involved product-based incremental change with benefits more likely to be specific to the individual firm conducting the research.[4] As such, this type of activity *was likely to* involve lower levels of spillover benefits (the predominant rationale for government support) compared with truly novel and technically risky research and that with broader potential utilisation. This conclusion was supported by a number of submissions, including that by the DITR which acknowledged this feature in the following way:

> Most Australian industry innovation is incremental — ie it does not involve the introduction of radical new products, processes or changes that may create a new industry, but poses improvements to existing products or systems. It generally does not involve a new to the world technology, service, process or organisational change, but more commonly encompasses 'new to the business' or 'new to the industry' innovation. (sub. 93, p. 34)

The submission from Biota Holdings Limited (in making a case for extending the concession to larger tax loss companies) similarly highlighted the current nature of activities supported by the program:

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[3] DITR (sub. DR185, p. 5) noted that around $1 billion of R&D was supported by the premium component in 2004-05.

[4] CSIRO (sub. DR184, p. 10) made the distinction that 'incremental innovation is largely about maintaining competitive advantage, while radical innovation creates competitive advantage, transforms industries and creates completely new opportunities.'

As such, the [lack of] application of the R&D concession to truly innovative companies is actually counter to the spirit of innovation, where high risk takers are penalised and those engaged in low level, low risk innovation are the prime beneficiaries of one of Australia's primary [support] mechanisms for research and development. (sub. 94, p. 4)

CSIRO contrasted the features of incremental and radical research in concluding that public support should preferentially target radical innovation on both spillover and additionality grounds:

Radical innovation can create a broad range of options relevant to a greater diversity of players than can the far narrower scope of incremental innovation. This means that spillovers have the potential to be larger. Radical innovation is also linked with spillovers much more strongly than incremental innovation. (sub. DR184, pp. 9–10)

Another participant, Roy Rose, an individual with a background in corporate R&D management, addressed the issue in terms of R&D quality. He commented that the eligibility criteria for both the incremental and basic concession took no account of this feature:

As with the standard concession, there is no reference to the quality of the increased R&D, only the fact that the quantum has increased, regardless of the starting level. (sub. DR198, p. 3)

Other participants disputed the Commission's view and highlighted the importance of incremental research. They also revealed the private incentives for its provision (including on a collective industry basis) in competitive product markets. Rio Tinto, for one, said:

We question the underlying assumption that 'much of the R&D undertaken in Australia' involves 'product-based incremental change' and would have taken place anyway. We would argue that the definition of eligible R&D as 'investigative and experimental activity that involves innovation or high levels of technical risk', together with the existing list of exclusions is adequate to exclude routine incremental product development. For an industry such as ours with its reliance on long term capital investment, significant incremental process improvement can be slow in the absence of external incentives, but when it happens the impacts are likely to be industry-wide. (sub. DR142, p. 2)

Similarly, the Ford Motor Company noted that:

… the company believes the Commission has seriously under-estimated the national contribution of what it describes in the draft report as incremental catch-up research and development. …

A global characteristic of technically-based industries such as automotive manufacture is the evolutionary nature of product development. This in part reflects the enormous capital demands of the industry with model specific infrastructure such as engine, stamping and assembly plants, together with ever reducing model life-cycles with a focus on continuous incremental improvement and very strong competitive intensity in

> the marketplace. In such an environment, incremental research and development plays an important role in determining competitive success. (sub. DR188, pp. 1–2)

While the Commission acknowledges that the nature of (and incentives to perform) R&D will vary across industries due to differences in both technical demands and market characteristics, the rationale for public support is to target activities that have two features: they generate high spillovers and they would not take place in the absence of that support. As such activity is likely to involve higher levels of novelty and technical risk, eligibility criteria determining access to support should, to the extent practicable, reflect those features.

Currently, the definition of R&D (noted in Rio Tinto's submission above) contained in section 73B of the Income Tax Assessment Act 1936 (ITAA 1936) is broader in scope than that used in internationally-recognised classification systems such as the Frascati and Oslo Manuals (OECD and Eurostat 2005).[5] In particular, the Frascati definition requires R&D to be both innovative **and** involve technical risk rather than meeting the lower hurdle of either feature being present (as in the current definition used for the tax concession).

In addition, the Oslo Manual (Third Edition 2005) defines innovation as the pursuit of either new or **significantly** improved goods, services or processes. The definition used for the tax concession, on the other hand, includes activities carried on to create either new or improved outcomes in these areas (although innovation is deemed to require an appreciable element of novelty).

The Commission recognises that restricting the scope of R&D eligible for the tax concession will necessarily increase both the administrative and compliance costs associated with the program as access determinations will involve a greater degree of discretion, firms will be motivated to lobby program administrators for favourable treatment and litigate in the event of adverse outcomes. The potential for a range of unforseen consequences associated with any particular wording changes will also likely increase. For these reasons, care needs to be exercised in considering the context of any amendments.

Nevertheless, the Commission sees merit in examining the current wording used to define R&D for the purposes of the tax concession. A potential amendment would involve moving to a requirement that eligible activity be both highly innovative **and** involve high levels of technical risk. The Commission is aware that a similar change

[5] DITR (2005b) noted in a recent comparison of R&D support arrangements in Australia, the United Kingdom, Ireland, Canada and the United States that the scope of eligible activity is most generous in Australia and Canada (largely due to the eligibility of supporting activities).

was in fact part of the original package of measures announced under the Backing Australia's Ability initiative but was later rescinded.

This process could even be broadened to align the different definitions of R&D used to meet different corporate reporting obligations and thereby reduce the associated uncertainty and compliance burden. As Integrated Research Limited noted:

> Australia has a highly regulated and bureaucratic system for dealing with, and the reporting of, activities that involve research and/or development. Currently, the complexities include the basis for recording research and/or development activities for accounting, taxation and Australian Bureau of Statistics requirements. Going forward, it is our request for these disparate requirements to become more closely aligned as a means to simplify the reporting burden imposed upon commercial enterprises. … In particular, this could be addressed by progressing towards a closer alignment of the reporting requirement needs of the ABS (and the definition used by the ABS) with those of either Australian Accounting Standard AASB138 or alternatively section 73B of the ITAA. (sub. DR208, pp. 1–4)

Other potential changes to restrict eligibility would necessarily involve a high degree of subjectivity. For example, access could be restricted on the basis of firm size and R&D intensity as smaller firms with a greater R&D focus are more likely to perform genuinely new and more widely-utilised research. But the choice of what is an appropriate activity threshold would be arbitrary and, unless carefully designed, involve perverse incentives as firms would effectively be penalised for growth beyond the threshold.[6]

Alternatively, only firms with a continuous record of R&D activity over a given time period (say three years) could be allowed access to the concession as this group of firms is also more likely to be R&D intensive and involved in performing genuinely new R&D compared with those firms who conduct R&D intermittently. In this case, however, start-up firms would require special access provisions and some firms may be inadvertently denied access (even where their R&D behaviour would be influenced by the concession) if they were involved in only a relatively small number of projects with discrete (lumpy) funding requirements. This is more likely to be the case for smaller firms. Design issues are discussed in greater detail below.

Finally, in contrast to the discussion above, some participants sought a broadening in the coverage of activities eligible for the tax concession. For example, the Council for the Humanities, Arts and Social Sciences (CHASS) argued that research in the fields it represented '…is scientific in and of itself, or else it is a contributor to Australia's innovation system alongside the sciences — and inextricably bound

6 By way of example, there is currently evidence that some firms are restricting R&D activity in order to qualify for the R&D tax offset (DITR 2005a).

up with them. (sub. DR171, p. 171, p. 5) It went on to suggest that because such research was denied access to the concession this was marginalising the role of knowledge work in the creative arts, humanities and social sciences in the for-profit sector.

The Commission shares the view put by CHASS that research in these areas is critical to innovation. It plays an important role in many government activities and in those instances it is routinely funded by government. It is also increasingly important in business as the service sector expands and as less technological activities play a larger role in innovation generally (such as business activities that require understanding of complex human behaviours — marketing, business re-organisation, and human resource management).

However, the key problem in extending eligibility to the tax concession to HASS research is not that the activity is not intrinsic to innovation; but that it is so entwined with innovation that it would be hard to implement a policy that did not subsidise activities that would have happened anyway. This aspiration is hard enough to achieve for technological R&D. Accordingly, on implementation grounds, the Commission is wary about widening the eligibility for the tax concession to research in the humanities, arts and social sciences.

FINDING 10.1

The definition of R&D contained in section 73B of the ITAA 1936 should be reviewed and, if practicable, amended to focus on activity that is more likely to involve high levels of spillovers. That definition alone should be uniformly applied to meet all corporate reporting requirements to reduce the complexity associated with current arrangements.

The basic 125 per cent concession poses problems

As noted above, public programs should aim, in addition to targeting activities that involve significant spillovers, to have the highest possible inducement rate. However, the basic tax concession is likely to have a relatively low inducement rate because it provides an across-the-board subsidy to eligible expenditure regardless of whether the R&D would have been undertaken anyway. In that case, large annual transfers are being provided to R&D performers and the consultant firms that advise them. These transfers generate economic costs arising from the distortionary taxes that are levied to make up for the revenue forgone under the scheme. Accordingly, the net social benefits from the program are likely to be lower than they would have been had the program been better targeted.

The importance of inducement was acknowledged in the submission by the program designer — the Department of Industry, Tourism and Resources (DITR) — as was (by omission) the failure of the basic concession to meet this criteria:

> Most DITR programs are designed to induce additionality — that is, to induce an outcome or behaviour that would not otherwise have occurred, or would have occurred more slowly, if government support had not been forthcoming. Competitive entry programs like Commercial Ready do this through the assessment process while the 175% R&D Tax Concession and [the Pharmaceuticals Partnerships Program] only subsidise activity above a historical base. A focus on additionality helps to ensure that the support provided by Government is economically efficient. (sub. 93, p. 11)

Submissions from some program beneficiaries supported this conclusion. In responding to the draft report, CSL, for example, said:

> They [the Commission] were particularly concerned that [the program] 'subsidised' R&D that would take place without the concession. It is certainly our experience that efficient firms face a minimum level of non-discretionary R&D expenditure, consistent with the Commission's view. But we accept that this will vary across firms, and there are undoubtedly some efficient firms that do undertake additional R&D on the back of the 125% concession. (sub. DR177, p. 18)

Despite this feature, several evaluations of the program have concluded that it has still delivered a net social benefit to the Australian community. For example, the Bureau of Industry Economics (1993) found that the earlier 150 per cent tax concession provided a net social benefit of $56 million per annum even though up to 90 per cent of the supported R&D would have occurred anyway. Importantly, that study found the program had much higher inducement for small firms (with less than 20 employees) compared with larger firms (this is relevant to the discussion below). A more recent cost-benefit analysis found the net social benefit from the 125 per cent tax concession was around $52 million per annum despite the scheme raising R&D by 10 per cent at most (Lattimore 1997). That study also found that the net social benefit would have nearly doubled if transfers to firms had been avoided.

Similarly, the most recent evaluation (CIE 2003b) concluded that a likely benefit-cost ratio associated with the scheme was around 1:1 with around 70 per cent of the budget cost of the program ($280 million in 2003-04) invested in marginal R&D projects and 30 per cent simply a (non socially beneficial) transfer between the government and firms. As noted by the CIE, the results of its analysis rest crucially on the estimate of spillover benefits for which there is little hard evidence. On the basis of the range of inducement and spillovers rates preferred in that study, the Commission noted in the draft report that it is quite plausible that the scheme involves a significant net social cost and that the risk of such an outcome would be considerably reduced if the inducement were higher (table 10.2).[7, 8]

The effectiveness of the basic concession in stimulating additional R&D activity received considerable commentary from participants with many current program beneficiaries (including firms, associated umbrella organisations and consultants) disputing the Commission's contention that the rate of inducement associated with the basic concession was low. These participants did not address the empirical evidence presented above, but claimed that the proposal would lead to a precipitous decline in domestic business R&D and an associated exodus of such activity to countries with more generous R&D incentives. Cochlear, for example, in concert with around eighty other almost identical form letters from individual firms said:

> Abolition of the base 125% R&D tax concession would, in our view be a backward step and would have a deleterious influence on our ongoing investment in Australia. Accordingly, Cochlear strongly recommends that the Commission rescinds its recommendation to abolish the base 125% R&D tax concession. (sub. DR131, p. 1)

This view was shared by Integrated Research Limited (IRI):

> Removal of the base R&D tax concession will have a significant impact upon companies undertaking R&D in highly labour intensive industries such as software development. Accordingly, given current exchange rates, reduction of (or removal of) the base R&D concession may force companies such as Integrated Research Limited to seriously consider relocating R&D activities to countries with more favourable forms of assistance for R&D activity. (sub. DR208, p. 1)

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7 The Commission notes that the CIE evaluation estimated the inducement rate associated with the program was between 50 and 90 per cent (with a best estimate of 69 per cent). While this is much higher than the findings from the earlier studies, it simply reflects the use of a different definition of inducement. The earlier studies defined the inducement rate as the increase in R&D as a share of total R&D eligible for the concession. The CIE defines inducement as the increase in R&D as a share of foregone tax revenue (a much smaller base). Based on the alternative definition, the CIE finding is equivalent to an inducement rate of between 4.5 and 8.1 per cent.

8 Of interest, one element of the CIE's multi-faceted methodology involved a survey of program recipients. Based on a sample of 744 firms (a 30 per cent response rate to the 2500 survey questionnaires distributed), the results indicated an upper-bound inducement rate equivalent to twice the revenue foregone from the program (although the CIE noted several reasons why this was likely to be an overestimate). In other words, program beneficiaries themselves indicated that up to 80 per cent of the R&D being supported would have been conducted anyway. The survey results also showed the inducement rate for small R&D performers (defined in terms of R&D expenditure rather than employment or turnover size) was 50 per cent higher than that for higher R&D performers (although this result did not hold for most of the other methods used by the CIE to estimate the rate of inducement from the program).

Table 10.2 **Benefit-cost analysis of the 125 per cent R&D tax concession**
$ million

Benefits	
Transfer from government to companies[a]	22.4 – 112.0
Private benefit from induced R&D[b]	112.0 – 201.6
Spillover and flow-on benefits from induced R&D[c]	42.0 – 327.6
Total benefit	***176.4 – 641.2***
Costs	
Budget cost of scheme	280
Efficiency cost	85
Administrative cost	10
Compliance cost	35
Total cost	***410***
Net benefit	**-233.6 to +231.2**

Note: Benefit calculations are based on an estimated inducement rate between 0.5 and 0.9 and assumed spillover rate between 0.3 and 1.3. No account is made of clawback of the tax concession through the dividend imputation system, which would reduce (increase) the net social loss (benefit) from the program.

[a] This is the budget cost of the scheme x (1 – inducement rate) x (1 – leakage to foreign firms). [b] This is the budget cost of the scheme x inducement rate x (1 – leakage to foreign firms). [c] This is the budget cost of the scheme x inducement rate x spillover rate.

Source: Based on the methodology used in CIE (2003b).

Similarly, TGR BioSciences noted:

> … a program that rewards only incremental R&D fails to benefit the companies that are already maintaining a very high level of R&D. It is in Australia's interests to help these companies maintain such high levels of innovation. Removal of a general tax concession could run the risk that such companies will decrease their level of R&D or even choose to relocate overseas. (sub. DR140, p. 2)

And the Minerals Council of Australia concurred:

> If the Tax Concession is removed there is a serious concern that BERD will drop if Australia does not provide a climate that is at least as favourable to investment in R&D as provided in other developed countries. (sub. DR210, p. 5)

Others noted that abandoning the basic concession would significantly affect the number of beneficiaries (small firms in particular). For example, the Taxation Institute of Australia said:

> It is worth noting that for 2004/05 only 1,182 companies accessed the incremental concession out of a total of 5,961 companies that registered with AusIndustry. As a result, if we take this as a typical year, it would mean about 80 per cent of companies engaging in R&D would not have received any support for their R&D during 2004/05 if the base concession was removed. We believe that this would send a very negative message to a large number of companies during a time when innovation is seen to be

> key to increasing the global competitiveness of the Australian economy. (sub. DR199, p. 2)

DITR (which also provided supporting evidence highlighting the volatile nature of small firm R&D) cited international experience with incremental schemes to illustrate its concern with the Commission's draft proposal:

> Incremental only tax schemes assist few firms. The 175% Premium assists around 1,000 firms. And these are predominately large firms. The US scheme is accessed by 0.2% of US firms. France's largely incremental scheme is only accessed by 4,000 firms. Should Australia only retain the 175% incremental regime, only round 1,200 companies could be assisted by the R&D Tax Concession. This would be contrary to the Government's objective of promoting business R&D expenditure. (Industry Research and Development Act 1986). (sub. DR185, p. 5)

In response, the Commission notes that while the draft proposal may significantly reduce the number of firms accessing the tax concession, the overall community benefits from the program are still likely to increase as a result. However, as discussed in the draft report, there may be a basis for maintaining the basic concession for small firms only (see below).

A number of participants supported the Commission's view on inducement (many of which also detailed their reasoning). For example, Roy Rose questioned the impact of the concession on stimulating new activity and its associated influence on location decisions (noting there were many countries where high quality R&D could be conducted at much lower cost than in Australia regardless of the concession). He said:

> In my experience the availability of the R&D tax concession has **never** influenced either the quantum or nature of the R&D undertaken. From discussions with other technology managers (largely at [the Australian Industrial Research Group] meetings) the same can be said for most other large research intensive companies. Indeed, I am yet to meet a technology manager who claims that there is a connection between the availability of the concession and the amount of R&D undertaken in his or her organisation! (sub. DR198, p. 2)

Similarly, Rio Tinto argued that factors other than the concession were more important determinants of location decisions:

> While existing incentives such as the 125% tax concession are important, they are unlikely to play a key role in influencing Rio Tinto's decision on where to locate significant research infrastructure, particularly infrastructure that is aimed at unlocking breakthrough technologies. Such decisions are far more likely to be influenced by the existence of a critical mass of world-class research facilities and researcher supporting basic science, with which we can establish strong relationships. (sub. DR142, p. 3)

This was reinforced by CSL, which noted that its commitment to R&D in Australia '…conforms to a well-established fact that even companies that are highly internationalised display a degree of "home market bias" in their R&D decisions, for example by locating R&D close to corporate headquarters'. This reflected several factors including:

> Unique knowledge of, and ability to exploit, innovation-related skills in its home market may be a source of competitive advantage, for example, because of long-standing ties to research establishments and key researchers. (sub. DR177, p. 6)

Roy Rose raised a similar point:

> The nexus between the R&D and marketing functions is critical in terms of the ***market effectiveness*** of the R&D function. Separating these functions geographically, even within a country or city, lowers this effectiveness (sub. DR198, p. 2)

In summary, the Commission notes the divergent opinions of participants but, on balance, remains convinced that the basic R&D tax concession has low inducement, particularly for large firms. There is some evidence (although not universally accepted) of higher inducement for smaller firms. And, as discussed below, the volatile nature of R&D and turnover activity by small firms may preclude them from access to an incremental scheme. In that context, the alternative canvassed in the draft report of maintaining the basic concession for this group alone may be the most effective way of improving the net payoff from the program (see below).

FINDING 10.2

The extent to which the basic R&D tax concession stimulates additional R&D is low, particularly for large firms.

Factors affecting inducement

Several participants to this study implied, either directly or indirectly, that the ability of the basic concession to induce new activity had been compromised by restrictions on its accessibility (primarily the beneficial ownership requirements for intellectual property and the activity thresholds applying to the tax offset) and a reduction in the value of the concession due to a lowering of the corporate tax rate and the concession rate (from 150 per cent to 125 per cent) and the impact of the dividend imputation system.

Beneficial ownership requirement

The beneficial ownership requirement effectively prevents subsidiaries of foreign owned companies from access to the tax concession. The submission by GlaxoSmithKline outlined the nature of the restriction in the following way:

> Under the Income Tax Assessment Act and the IR&D Act the concession is limited to those entities that hold the intellectual property associated with the R&D domestically. This effectively prevents subsidiaries of multi-national entities, for which head office requires intellectual property to be held centrally, from accessing the benefit and means that a significant proportion of the R&D carried out by members of the pharmaceutical industry is without any significant public support by way of tax incentives. (sub. 38, p. 27)

The apparent rationale for restricting access has been a desire by Government to avoid transferring revenue to foreigners without delivering a corresponding benefit to Australia.[9] For their part, foreign firms have previously argued that lack of access to the concession makes Australia a less attractive location to conduct R&D than other countries. However, as touched on above, in the Commission's view the modest subsidy provided by the concession is unlikely to play a key role in influencing location decisions especially in comparison to other features of Australia's innovation environment. As AusBiotech noted in it submission:

> Australia has an innovative and cost-effective research base. Compared with ten countries in Europe, North America and Asia as of January 2006, Australia was ranked the second most cost-effective location to conduct biotechnology research over the past ten years, behind Singapore. Austrade sees Australia's high ranking due partly to a strong supply of highly-qualified scientists, with more graduates in the fields of science and technology relative to other fields than in other developed countries. (sub. 95, p. 4)

As noted above, Rio Tinto similarly highlighted the importance of access to high quality researchers (as well as research facilities).

Nevertheless, the concession would obviously be of some value to foreign firms as it could be applied to the R&D activity they already conduct in Australia (that is, activity that would not be stimulated by the concession). In considering whether to relax the restriction, however, the relevant criteria that should be applied is whether the net social benefits (spillovers) to the Australian community from foreign access outweigh the associated leakage and financing costs. Empirical evidence suggests that this is not the case. For example, one Australian study concluded that the net

9 DITR (sub. 93, p. 21) noted that there is no beneficial ownership restriction under the Pharmaceutical Partnerships Program because the support provided by that program '… is based on the rationale that spillovers are derived from conducting R&D activity, rather than owning the IP, which is why [it] has an emphasis on partnering and requires all R&D to take place in Australia.'

social return to Australia from providing the tax concession to foreign-owned firms was highly negative largely because of the social cost of the transfer payments (Lattimore 1997).

In addition, the Commission's recent evaluation of Pharmaceutical Industry Investment Program (PC 2003a) noted a range of risks involved in making a *broad* change to beneficial ownership requirements and also that the advantages of quarantining such a change to the pharmaceutical industry were outweighed by the disadvantages. It went on to suggest:

> … the problems associated with accessing the Tax Concession and the other identified rationales for intervention provide a prima facie case for some other form of direct industry assistance, oriented to R&D. (PC 2003a)

And, as noted in the submission by Medicines Australia (sub. 99, p. 23), the implementation of the Pharmaceuticals Partnerships Program (succeeding the earlier program and that now provides a 50 per cent public subsidy for increases in eligible R&D) could in part be described as the Government's response to that recommendation.

On the basis of this evidence, the Commission noted in the draft report that there did not appear to be a strong case for relaxing the beneficial ownership requirements applying to the 125 per cent tax concession. However, given that the extent of transfers is likely be lower for an incremental program (due to higher expected inducement) the draft report commented that it may be worth considering allowing access to the premium component of the tax concession scheme (see below).

Accordingly, the Commission went on to propose the removal of the beneficial ownership requirement for the incremental scheme alone. The proposal was supported by a number of participants including DITR — although it cautioned that the wording in the draft report was too broad and could be interpreted as applying to Australian domiciled firms as well as the subsidiaries of foreign firms. This raised the prospect of abuse. It said:

> DITR sees merit in the Productivity Commission's recommendation to enable firms that hold their IP offshore to receive support only for incremental R&D. This is a trade-off between stimulating additional R&D expenditure in Australia, possibly lower spillovers where royalty income flows overseas, and the contention that MNEs generally engage in higher quality and more innovative investment than smaller companies.
>
> …
>
> However, the specific wording of the finding in the Report needs to be more precise as the concept of 'beneficial ownership' is the prime mechanism for determining the exact recipient of tax deductions across the whole concession, not just for the issue of foreign

owned firms. It also is one of the key compliance protection measures and should not be changed more broadly. (sub. DR185, pp. 26–27)

The Taxation Institute of Australia also supported the proposal but noted that the change may not be as important as other factors in encouraging the location of R&D activities in Australia. It said:

> The proposal to relax the beneficial ownership requirement for the IP resulting from the R&D activities of the incremental scheme alone mirrors the current arrangements in place for the Pharmaceutical Partnerships Program (P3). If the intention is to simply increase the level of R&D activity in Australia similar to the intent of P3 (to promote additional, high-quality R&D and encourage partnerships and collaborations between multinational firms and local companies), then this suggestion may be effective. However, as noted in AusBiotech's submission to the Commission, there are many other reasons for locating R&D activities in Australia and this proposed change to the scheme may not be a sufficient incentive in itself. (sub. DR199, p. 3)

On the basis of this input, the Commission has maintained the intent of the draft finding but also narrowed its potential application to subsidiaries of foreign-owned firms only.

FINDING 10.3

The beneficial ownership requirement for subsidiaries of foreign-owned firms should be relaxed for the incremental scheme alone.

Activity thresholds applying to the tax offset

Several participants were critical of features of the present treatment of tax loss firms undertaking R&D. For example, Biota Holdings noted the detrimental impact of excluding larger firms that were in a tax loss position from access to the concession or the tax offset because they needed access to capital. It said:

> … many innovative companies can not access the benefits of the R&D tax concession when they most need it (during the capital intensive development phase) and gain access to the benefits of the concession when they least need it (often after they have commercialised the innovation and are profitable). This scenario may account for the increasing number of companies who are unable to fund the ongoing research needed to produce innovative results and goes some way to explaining why so many companies are unable to take innovation through to commercialisation. (sub. 94, pp. 3–4)

In a subsequent submission, Biota highlighted both the discriminatory nature of the present arrangement and the potential for some firms — particularly those in the bio-technology sector — to be denied access to the benefits of the concession even when they eventually become profitable (in cases where they are the subject of a takeover). They said:

When consolidation occurs, as the same business test is principally met, the tax losses of both the acquirer and acquired should be available to the combined entity. Losing the ability of the acquirer and acquired businesses to maintain tax losses serves to decrease the value of the business being acquired. (sub. DR187, p. 5)

According to DITR (sub. 93, p. 16), the basis for explicitly targeting small firms with the tax offset is that capital is a critical issue for these firms if they are to sustain their research programs. As noted in chapter 3, there is some evidence that capital constraints may be more significant for small firms and start-ups than for larger firms. Consequently, the Commission does not see a general case for expanding access to the offset on the grounds of the need to access capital.

However, the asymmetric treatment of tax losses would significantly reduce the value of R&D support for firms such as Biota with long lead-times in product development (and may extinguish it if there is a change of ownership). While complete removal of expenditure and turnover thresholds for the tax offset (as proposed in the draft report) would overcome the effects of such asymmetries, this would pose several major risks for government.

The revenue implications (especially in the short term) of completely relaxing the activity thresholds are likely to be substantial given the number of tax-loss companies with large accumulated R&D expenditures that are currently ineligible for the Tax Offset. R&D tax concession registration information provided by DITR subsequent to the draft report's release suggests that additional R&D expenditure by firms in tax loss but not currently gaining the Offset was between $400 million and $2400 million in 2003-04.[10] Accordingly, the additional R&D expenditure that would become eligible for the Offset under the Commission's draft proposal (removal of the activity thresholds) could have been as high as $2.4 billion in that year. The associated cost to revenue in that case would be $180 million (assuming all the expenditure was eligible for the basic Offset alone) — more than four times the estimated cost of the Offset in 2003-04 (Treasury 2006).

The revenue consequences of the Commission's proposal would also be magnified because the tax offset (as a cash equivalent payment) is not subject to clawback through the dividend imputation system. As discussed below, a significant portion of the benefit from the tax concession may be clawed back as a result of imputation depending on the dividend profile of individual firms. Accordingly, the tax offset is

10 The lower end of the range excludes all firms where the reported profit was zero (or not provided) and all firms with an ultimate holding company. Under current grouping rules, R&D is ineligible for the Offset where the grouped entity is not in a tax loss position. The upper end of the range <u>includes</u> all firms with a reported profit of zero and all those with ultimate holding companies.

far more valuable to firms (and far more costly to government) than is the tax concession.

As such, the removal of the activity thresholds may heighten the potential for some firms to act strategically by misreporting their financial position or reorganising their corporate structure in order to gain access to the benefit. The Commission also understands that the activity thresholds were introduced, at least in part, to guard against such strategic behaviour. For these reasons, the Commission has reconsidered its original proposal to completely relax the activity thresholds applying to the tax offset.

However, there are still grounds to consider the impact of the thresholds used for the tax offset. DITR noted the perverse nature of the incentives they created:

> DITR considers that there is evidence … to support further examination of the $1 million R&D expenditure threshold for the Tax Offset. There appear to be firms not increasing their R&D beyond the $1 million dollar mark to ensure they retain access to the Offset. Small tax-loss firms spending more than the current cap of $1 million on R&D are subject to the same financial market failures and tax distortions as those spending below the $1 million cap. (sub. DR185 p. 22)

As such, the threshold effectively acts to impose a very high marginal tax rate once R&D expenditure exceeds $1 million. An option to overcome this problem would be to allow eligible firms access to the offset up to the R&D threshold with any activity above the threshold being eligible for the tax concession. Such an option was in fact put forward by PriceWaterhouseCoopers in commenting on the Commission's draft finding to allow start-up firms access to the incremental concession:

> In our experience, further attention should be focused on allowing businesses who meet the $5 million turnover threshold but fail the $1 million R&D threshold to cash out their R&D spend up to the $1 million mark and then access either the 125% or 175% concession for the remainder of their eligible R&D spend. This would provide the greatest advantage to these start-up businesses in our opinion. (sub. DR196, p. 3)

The turnover threshold could be viewed as acting in a similar manner (although it might be reasonably argued that a firm is less likely to forego potentially profitable sales opportunities compared with R&D with an uncertain payoff just to receive a modest upfront subsidy). In this case, it may be worth considering a phased withdrawal of access to the offset for firms whose turnover is above $5 million, (say up to $10 million).

FINDING 10.4

The design of current expenditure and turnover limits for eligibility to the tax offset create perverse incentives against undertaking R&D above a certain amount. The design of the threshold arrangements should be amended.

Reductions in the concession rate

Some participants also raised concerns regarding the erosion in the value of the basic concession over time and its effects on R&D. The submission by Engineers Australia, for example, stated:

> The R&D tax concession has been extremely successful, and Engineers Australia supports its continuation. Where successfully applied by companies, it has the added advantage of providing government with taxes after the initial development period, which can, in many cases, adequately cover the initial outlay. However, business has been deterred from investing in R&D by frequent changes to incentives, and by the reduction in their value. (sub. 88, p. 6)

Integrated Research Limited strongly argued that the impact of the concession on the company's R&D had been systematically eroded by reduction's in its value although it also acknowledged that:

> … the R&D premium goes some way towards restoring the R&D tax concession's value that has diminished over time via successive changes to the company tax rate and reduction in the base R&D tax concession from 150% to 125%. (sub. DR208, p. 5)

The Victorian Innovation Economy Advisory Board went further by asserting a causal link between the reduction in the concession rate and subsequent trends in Australia's business R&D:

> … since 1996, when the 150 per cent tax concession was reduced to 125 per cent … this had an immediate and negative impact on business R&D. (sub. 89, attachment p. 2)

While the timing of the reduction in the concession rate certainly coincided with a decline in Australia's BERD to GDP ratio, there were a number of other policy changes around that time that were far more important influences. In particular, the syndicated R&D program (which accounted for more than 30 per cent of claims under the tax concession in 1994-95) was terminated as a result of concerns regarding abuse of the scheme and the definition of eligible R&D was tightened to exclude a range of overheads, consumables (such as feedstock) and interest items from being claimed. Against that background, the rise in the BERD to GDP ratio in more recent years is even more significant.

Dividend imputation system

Finally, some also highlighted the dilutive impact of the dividend imputation system on the value of the concession to firms. The Australian Industry Group (Ai Group), for example, commented that:

> For most companies, the effectiveness of the current R&D tax concession is substantially eroded by the workings of Australia's imputation system. Companies eligible to receive the R&D tax concession pay less company tax. However, they also do not accumulate franking credits in respect of the saving in company tax. The shortfall in franking credits implies a higher level of tax paid by shareholders on dividends received. For many companies, the saving in company tax due to the R&D tax concession is exactly offset by the higher level of tax paid by shareholders on dividends. (sub. DR121, p. 5)

The Ai Group went on to propose a remedy by allowing firms to '… credit their franking accounts by the amount of company tax saved as a result of the R&D tax concession.' (sub. DR121, p. 5).

The Commission acknowledges that the imputation system has the potential to significantly clawback benefits from the program with the actual impact dependent on the tax position and dividend profile of individual firms (box 10.2). However, empirical evidence points to considerable uncertainty about the overall magnitude with estimates ranging between 5 per cent and 15 per cent.[11] Importantly, the higher the level of clawback through the imputation system the greater the net social benefits from the program. This point was emphasised by the DITR in its response to the draft report:

> The CIE (2003) found that the benefits generated by the 125% concession are between $0.70 and $1.98 for each dollar of tax revenue foregone. This estimate does not account for the substantial clawback of government costs through reduced franking credits to investors. (sub. DR185, p. 20)

That said, the Commission does not support the suggestion by the Ai Group to allow firms to credit their franking accounts by the amount of company tax saved as a result of the concession. Applying such a credit would, in effect, be equivalent to an increase in the concession rate. In addition, given the likelihood that firms paying fully franked dividends are larger firms (which are generally less responsive to the concession) the impact of the imputation system will generally be lower than for with firms paying unfranked dividends. The measure would therefore increase the risk to revenue for, at best, uncertain gains. It may also increase the complexity and administrative burden associated with the company tax system.

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11 The Commission is aware of much higher assumptions regarding the extent of clawback used by some organisations.

Box 10.2 **Impact of dividend imputation on the R&D tax concession**

The imputation system was introduced in Australia in 1987 to remove the double taxation of dividend income. Under the system, dividend payments to resident shareholders carry tax credits (known as franking credits) equal to the rate of company tax paid on corporate profits. The effect is that income earned by companies and paid as dividends is only taxed once, at the marginal income tax rate of the shareholder.

As it currently operates in Australia, however, the imputation system has the potential to reduce or eliminate the value of any concession received by a company (such as the R&D tax concession), which reduces the amount of tax it is required to pay on profits. This is because companies using the concession will in general not have sufficient credits to pay all of their post-tax income as fully franked dividends.

Companies may be able (at least partially) to avoid this effect if they retain and reinvest earnings that have not been subject to company tax because of the concession. Shareholders therefore benefit from the returns obtained on the retained earnings (which also increase the capital value of the firm), part of which is contributed by government in the form of a temporary tax saving. However, even in this case, the eventual taxation of capital gains may also reduce the value of the concession (although the recent introduction of the discounted capital gains tax regime will mitigate this to some extent).

Accordingly, washout may lead to significant variation in benefits from tax concessions between shareholders of different types of companies and according to the companies' financial circumstances and decisions (assuming firms take account of shareholder returns). For example, there will be no dilution of the concession's value for smaller start-up R&D performers in a tax loss position because they have immediate access to the tax offset (effectively a grant).

On the other hand, shareholders in profitable firms that pay unfranked dividends will incur at least partial washout. Elsewhere, shareholders in firms reluctant to pay unfranked dividends (typically larger established companies) will benefit from the concession to a greater degree. And in another case, companies whose eligible expenditure represents a significant share of taxable income (hence limiting the ability to pay franked dividends) the tax concession may encourage the retaining and reinvestment of company earnings.

Some tentative support for these conclusions is provided by a survey of member firms by the Business Council of Australia (BCA 1999) conducted following the lowering of the tax concession rate from 150 per cent to 125 per cent. The results suggested the extent of the impact on R&D depended on a firms dividend policy. In the BCA's words:

> Firms that do not pay dividends, or that pay unfranked dividends, cut their R&D most; those that pay fully franked dividends cut it somewhat, and those paying partly franked dividends increased it although it although not by as much as the growth rate of all firms before the changes.

Source: Bureau of Industry Economics 1993, Business Council of Australia 1999.

The incremental scheme

Given its concerns over the effectiveness of the basic concession, the Commission argued in the draft report that, in principle, the premium component of the tax concession scheme offered much greater potential to encourage additional R&D and increase the net social benefits from the program. This feature was also highlighted by the program designer:

> The 175 per cent Premium Tax Concession promotes higher additionality by offering the higher rate only to firms that increase their average investment in R&D. (DITR sub. 93, p. 16)

Importantly, while incremental schemes have the capacity to reduce non-beneficial transfer payments significantly, they are unlikely to eliminate them entirely as firms will still accept support even if the increase in R&D is not stimulated by the subsidy. However, it is very difficult to design policies that do not subsidise some R&D that would have occurred anyway (see below). The submission by the Corporate Tax Association (representing the taxation interest of Australia's largest companies) emphasised this point:

> We acknowledge that in an ideal world, the concession would only flow to incremental activities — ie those which would not take place at all but for the concession. The reality, however, is that no government anywhere in the world has been able to design a tax based concession that avoids subsidising to some extent R&D activity that would have taken place anyway. In our view, however, a general tax-based concession system that allows companies to make choices about which activities to pursue is preferred over government agencies making judgements about what is or is not incremental R&D activity. (sub. DR197, p. 1).

That said, the Commission argued in the draft report that for a given level of assistance to marginal R&D, it was reasonable to assume that an incremental scheme will require less revenue and has the potential to generate higher rates of net social benefits. In turn, this can allow for a higher rate of incentive to be provided (which could also increase progressively, the greater the increase in activity from a base period) or for the revenue to be redirected to alternative business R&D or other innovation programs (see below).

Accordingly, the Commission proposed that the R&D tax concession program should be reoriented toward the incremental component (with an option of maintaining access to the basic concession for small firms only on the grounds that the inducement rate was likely to be higher for this group).

There was a degree of support for the draft finding. CSL, for example, endorsed it and, in doing so, highlighted the differential nature of induced R&D:

> Notwithstanding [that some firms undertake additional R&D on the back of the 125% concession], there are grounds for rebalancing the tax concession towards a higher concession rate for truly additional R&D, R&D that is most likely to be innovative in nature. (sub. DR177, p. 18)

Rio Tinto also expressed support and added that a higher concession rate could be applied to R&D that involved higher levels of risk — an option the Commission endorses. It said:

> We would support a move to apply the R&D tax concession in a more targeted way and in particular a shift towards a higher level of subsidy for transformational innovation. (sub. DR142, p. 2)

The Ai Group (sub. DR121, pp. 3–4) also called for a higher benefit to be paid for incremental R&D (although it considered the basic concession should be retained) with the concession rate increasing the greater the change in R&D expenditure.

Roy Rose, on the other hand, questioned the Commission's view that smaller firms would be more responsive to the concession:

> While it may be argued that [the lack of influence of the concession on the quantum or nature of R&D] is not the case with smaller R&D intensive companies, I have not yet been presented with a well argued case to support this proposition. At meetings attended by the author, the strongest support for the concession for smaller companies appears to come from the consulting firms providing R&D tax advice to these companies whose motivation may possibly be driven by issues other than the value of the R&D. (sub. DR198, p. 2)

The submission by DITR, on the other hand, highlighted its concerns regarding the removal of the basic concession for small firms arguing that the nature of R&D activity conducted by that group was not suited to an incremental scheme. It noted that '…erratic patterns of R&D expenditure by small Australian firms reinforce the difficulty that they would face to qualify for the 175% premium scheme.' (sub. DR185, p. 20)

Another participant — the Medical Devices Industry Action Agenda Implementation Group — touched on this feature in contrasting the experience of small and large R&D performers and suggested that a different support mechanism for each of these groups may be required. It said:

> R&D expenditure by small to medium sized companies (SMEs) is often 'lumpy' and varies from year to year. SMEs generally operate on small budgets and find it hard to increase funding for R&D. At the same time, R&D expenditure by large companies is often more fluid with flexibility to continually invest and possibly incrementally increase R&D expenditure. (sub. DR 182, p. 2).

Some participants opposed the draft finding because of the discrete nature of R&D cycles in some sectors and the consequences for moving further toward an incremental scheme (although it could be questioned whether such R&D could be stimulated by either the basic or premium concession). Ford Motor Company, for example, said:

> A tiered-system may also penalise significant research and development investors like the automotive industry because of its exposure to investment peaks and valleys associated with model cycles. (sub. DR188, p. 3)

Others argued that such a move would hamper the ability of firms to plan for the future. The Business Council of Australia said in this regard:

> Moving exclusively to an incremental program would also create an overall environment of uncertainty and provides no basis for budgeting, planning and long term investment. Under an incremental program it will not be until year end, when the realities of the business and R&D effort are calculated, that companies will have any certainty as to the benefit of the R&D tax concession, if any. (sub. DR204, pp. 8–9)

The Commission agrees that there is less certainty associated with an incremental scheme compared with one where firms receive a benefit regardless of whether they would have performed the R&D anyway. But it also considers that this is much less likely to be an issue for larger well-established firms with a long history of forecasting annual sales and expenditure budgets and dealing with the vagaries of the business cycle. For smaller firms, however, this may well be an important factor inhibiting the effectiveness of the program. Accordingly, it supports the case for maintaining access to the basic concession for that latter group alone. However, in advocating differential support mechanisms, the Commission is mindful that threshold issues regarding firm size will need to be addressed to avoid, as far as practicable, the introduction of adverse incentives for growth.

FINDING 10.5

Access to the 125 per cent R&D tax concession should be restricted to small firms.

FINDING 10.6

The 175 per cent premium R&D tax concession should be maintained for both small and large firms.

In the absence of information about the behaviour of *individual* firms accessing the incremental scheme both prior to and following its introduction, it is difficult to accurately estimate the extent of inducement and the net social benefit from that component.[12] While the submission from DITR noted that the premium component '… has stimulated additional R&D expenditure in a select group of mainly larger firms…' (sub. DR185, p. 5) and that the R&D supported by that component had risen from $400 million to over $1 billion in the four years since its introduction, it is not possible to judge how much of the increase would have occurred anyway on the basis of available information.

The Commission commented in the draft report that the actual social return will depend critically on the specific features of the incremental scheme with the challenge to design a program that delivers the biggest net benefit for the amount of revenue forgone. As discussed below, while there is a range of alternatives available, it is likely that a scheme with a fixed activity base will have a higher return than a rolling base especially if the fixed base is appropriately indexed.

As an illustrative example, a recent empirical study in the United Kingdom used the historical R&D experiences of a sample of UK firms to estimate the cost to revenue and associated net benefit of four different R&D support scheme designs (table 10.3). It found that the effectiveness of a sales-indexed fixed activity base was more than three times greater than a three year average rolling base — the latter being a design similar to that currently used in Australia (Bloom et al. 2001).

The design of the incremental scheme

As mentioned, the extent of inducement from incremental schemes depends on their design characteristics. In this respect, the definition of the activity base against which future R&D expenditures are compared can have a significant impact on the behaviour of R&D performers. As noted in an earlier Industry Commission report (IC 1998), there is a range of potential dimensions to determining the base including: whether it moves over time or is fixed; the length of the base period; the activity measure used; whether the benchmark is an individual firm or industry; and whether the base is adjusted for differences between firms.

The Industry Commission argued that adopting a rolling base (such as that which is now used in Australia's incremental scheme) could lead to perverse incentives for R&D performers if R&D does not follow a smooth growth path. For example, its operation would mean that the more a firm spends in one year, the lower the opportunity to access the scheme in future years. The submission to this study from the Corporate Tax Association agreed with this assessment:

12 At the time of writing, the database of firms registered for the tax concession was in the process of being upgraded and the Commission was unable to interrogate the information contained within it. Once that process is complete, the opportunity to conduct such an exercise will be much simpler than is currently the case.

Table 10.3 **Impact of different R&D scheme designs**

	Volume credit (no base)	*Three year rolling average base*	*Inflation-indexed fixed base*	*Sales-indexed fixed base*
A: Induced R&D[a]	£684.0m	£113.0m	£497.0m	£427.0m
B: Revenue Cost[b]	£820.8m	£126.0m	£199.2m	£145.2m
C: Ratio of A to B	0.83	0.90	2.48	2.94

[a] Estimates based on a long run own price elasticity of R&D demand of -1.0. [b] Headline tax credit rate is 20 per cent.

Source: Bloom et al. (2001).

> In relation to the 175% premium deduction scheme, we strongly agree with the views expressed in the draft report that the rolling base for the premium incentive can lead to perverse outcomes. Member companies have reported that qualifying for the premium concession has become something of a 'lucky dip', and is unlikely to be driving corporate behaviour in the way that was intended. (sub. DR197, p. 2)

In addition, a rolling base may also encourage some firms to deliberately increase the variability of their R&D expenditure.[13] And, it is simply not possible for a firm to continually increase its R&D activity in perpetuity — a requirement for ongoing support under a rolling base.

This point was recognised by CSL in its response to the draft report:

> Unfortunately the current 175% increment tax concession can only reward firms that exponentially increase their R&D expenditure and have development lifecycles as a short as a few years. This is an unrealistic base for any firm's innovation strategy, and perhaps explains why the 175% concession represents less than a quarter of the government assistance through tax. If the higher rate concession is to deliver social benefits, it must lock in the higher rate for longer periods that reflect realistic project development timescales. (sub. DR177, p. 18)

Integrated Research Limited agreed:

> Access to the full 175% Premium requires claimant companies to continue with year-on-year incremental increases (in perpetuity) in eligible R&D activities against a (3) three-year rolling average of eligible R&D expenditure in prior years. Year-on-year, the requirement for perpetual (and significant) increases in expenditure is simply not sustainable in the commercial world on the basis that claimants often reduce expenditure in one year versus another. Such expenditure reductions may arise due to changes in business economic conditions, definitional issues arising (which affect eligibility of R&D activities for taxation) when calculating R&D tax expenditure and changes in financial priorities which occur during normal business cycles. (sub. DR208, p. 7)

13 The Commission acknowledges that the current arrangements include a moderating facility where there has been significant prior-year downswings in R&D expenditure.

Roy Rose (sub. DR198, p. 3) contended that implementation of the Commission's findings would go a long way to addressing a number of deficiencies with the current incremental scheme including the unrealistic expectation that there will be a steadily increasing expenditure on R&D over the medium term.

In its earlier report, the Industry Commission suggested that the use of a fixed base would be the preferred route for Australia. It also endorsed the use of R&D to sales as the relevant activity measure (the approach used in the United States) as it provided a more effective means of targeting changes in real R&D activity than a general inflation measure.[14] The desirability of this approach was also raised by the Victorian Innovation Economy Advisory Board in its pre-draft report submission:

> It would also be useful to consider a differential tax concession on the basis of R&D intensity, eg as a proportion of sales revenue. The objective would be to encourage more Australian companies to increase their R&D activity to a scale comparable with leading international companies. If budget neutrality was required, it could be achieved through careful management of the various levels of the concession. Notwithstanding this, we would prefer to see an increase in the overall level of incentive being made available. (sub. 89, attachment p. 4)

The Corporate Tax Association agreed:

> The current premium incentive provides little or no support to companies that achieve and maintain a high level of R&D intensity. We agree that that a fixed base, such as R&D to sales income would be a more appropriate way of designing the premium concession. (sub. DR197, p. 2)

The South Australian Government also supported the suggestion on the basis that it would motivate the manufacturing sector to '… invest in more knowledge intensive products and processes if it is to successfully compete in an increasingly global marketplace.' (sub. DR212, p. 3). It also commented on the design issues raised by the Commission saying:

> … the R&D tax concession should move towards the 175 per cent increment component of the program through the adoption of a fixed base of an R&D to sales ratio as the basis of payment, rather than the existing rolling base. This will enable firms who exceed their fixed base ratio to access the 175 per cent concession without having to meet the unrealistic requirement of continually increasing their R&D activity in perpetuity. (sub. DR212, p. 3)

However, a number of participants disagreed. DITR noted that a fixed activity base had been a feature of the incremental scheme when it was originally introduced in 2001 but was '… subsequently replaced by a volume-based scheme following

14 This conclusion is supported by Bloom et al. (2001) although they note that one problem with this activity measure is that the base will expand or contract in line with total sales, which may be more volatile than R&D expenditure.

strong industry representations about its negative impact on growing firms' (sub. DR185, p. 25). DITR argued that difficulties with using a scheme based on R&D to sales included that:

- It would reward losers ie those whose turnover fell;
- It would offer no reward for spending more on R&D;
- It would penalise firms that are growing;
- It would reduce predictability for firms who are price takers or where sales vary independently to R&D; and
- It would encourage off-shoring, eg manufacture in China while keeping R&D in Australia. (sub. DR185, pp. 25–26)

It also did not support the use of a fixed date to determine the base activity level because the '… high degree of year to year variation precludes this being a fair or accurate measure, and it would encourage company restructuring of R&D timing to establish an artificially low base.' (sub. DR185, p. 26)

While the Commission has reservations about the significance of some of these claims (especially given the ability to employ compliance protection measures),[15] it acknowledges that some firms will be disadvantaged (from time to time) by the design features canvassed in the draft report. As noted above, it is simply not possible to design a perfect scheme. In seeking to improve the effectiveness of the current program, however, it would be instructive to simulate the impact of the Commission's proposal by applying it to the historical R&D experience of firms registered for the tax concession. This would allow for a redesigned scheme to be tailored to minimise undesirable consequences (such as the choice of a base period with an unusually high R&D to sales ratio that would make it difficult for firms to access the scheme in the future).

The Commission has been unable to conduct this exercise because the tax concession database was not in a suitable form to allow such investigation. However, it understands that the database is currently being upgraded. When this process is completed (due around the middle of 2007) the program administrator will be in a position to both test the significance of the perceived difficulties it highlighted in its submission (such as the number of firms that would have gained access to the scheme simply on the basis of a decline in sales activity) and evaluate the most efficient design parameters of an intensity-based scheme to maximise the inducement associated with the incremental concession.

15 For example, firms would not be able to influence their activity base if it was determined ex post.

The Commission accepts that the nature of R&D and sales patterns by small firms will preclude many of them from access to an incremental scheme. But this will not be the case for many large firms with relatively stable activity paths.[16] Moreover, the submission from DITR noted that the perceived difficulties associated with an R&D-to-sales activity base may also be less acute for such larger firms:

> It is possible that an intensity based measure may be more practical for these large firms which have a more stable R&D and turnover. (sub. DR185, p. 26)

Other opponents of the Commission's draft finding focused on the uncertainty that an R&D-to-sales activity base would create for firms in terms of their ability to plan and predict their entitlement. In some cases this was due to the cyclical nature of revenue streams in specific industries. Rio Tinto, for example, commented:

> We note the draft finding that the system could be improved by changing the base on which the incremental subsidy is paid. We would point out however, that while a fixed base relative to sales at a given point in time would work well for firms and industry sectors which experience a relatively smooth sales profile, it might be problematic when applied to cyclical sectors such as mining. (sub. DR142, p. 2)

In others it was because of the impact of exchange rate volatility. Cochlear, in this context, said that because its revenues were denominated primarily in foreign currency (which the Commission presumes, therefore, are unhedged), fluctuations in exchange rates could make its R&D to sales ratio volatile. As a result, it considered that '… a more effective measure of R&D growth is the real increase in R&D expenditure.' (sub. DR 131, p. 3)

Many argued that the change would add to the complexity of the current scheme. PriceWaterhouseCoopers stated in this regard that:

> The incremental 175% tax concession is already an extremely complex piece of legislation. Adding further complexity by overlaying an R&D-to-sales ratio would only further confuse companies wanting to access this benefit. (sub. DR196, p. 2)

Integrated Research Limited also commented on the complexity of current arrangements:

> … the current process for accessing the Premium is cumbersome and full access to the 175% deduction is not attainable to many longstanding applicants. Should the access criteria be amended, we envisage further difficulty to accessing the full 175% Premium and accordingly we request that your recommendations include making full access simplified. (sub. DR208, p. 1)

16 The Commission understands that a relatively small group of large firms accounts for around half of the R&D claimed under the incremental component.

Biota suggested the uncertainty could potentially be reduced via the following modifications:

- A standard 50% concession for all eligible expenditure; or
- A static base level of expenditure could be set for each company (applicable for each year), with additional expenditure above a predetermined level eligible for the 75% premium. This would overcome the complexities with the use of the 3 year rolling average. (sub. DR187, p. 7)

In response to Biota's suggestions, however, the Commission notes that the first option would simply serve to increase the current level of unnecessary transfers to firms while the second would increase the risk of strategic behaviour by firms (for example, by manipulating the timing of expenditures to access the concession). For these reasons, the Commission does not endorse either proposal.

More broadly, the Commission reiterates its view that it is simply not possible to design a program that will treat all firms consistently at all times and in all circumstances. The aim is to improve on the current arrangement — one where robust evidence exists questioning its effectiveness.

FINDING 10.7

The base on which the incremental subsidy is paid should be changed to a firm's ratio of R&D-to-sales at a given, fixed date.

Another issue is the treatment of start-up firms — traditionally an important source of innovative activity — which have no base year defined by their past experiences. Under current arrangements, companies require a three-year history of registering for, and claiming the concession (AusIndustry 2006b). This effectively excludes many start-up firms from access to the 175 per cent concession and the premium tax offset (the latter providing a potentially significant benefit for what are characteristically loss-making and liquidity-constrained high technology firms).[17] The lack of incentive for these firms was highlighted by the Victorian Innovation Economy Advisory Board:

> The R&D tax concession is, of course, not a universal solution. It does not, for example, provide an incentive for those companies that are R&D intensive but not paying tax, such as high technology start ups. (sub. 89, p. 4)

Under a revised arrangement based on the ratio of R&D to sales, the Commission argued that this issue could be addressed by setting an appropriate reference number against which to compare current R&D-to-sales ratios for start-up firms (again the

17 The IR&D Board (sub. DR191, p. 3) noted that start-ups are supported by the tax offset and that use of the R&D START program or Commercial Ready can be used to establish a three year history for a start-up firms seeking to access the premium tax concession.

approach adopted in the US) with those firms falling below the benchmark able to claim full deductibility if they were profitable or the tax offset if they were in a position of tax loss. This would address the concern expressed by the Taxation Institute of Australia that newer firms with little sales activity would be disadvantaged by a shift to an R&D intensity base. It said:

> The Commission's report acknowledges the impact that a volatile R&D spend can have on a company's ability to access the 175% incremental concession. Similarly, we would suggest that the proposal to change the base to a company's ratio of R&D to sales at a *given, fixed date* could result in adverse outcomes for those R&D intensive companies with low or no sales revenue at that given, fixed date. As such, companies in this situation with a high level of R&D intensity would be presented with a significant challenge in subsequent years when sales commence or increase to, once again, access the incremental concession at all or to the same extent. (sub. DR199, p. 3)

It would also guard against the risk of a strategic response by firms of the kind cautioned by the DITR:

> The proposal to give immediate access to start-up firms would create opportunities for firms to artificially structure their R&D to establish a lower base than otherwise. (sub. DR185, p. 25)

FINDING 10.8

Access to the incremental scheme by start-up firms could be improved by assigning an appropriate benchmark value against which to compare current R&D-to-sales ratios.

In conclusion, the Commission maintains its view put in the draft report that net payoff from the concession could be substantially improved by rebalancing the tax concession away from the generally available 125 per cent component towards the 175 per cent incremental component of the program. This could be achieved by maintaining the basic concession for smaller firms, whose R&D is more responsive to the subsidy, and using the 175 per cent incremental component as the principal vehicle for stimulating business R&D by large firms. However, threshold issues regarding firm size would need to be carefully considered to avoid the provision of adverse incentives for growth by firms accessing the basic concession.

Complementary arrangements

Rebalancing the scheme toward the incremental component has the potential to significantly reduce the revenue forgone under current arrangements. This would provide scope to generally increase the concession rate for the premium component or perhaps introduce a tiered system with progressively higher subsidy rates depending on the extent of the increase in a firm's R&D activity.

Alternatively, part of the budgetary savings could be used to pilot and (depending on the outcome of an evaluation based on the framework outlined in chapter 8) establish a program that provides a financial incentive for firms to form R&D networks undertaking collaborative research projects in groups or in conjunction with universities and public sector research agencies. The appropriate design of such a program has the potential to both increase inducement and target research projects with high spillover benefits. As discussed below in the context of the CRC program, there are a number of different options for establishing flexible collaborative arrangements.

Such an alternative was supported by Roy Rose who suggested that the basic concession, and possibly even the premium component, should be scrapped with the budgetary savings from these changes:

> …directed at the development of commercialisation of leading edge science that would not otherwise be funded and in encouraging a greater degree of collaboration between the private, public and academic research sectors. (sub. DR198, p. 1)

The development of other forms of intermediation between business and research organisations was raised in chapter 7.

Other options

At a more general level, other options to raise inducement levels include moving to a greater reliance on competitive grants as they may provide a more effective means of targeting socially valuable activity that firms may be reluctant to undertake. However, as discussed below, inappropriate design features can compromise project selection and heavy information requirements make these approaches costly to administer.

Other alternatives include stock-option grants or contingency-based repayable loans to encourage firms to undertake genuinely new projects (box 10.3). In these cases, it may be appropriate to contract out their management to independent third parties expert in financial management and avoid the difficulties that governments have in recovering loans or exercising their stock options (see below). While they are not perfect methods of inducing socially valuable innovation they do offer insights on ways to improve on current arrangements.

Box 10.3 **Incentive compatible R&D schemes**

There are a number of approaches available to reduce the motivation for firms to accept payments for R&D that they would have been prepared to fund in the absence of an incentive. Incentive compatible mechanisms aim to achieve this by penalising firms seeking unwarranted support. A requirement for the disclosure of the intellectual property from a research project is one such mechanism. Another involves a stock option grant.

Stock option grants

With a stock option grant, the government purchases a share in a company established to undertake and commercialise a technology. After a specified time, the government has the option of selling its share and profiting (if the project was successful) from the sale. A private firm that has a commercially attractive R&D proposition will be reluctant to dilute its interest in that project by agreeing to such an arrangement as it would lead to a net less of income. Royalties and repayable grants impose similar disciplines on firms to present truly additional projects.

A firm that would not have proceeded, on the other hand, may be willing to allow such equity participation. However, as noted by the BIE (1993) there are a number of practical difficulties in the application of stock option grants including the fact that share values can be influenced by factors other than the success or failure of R&D projects. Perhaps for these reasons, the Commission is unaware of any international example of the use of stock option grants. As such it illustrates a conceptually appealing yet practically flawed policy instrument.

Incentive subsidies

Another option involves providing a subsidy that is proportional to the social returns from a project. In this context, the subsidy increases as the expected social benefit rises to provide firms with an incentive to choose the most socially beneficial projects. In principle, this approach can also be shown to discourage the acceptance of mere transfer payments and encourage firms to diffuse the results of their research — effectively compensating them for lowering the private value of an invention but raising the social value.

Fölster (1991) argues that while a perfect incentive policy is impossible to devise due to uncertainty about the private and social benefits of a project, there are near substitutes. He advocates that firms be required to repay a share of profits from successful projects that are at least equal to the level of subsidy they receive (a form of repayable loan). This would encourage firms to seek support for R&D projects that would not otherwise go ahead. In contrast, unsuccessful projects would not be required to repay the subsidy. This feature is important because it provides an incentive for firms to conduct projects with expected private and social benefits but that they view as being too risky to undertake.

Sources: Fölster (1991), BIE (1993), Lattimore (1997).

10.5 Competitive grants programs

Key features

Fiscal incentives for business sector R&D in Australia have included a suite of programs providing merit-based competitive grants to individual firms since 1986. A major motivation for these programs (at least until the current arrangement was introduced) has been to complement the R&D tax concession by supporting smaller firms unable to access benefits from the more generally available scheme (such as where a firm is in a tax loss situation). While the programs have also served a range of other evolving objectives, the criteria used to assess project eligibility have remained relatively constant (see below).

A set of five different grant schemes was originally introduced at the same time as the R&D tax concession with the relative merit of project applications assessed on the basis of economic, technical and commercial criteria. Largely because of industry concerns that the number of schemes was causing unnecessary complexity, they were amalgamated into a single scheme — Competitive Grants for Research and Development — in 1994 with a single set of eligibility and merit criteria. Under the new scheme, the maximum grant available was a uniform 50 per cent of the total eligible project cost with no minimum level of expenditure.

A new measure focusing on larger commercially-oriented R&D projects in smaller firms was introduced in 1996 — the R&D START program. Funding was offered in the form of both grants and loans on a competitive basis. Grants of up to 50 per cent of project costs were available for smaller companies (annual turnover less than $50 million) and up to 20 per cent for larger companies. Importantly, repayable loans were also provided for 'high-quality' projects that increased the maximum subsidy rate to 56 per cent of total project costs for both small and large firms. As discussed below, repayable schemes raise the likelihood of inducing new activity as a firm that would proceed without support has no financial incentive to apply.[18]

According to the IR&D Board (2005), the key eligibility criteria for START were that projects had to have clearly identified commercial potential and that applicants had to demonstrate the projects could not proceed 'satisfactorily' without support. Program funding of just over $1 billion was allocated to START and other programs sharing similar objectives through to 2006 (Allen Consulting Group 2000). The program (along with two smaller programs) was incorporated into the latest business innovation policy measure — the Commercial Ready Program —

18 However, repayable schemes do not encourage projects with low private but high social returns.

which again focuses on commercialising R&D outcomes. Introduced in 2004, the stated objectives of Commercial Ready include:

- increasing the level of R&D, early-stage commercialisation and proof-of-concept activities of small- and medium-sized Australian enterprises; and
- generating national benefits, such as through higher productivity, supporting collaboration and developing Australia's skills base (IR&D Board 2005).

The program provides up to $200 million annually over seven years and is expected to assist around 1700 small- and medium-sized enterprises (the annual turnover threshold was recently increased from $50 million to $100 million) over that period. Around 50 per cent of program funds are to support R&D activities with 30 per cent for early stage commercialisation and 20 per cent for proof-of-concept activities (sub. 93, p. 5).

Funding is provided in the form of competitive grants with successful applicants receiving up to 50 per cent of project costs. A grant ceiling of $5 million applies. Importantly, the repayable-loan component of the START program was not carried over to Commercial Ready. Applications are assessed on five merit-based criteria, each of which receive equal weighting (box 10.4). Given the relatively recent introduction of the program, the discussion below draws on the experience of its predecessors in order to assess the likely impact of the current program.

Key design issues — inducement, adverse selection

The importance of avoiding transfers to firms is explicitly acknowledged in the objectives and eligibility criteria of Commercial Ready and its predecessors. In principle, selective assistance of the type funded by competitive grants should provide greater scope to target R&D projects that would otherwise not proceed (including those with high social returns) because they allow for detailed scrutiny of individual proposals. This is also how other innovation funding programs, notably those managed by the ARC and NHMRC, operate.

In practice, however, asymmetric information regarding an applicant's motivation for seeking support makes effective program design critical. It also means administration and compliance costs are likely to be higher than entitlement-based programs such as the R&D tax concession.[19]

In assessing the effectiveness of earlier grant programs (including R&D START) in encouraging new activity, it is important to recognise that eligibility for the various

19 According to Allen Consulting Group (2000), the administrative cost of the R&D START program was three times higher than the R&D Tax Concession.

schemes required only that grant support be necessary for a project to proceed *satisfactorily*, and that this is a considerably lower hurdle than requiring assistance be provided only to projects that would not proceed in the absence of funding. The apparent rationale underlying this weaker criteria is that where speed to market ('first mover advantage') is critical to an innovation's commercial success, the grant would allow the project to be completed earlier (IR&D Board 2005). Notably, the eligibility criteria for the current Commercial Ready Program maintains the reference to satisfactory project progression (box 10.4).[20]

A number of empirical studies have attempted to assess the proportion of subsequent projects that were likely to have been induced by earlier schemes. Survey results from the three main grant programs that preceded START (the Discretionary Grants Scheme, Generic Technology Grants Scheme and the National Procurement Development Program) showed that up to 50 per cent of the projects would have proceeded without support, although they would have taken longer to complete. A fourth program (the National Companies Teaching Scheme), was independently assessed with the main finding that two-thirds of the projects supported would have proceeded without public funding (IC 1995).

More recently, a survey of 100 START grant recipients found that while more than 60 per cent of firms suggested their project would have been undertaken without public funding the majority of those firms indicated that the absence of support would have resulted in a project that was slower, less well resourced and with reduced outcomes (IR&D Board 2005). In commenting on this result the program administrator said:

> The need to get high quality innovative products to market quickly is critical to the competitiveness and growth of Australian industry. As such the R&D Start grant has a clear and positive impact, even on projects which would have proceeded in the absence of grant funding. (IR&D Board Annual Report 2005, p. 51)

While the Commission acknowledges the importance of 'first mover' advantage in determining commercial viability it remains sceptical that this should form a basis for the provision of public support. Leaving the case for supporting commercialisation objectives aside for the moment, it questions why a rational firm would undertake a project (without public support) if it considered its innovation would not reach its market quickly enough to ensure commercial viability. This suggests that much of the grant funding under START simply represents an unnecessary transfer to firms.

[20] The IR&D Board (sub. DR191, p. 2) noted that the merit criteria receive equal weight during the assessment process.

Box 10.4 **Merit criteria for Commercial Ready program funding**

Management Capability

- An appropriate level of expertise in:
  - commercialisation management
  - project management
  - business management, including in human resources and financial management
- a core business that is directly relevant to the project
- demonstrated company stability and/or growth over the last two years
- a business plan that includes and supports the proposed project.

Commercial potential

- solid track record in commercialisation and marketing of innovative products
- well articulated and sound commercialisation strategy
- realistic appraisal of the commercial potential for the project outcomes, including the product
- understanding the route to market for the project, such as trade barriers, manufacturing and timeframe to commercial exploitation
- understanding of the competitive situation the project outcomes will face:
  - the extent of competitive advantage from the project's commercial outcomes such as on cost, IP position and strengths and weaknesses compared with competing products
  - the frequency with which new products or services enter the market.

Technical strength

- The technical capacity to undertake the project, including:
  - adequate infrastructure, facilities and equipment to meet project requirements
  - good understanding of technical product development, testing and production start-up
  - appropriately skilled technical staff and/or sub-contractors
- well articulated project plan, eg methodologies and milestones linked to a feasible timeframe
- strong track record in the project field
- appropriate level of innovation
- appropriate level of technical risk, demonstrated by uncertainty over results.

National benefits

- how the project will improve national productivity and contribute to economic growth
- how the project will result in social, community *and/or* environmental benefits
- that significant spill-over benefits will accrue to Australia through conduct of the project and/or commercialisation of its results including:
  - diffusion of knowledge and skills
  - diffusion of new products, processes or services, and/or
  - increased collaboration between businesses and/or businesses and research institutions.

Need for funding

- the project budget is realistic
- *Commercial Ready* funding is required for the project to progress satisfactorily, for one or more of the following reasons:
  - insufficient resources to fund the entire project
  - longer time frame for project delivery would erode competitive advantage
  - the technical risk of the project mitigates against it proceeding, and/or
  - project benefits that may justify government investment cannot be adequately captured.

Source: AusIndustry (2005).

Although the IR&D Board has used these results to support the effectiveness of the grant programs it administers, the Commission is concerned about the prominence of commercial outcomes in project selection. In this context, the Board describes its overall mission as being:

> To increase the economic return from successful technology-based enterprises in Australia by supporting their performance and commercialisation of research and technical development. (IR&D Board Annual Report 2005, p. 1)

Accordingly, the merit criteria of grant programs are tailored to increase the likelihood of selecting projects that have the greatest potential for commercial success. In Commercial Ready, for example, emphasis has been given to indicators such as the applicant's track record in commercialisation, expertise in commercialisation management and the commercial environment faced by the innovation (box 10.4).

A number of submissions defended the focus on commercialisation objectives. The South Australian Government, for example, said:

> … the Commercial Ready program is specifically targeted at stimulating expenditure on commercially focused R&D by business. As Australian BERD as a proportion of GDP is generally lower than those of other advanced economies, the South Australian Government would not support the Commercial Ready program changing its focus away from its commercialisation objectives. (sub. DR212, p. 3)

Similarly, GlaxoSmithKline argued:

> This finding is interesting given the objectives of the Commercial Ready program. The Program was established to assist firms in early-stage commercialisation activities, including R&D with a commercial potential. It is one of the few programs that exists to support innovation activity in its broadest sense, such as providing support for proof-of-concept activities. As discussed above, most innovation activity undertaken by Australian firms is not R&D activity, and it is just as important that this activity continues. (sub. DR154, p. 6)

But while the Commission recognises the general shift toward commercialisation objectives across innovation policies both in Australia and overseas, it views the case for public support in this area as having much less force than activities that involve benefits not readily amenable to capture by the innovator. In addition, using commercial success as a major objective for an R&D support scheme can adversely impact on the behaviour of the program administrator. As Fölster (1991) noted:

> The likelihood of a project succeeding commercially depends on two things. First, the administrators' skill in choosing winners and helping to shape a project so that it succeeds. Second, the inherent riskiness of the project. The less risky a project is, however, the greater the chance that the firm would have conducted it anyway and the less effective the government subsidy in stimulating innovation. The administrator

> therefore has an incentive to pick non-risky projects that the firm would have researched anyway in order to show its acumen for spotting winners. (p. 36)

To highlight his point, the author drew on the results of an early Australian study that showed that R&D grants were given to exactly the same kinds of projects that firms conduct without the aid of public support.

Some respondents to the draft report agreed with this assessment. For example, the Federation of Australian Scientific and Technological Societies said:

> We are also concerned that the program is becoming a bit more risk averse in its operations. Anecdotal experience suggests some convergence on more conservative projects which are a bit closer to the market are getting supported. (sub. DR144, p. 13).

However, the IR&D Board disagreed and argued that it did not fund projects that would have been conducted in a competitive timeframe without public support. It said:

> The Board rejects the Report's further assertion that in the case of business commercialisation, public support may currently be provided to firms who can undertake the innovation activity without such assistance. This view fails to take account of the assessment process used by the Board in administering competitive innovation support programs, which requires an assessment of the 'need for funding'. If a firm can undertake the R&D or associated activity in a competitive timeframe without government support, the application for funding assistance is rejected. (sub. DR191, p. 1)

Similarly, DITR rejected the Commission's conclusions in their entirety (including) on the basis that:

> Commercial Ready provides benefits to the economy by supporting projects of Australian SME's which have the potential to successfully bring their product to market but which also must demonstrate the need for funding to satisfactorily progress their project. As such it aims to support additional activity. (sub. DR185, p. 27)

The Ai Group also criticised the conclusions on the basis that '… the Commission needs to provide much more convincing evidence to support its contention that using commercial success as a major objective "can adversely impact on the behaviour of the program administrator".' (sub. DR121, p. 7). It said:

> The Commission questions the validity of commercialisation objectives and implies that less risky projects are being supported, and that such projects 'do nothing' to support high social returns.
>
> While acknowledging that there should be a balanced mix of social and commercial outcomes from publicly funded activity, Ai Group believes that the Commission's arguments need to be more substantially grounded: it provides no proof of capture; it relies on research that pre-dates the Start program (let alone the new Commercial Ready program); it relies on empirical research untested against specific programs; it

makes comparisons with unfunded projects which can be questioned; and it seems somewhat dismissive of the IR&D Board findings of 2005, that in the absence of support results would have been 'slower, less well resourced and with reduced outcomes.' (sub. DR121, p. 7)

However, following the release of the draft report the Commission gained access to two comprehensive evaluations of the earlier START program commissioned by DITR and conducted by the independent Centre for International Economics in 2003 (CIE 2003d,e). The results of both evaluations are cause for significant concern — not just because of the quantum of funding possibly wasted (see below).

The studies took two broad approaches to estimating the extent to which START funding increased the likelihood of a project proceeding. In the first, a survey of both START grant recipients and START applicants who were rejected — non-recipients — was undertaken to assess the difference that START funds made to project outcomes. This approach compared project outcomes for successful START applicants with those of the control group (those that were unsuccessful). It found that the START subsidy made virtually no difference to whether a firm would have proceeded with a project. This conclusion was consistent with the finding that up to 94 per cent of the total benefits from START projects were captured by the firm and, accordingly, 'it could be reasonably expected that such projects would go ahead without the subsidy' (CIE 2003d, p. xi).

Summarising the main conclusions using that approach, the CIE noted that the lack of statistically significant difference between the two groups of firms suggested that the:

- inducement effect of the program on recipients was low;
- national benefits from the induced R&D were minimal; and
- additional national benefits to costs may range from a negative rate of return of $0.85 for every dollar spent to, at best, a relatively low positive rate of return of $1.44 for every dollar of program funding over a 15 year pay back period.

Subsequently, the DITR commissioned the CIE to modify the underlying approach to the evaluation on the basis that the use of the control group had been rejected by two anonymous reviewers who considered that it suffered from selection bias (inter alia because it did not include firms that did not apply for START funding). While the Commission acknowledges that there may be a basis for questioning the composition of the control group, it does not consider this to be the case on the grounds put by the reviewers (appendix M).

In particular, it considers that the relevant comparison should be between START recipients and that group of START applicants that met the eligibility criteria for program funding but were unsuccessful because they were out-ranked by more highly rated proposals. The information necessary to undertake this comparison will be contained within the survey database. Access to that database is controlled by DITR.

Nevertheless, the second evaluation by the CIE relied on the survey responses of successful START applicants and used a range of potential spillover and inducement rates to estimate the net benefit from the program. The results were equally concerning. Using this approach, the CIE could only conclude that '… assessed against the main rational for R&D subsidies — knowledge spillovers — the net national benefits of the program are uncertain…' (CIE 2003e, p. xix).[21]

But more importantly, the CIE reported that based on the survey '… reasonable analytical interpretations of the recipients' responses suggest inducement rates could be anywhere between about 20 and 80 per cent' (CIE 2003e, p. xvi). This means that despite detailed scrutiny of individual project proposals to determine whether they would have proceeded without support, the inducement rate under R&D START is actually lower than a program that has no such requirement — the R&D tax concession (where the CIE estimated an inducement rate of between 50 and 90 per cent).[22]

FINDING 10.9

There is robust evidence indicating that the Commercial Ready program supports too many projects that would have proceeded without public funding assistance.

Governance issues

Neither the IR&D Board nor DITR referred to these findings in their submissions nor have they adequately facilitated public access to them (via either initial or ongoing posting on their internet websites).[23] More concerning, the policy lessons from the significant shortcomings of the START program have not been addressed in the design of Commercial Ready as that program has essentially the same

21 The CIE also stated that against a secondary rationale of capital market failure, there is a possibility that the net national benefits are very large. However, as discussed in chapter 3, the Commission has strong reservations about the use of capital market failure as a justification for public support.

22 Whether the net social benefits from START exceed those of the R&D tax concession will depend on whether spillovers from START projects differ from those associated with the tax concession.

23 The Commission gained access to the first study (CIE 2003d) from the DITR website but the document has since been removed. The second study (CIE 2003e) has not to the Commission's knowledge been placed on the internet by DITR.

selection criteria as R&D START. This is indicative of major deficiencies in current program governance arrangements.

In part, this outcome simply reflects an understandable response by the agencies to the wider needs of their portfolio. Nor is this a recent phenomenon. Spanning over several decades of experience with inquiries and research studies, the Commission has often been confronted with similar failure to fully reflect the results of program evaluations in subsequent policy and program design.

There are a number of options available to address the problem. The most preferable involves shifting responsibility for the commissioning or conduct of program evaluations to an independent agency (for example, the Australian National Audit Office), requiring full public disclosure of the findings and recommendations of those evaluations and also requiring a timely response on the action that is to be taken to address any shortcomings. Another would mirror the current arrangements in jointly administered programs (such as the R&D tax concession) where inter-departmental working groups are established to conduct and/or oversight the evaluation process. In the specific case of Commercial Ready, the Commission considers that involvement by Treasury and the Department of Finance in such a working group would serve to balance the interests of different portfolios.

FINDING 10.10

Governance arrangements relating to business programs need to change. Options include:

- *shifting responsibility for commissioning program evaluations to an independent third party or establishing an inter-departmental working group to oversight such evaluations; and*
- *requiring full public disclosure of the results and recommendations and a timely response on the action to be taken.*

Repayable grants

One potential option for improving Commercial Ready, highlighted by the CIE (2003d), is the use of repayable loans in the event of commercial success. The supplementary loan feature of the START program included such an instrument but it was discontinued under Commercial Ready. Repayable schemes have been widely used overseas, and in some countries they are major forms of R&D support.

In Israel, for example, repayment takes the form of royalty payments from successful project revenue up to a maximum value equal to the grant plus interest

(Lach 2002). The royalty proceeds are then used to fund future R&D projects with around a third of the administering agency's budget coming from that source in 1999 (up from 10 per cent in 1990). In addition, the program is entitlement-based in that all eligible proposals are approved with no requirement for competitive ranking. In that sense, it operates in a similar manner to Australia's tax concession.

Encouragingly, the value of these types of incentive mechanism have been recognised in other parts of Australia's innovation system. CSIRO, for example, is developing a competitive repayable funding program — *Australian Growth Partnerships* — to transfer technology to SMEs and provide technical assistance. In CSIRO's words:

> If the SME were to be successful in commercialising the technology, it would repay the funds received from the program. If participation did not result in successful (profitable) commercial outcomes, no repayment would be necessary. (sub. 50. p. 86)

Use of a repayable loan mechanisms as a means of improving the efficiency of R&D START was also advocated by the CIE (2003d) It proposed the introduction of a loan arrangement similar to that used in the higher education system:

> … given the high expected private returns to the funded R&D, potential recipients should be largely indifferent between receiving the funds in the form of a grant or being given a conditional loan, repayable only upon successful commercialisation and market development – a scheme similar to education HECS scheme. … The advantages would be that:

- the net cost in terms of public funds would be reduced;
- all allocated funds are likely to induce R&D and transfers are likely to be minimised;
- more projects with a smaller allocation of funds are likely to be made more effective;
- the 8 per cent of non-recipients who indicated they have moved offshore may be retained;
- an automatic monitoring of the system would be built in:
  - if rates of return are truly as high as anticipated, repayment of loans with interest would occur, and through time the scheme could be expanded as required; alternatively
  - if rates of return fall short of anticipated, failure of the scheme would eventually become apparent and it could be scaled back or eliminated. (CIE 2003d, pp. 71-72)

Some participants to this study also saw a role for repayment mechanisms. CSL, for example, in highlighting the need for funding to take products from basic research to proof-of-concept stage, said:

> The problem [proof of concept funding] has been tackled in other markets through a variety of mechanisms. … The funds may supply true grant funding, or may supply

> refundable grants which are repaid if and when the project achieves some commercial success. Consideration should be given to these types of mezzanine funding models…' (sub. DR177, p. 12)

However, the IR&D Board opposed such arrangements on the basis of associated administrative costs:

> The Board also notes the Productivity Commission's reference in the draft report to the possible advantages of introducing repayment or benefit sharing arrangements in competitive grant programs. From past experience, the Board would highlight the significant administrative overhead burdens associated with the management of such arrangements, both for companies and the government which would act as a disincentive for companies to access programs. (sub. DR191, p. 2)

Similarly, DITR expressed concerns based on its experience with the R&D START program noting the main problems were high administrative costs, the subjective nature of defining success and the potential for strategic behaviour by firms to avoid payment (including technical project failure, constraining profits or moving offshore). However, it went on to cite the repayment mechanism used in its venture-capital equity programs as its favoured approach to such mechanisms. It said:

> The Innovation Investment Fund [see below] operates on the basis of repayment based on commercial success. The Fund is required to repay the amount provided by Government when funds are obtained from successful exits. Note that the IIF is carefully designed so that the actual commercial assessment of firms and their management capability, along with processing, and exiting of investments is conducted by qualified private sector experts, with significant investment funds at stake. (sub. DR185, p. 29)

The Commission acknowledges the inherent trade-offs involved in (and the need to find a balance between) administrative simplicity and program effectiveness (section 10.1). That said, it considers the strength of the conclusions provided by the CIE evaluation of R&D START and the quantum of funding involved to argue for the re-introduction of a device to deter firms from applying for support they do not require. Accordingly, DITR should explore alternative approaches including a variety of possible repayment mechanisms, and implement the most effective option.

It also considers that elements of the approach favoured by DITR above could be used to recover grants from successful projects provided under Commercial Ready. In particular, while the IR&D Board would still be responsible for project selection, the management of the grant portfolio could be outsourced to suitably qualified private sector experts (forensic auditors) who would independently assess the commercial success of specific projects and, in that event, organise for the repayment of the grant. Alternatively, grant recovery could be achieved via notification to the ATO and repayment would be triggered when a firm achieves a threshold level of profitability (similar to the way the HECS scheme operates).

International lessons

More broadly, the Commission notes that international experience with grant programs has been quite mixed, with stronger evidence of inducement in European studies than elsewhere (appendix M). With the reasons for the differences unclear (including whether the more successful programs employed repayment mechanisms) it would be valuable to examine the features of alternative grant program design arrangements internationally with the aim of implementing any lessons. This task could be undertaken by DITR given its linkages with overseas program administrators and its experience in similar exercises such as the recent international comparison of R&D tax concession arrangements (DITR 2005b).

Alternatively, Australia could take the lead role in establishing and contributing to the funding for an international collaborative effort for evidence-based evaluations of business programs in general. This initiative could be modelled on the so-called Cochrane Collaboration — an independent organisation that produces and disseminates systematic reviews of healthcare interventions and promotes the search for evidence in the form of clinical trials and other studies of interventions. The major output of the Collaboration is a database of reviews that is published on quarterly basis. Review activities are directed by a steering group with the reviews themselves prepared by healthcare professionals and subject to editorial oversight to ensure rigorous quality standards. There are a number of Cochrane Centres worldwide that co-ordinate the activities of the Collaboration. The Australasian Centre is funded by the Australian Government's Department of Health and Ageing.

Another option would be for an international research agency such as the OECD to be encouraged to devote part of its research effort to such a cause.

FINDING 10.11

The introduction of a repayment mechanism in the Commercial Ready program offers scope to improve the inducement rate associated with the program.

FINDING 10.12

A detailed comparative assessment of the design features of successful grant programs in other countries should be undertaken.

Providing selective assistance

Another design issue involves the underlying rationale for providing selective assistance to small- and medium-sized enterprises in the first place. Historically, grant programs in Australia have been used as a complement to the R&D tax concession because new or small technology-intensive firms may often be in a position of tax-loss in their early years (thus rendering the R&D tax concession ineffective). However, the redesign of the tax concession scheme in 2001 included the introduction of a tax offset, which allows the cashing-out of the concession for firms without sufficient taxable income. Of course, the subsidy rate for the concession is considerably lower than the 50 per cent subsidy (up to the threshold) provided under the Commercial Ready program.

At a more general level, there is an in principle question of why large firms should be excluded from access to grant funding. The main rationale for targeting small- and medium-sized firms appears to be based on their perceived inability to access finance. While the Commission accepts there is evidence that capital constraints may be more significant for small firms than for larger firms, it also notes that in an environment of limited budgetary resources, projects with the highest social returns should receive funding priority. Excluding large firms from access to grant funding potentially limits the scope to maximise the social benefits from these types of program.[24,25] However, this may also require a substantial increase in overall program funding given differences in the scale of research activity by larger firms.

Not surprisingly, broader access to grant funding was raised by larger firms and their representative associations. Science Industry Australia (which represents scientific product manufacture and marketing interests), for example, said:

> The $50 million turnover criterion for programs such as Commercial Ready is unrealistic. … The effect of this limit is that the relatively few larger Australian science industry companies that compete in world markets and contribute to Australia's economic and social welfare are denied access to many government support measures. … R&D and other innovation activities are an on-going high risk process for all science industry enterprises, and a higher more realistic turnover ceiling should be established in the range of $100m to $150m. (sub. 22, p. 11)

As noted above, the turnover threshold has recently been increased to $100 million.

24 The exclusion of locally based subsidiaries of multi-national enterprises may also be questioned on these grounds.

25 The threshold issue has also recently been considered by the House of Representatives Standing Committee on Science and Innovation (HRSCSI 2006) which recommended that consideration be given to raising the threshold as part of a review by DITR of the effectiveness of the program.

Other programs

A range of other business programs administered by the IR&D Board also focus on the commercialisation of research conducted by SMEs. They include the Innovation Investment Fund, a competitive program committing $200 million in public support over five years to early-stage venture capital. A maximum subsidy rate of 50 per cent is provided with private sector fund managers responsible for selecting and managing early-stage investments. The Commercialising Emerging Technologies Program aims to assist *very* early stage development for firms that lack knowledge about market opportunities and intellectual property issues through funding for business advisory services. Competitive allocation of $100 million in program funds (over seven years) provides up to an 80 per cent subsidy on eligible expenditure.

The Industry Cooperative Innovation Program involves $25 million in competitive grants providing up to 50 per cent matched funding on cooperative innovation projects that can demonstrate spillover benefits (sub. 93, p. 25). In a different context, the Pre-Seed Fund was introduced to raise the commercialisation of research within higher education, CRC and public research agencies by establishing four venture capital funds with around $70 million in program funding. The subsidy rate is up to 75 per cent with a repayment of all public funding required upon divestment of successful commercialisations.

As a collective comment, the rate of support provided by these programs (at up to $300 for every $100 contributed by industry) is very high. This increases the chance of encouraging an unwanted behavioural response from the selected fund managers and firms because it reduces the consequences of failure. In turn, this could lead to potentially poor project management and project selection. In addition, a greater reliance on repayment and benefit-sharing mechanisms (such as that used in the Pre-Seed program) would provide more effective incentives in these areas.

10.6 State Government support

State and Territory Government support for science and innovation totalled $977 million in 2004-05 (ABS 2006c). This represents less than 20 per cent of the funding provided at the Federal level (including spending on higher education research). The distribution of State and Territory funding is dominated by three research fields: agriculture (consuming 50 per cent of the total), medical and health sciences (25 per cent), and biological sciences (12 per cent). Notably, agricultural research at the State and Territory level stands out among competing research areas as it accounts for half of total government funding (including that sourced from the Australian Government) applied to that field.

The broad objectives of State and Territory funding were variously described in submissions to this study to include support for the core business of government in service provision, policy and economic development, the delivery of public goods in social and environmental areas and skill acquisition. At a more detailed level, there was a common emphasis on commercialisation outcomes, targeting perceived priority or strategic areas such as the information and communications technology and biotechnology sectors, better engagement and collaboration between firms and the research sector and addressing perceived impediments to participation in R&D activity by SMEs.

These goals and the mechanisms used to deliver them mirror those of a number of programs administered at the Federal level. As such, the Commission restates its concerns (raised in this and earlier chapters) about the risks involved with supporting activities on (some of) these grounds as they are likely to lessen the prospects of delivering net benefits to the community. In that context, the effective application of criteria used to determine the role of Government by the Victorian Department of Innovation, Industry and Regional Development would serve to lessen those risks. These are:

- The existence of market, system or information failures which may warrant government intervention;
- Gaps in support from the Federal Government or other sources which mean that the intervention of the Victorian Government is needed. Where-ever possible Victorian Government support is intended to complement rather than compete with Federal Government programs; and
- That intervention will generate net benefits for Victoria. (sub. 84, p. 18)

But there is also a real risk of wasteful duplication of research effort across spheres of government (especially in areas such as agricultural research). This does not mean that the States and Territories do not have a part to play in this area. Aside from its use as an input to service provision and policy development, the New South Wales Government noted another dimension to this role:

> The Commonwealth Government is well placed to determine national research funding priorities, as well as providing overarching support for science and innovation. However, States and Territories, also have a critical role, as this level of governance is closer to the science and innovation research centres, the businesses and the special interest communities that benefit from public support. (sub. 91, p. 4)

Accordingly, inter-governmental coordination mechanisms offer scope to improve the efficiency and effectiveness of research effort in those areas where public support at the State and Territory level is justified. In that context, the initiative by the Primary Industries Ministerial Council to develop a national research, development and extension framework for Australia’s agriculture, fisheries and forestry industries will be useful, especially given the quantum of research funding, and the fragmented nature of that funding, in this area (DAFF 2005). There may also be a role for similar mechanisms in other fields of research — notably medical and health sciences.

10.7 Rural Research and Development Corporations

Key features

Rural Research and Development Corporations (RRDCs) were first established in 1989 under the *Primary Industries and Energy Research and Development Act*. As a group, they plan, fund (primarily from compulsory industry levies and public support) and manage much of the agricultural R&D conducted in Australia (CIE 2003c). There are currently 15 RRDCs (statutory and industry-owned) with all but two of these established to operate within specific industries (table 10.4). In many instances, primary producers contribute to, and benefit from, more than one RRDC (sub. 96, p. v).

The rationale for this industry-specific arrangement is based on the characteristics of many primary industries with a large number of producers, each accounting for a small share of broadly undifferentiated industry output. This makes it difficult for producers to capture sufficient benefit from R&D they might conduct individually in order for them to proceed. Accordingly, even though the collective benefits may justify the investment, there may be under-provision of rural research.

An effective means of addressing this potential problem is to conduct rural R&D cooperatively with funding sourced from producers in proportion to the benefits received. But in cases where there are a large number of producers, compulsory levy arrangements may be required in order to avoid free-riding by some on the R&D funded by others. Furthermore, the existence of benefits that extend beyond the primary industries themselves, but that are captured by the broader community (such as improved transport, storage and food safety and environmental benefits), are argued to justify the provision of some public support.

In practice, the Australian Government generally provides a matching contribution to R&D managed by the RRDCs usually up to a ceiling of 0.5 per cent of the industry's gross value added. In some cases, for example fisheries, horticulture and meat and livestock, the government also matches some industry funds raised for R&D under other arrangements (CIE 2003c). Elsewhere, in research areas with strong public good features such as land, water and vegetation management there is no direct requirement for industry to contribute. Importantly, producers in some

RRDCs contribute beyond the level that attracts matching support. Collectively, these differences mean that the level of public support varies considerably across rural industries (table 10.4).

However, the actual subsidy to rural research is considerably higher when combined with the explicit and implicit support (where the full costs of conducting research are not allocated to the purchasers) provided by those groups that actually perform the R&D for the RRDCs. These include the research arms of State Departments of Agriculture, the CSIRO, universities, CRCs (with 16 operating in the agricultural sector in 2005-06), industry-owned research institutions (including those formed from the statutory RRDCs), ABARE and a range of other groups including industry associations.

Evidence presented by the Department of Agriculture, Fisheries and Forestry shows that including some of these additional funding sources increases the potential subsidy rate significantly, depending on how the benefits are distributed. It said:

> Total investment in agricultural R&D in 2002-03 was approximately $1.2 billion, having increased by approximately 20 per cent in real terms since 1996-97. States and territories provide the greatest proportion of funds (43 per cent in 2002-03) but this has proportionally declined since 1996-97 (53 per cent). Commonwealth contributions (including higher education) have remained relatively constant (approximately 40 per cent) and business investment has increased in this period (from 8 per cent to 17 per cent). (sub. 100, p. 3)

In this context, a recent discussion paper on the national framework for primary industry research, development and extension (RDE) commented on the risks posed by current funding arrangements:

> The current system of funding is characterised by a number of subsidies to private purchasers of research, with the risk that public resources are likely to be diverted to financing private gains. (Frontier Economics 2006, p. iv)

Research planning in both statutory and industry-owned RRDCs involves the preparation of five-year strategic R&D plans in consultation with user groups and annual operational plans designed to focus research activity on objectives endorsed by the Australian Government. Importantly, this appears to be the Australian Government's primary influence on governance arrangements for the RRDCs despite the substantial funding contribution from that source.[26] The discussion paper mentioned above described this feature and what it inferred in the following way:

[26] The Commission notes that the statutory RRDC Boards contain an Australian Government representative from the Department of Agriculture, Fisheries and Forestry.

Table 10.4 **Industry and Australian Government contributions to total RRDC expenditures in 2004-05**

RRDC	*Industry contribution*	*Australian Government contribution*	*R&D[a] expenditure*	*Government contribution per $100 of industry spending*
	$ million	$ million	$ million	Dollars
Statutory RRDCs				
Cotton	4.58	4.32	12.62	94.3
Fisheries	11.20	16.90	29.06	150.1
Forest and Wood Products	3.77	2.97	8.20	78.8
Grains	64.19	35.74	119.53	55.7
Grape and Wine	9.68	8.10	16.89	83.7
Land and Water Australia	-	12.50	26.27	– [b]
Rural Industries	2.68	14.65	21.09	– [b]
Sugar	5.13	4.56	8.66	88.9
Industry owned corporations				
Australian Egg Corporation	0.75	0.76	1.71	101.3
Australian Pork Limited	3.80	4.22	7.67	111.1
Australian Wool Innovation	42.84	13.51	78.49	17.2
Dairy Australia	14.53	14.53	36.11	31.5
Horticulture Australia Limited	31.63	32.91	66.92	104.0
Meat and Livestock Australia	39.04	39.04	78.08	100.0
Total	**233.82**	**204.71**	**511.30**	**76.8[c]**

[a] Includes other sources of income such as royalties, interest, voluntary contributions and co-investments with public sector agencies and other RRDCs. In addition, contributions in one year may not be expended in the same year. [b] These are predominantly public good RRDCs. [c] Excludes the predominantly public good RRDCs.

Sources: Data drawn from sub. 96 and Commission estimates.

> The governance model which applies to the RDCs may be described as 'light-handed'. The Commonwealth government appears to exert most of its influence in the determination of high level objectives, which, in turn, determine the broad direction for RDC funding. Once these broad objectives have been set the Commonwealth government appears to leave the funding decisions to the individual RDCs with very little subsequent analysis or scrutiny of RDC performance (either in relative or absolute terms). As indicated previously, the annual review of RDCs undertaken by DAFF does not meet the requirements of a thorough and well-founded review of RDC performance. We conclude that governance of the RDCs is relatively weak and this may have implications for the overall performance of the R&D system. (Frontier Economics 2006, p. 17)

As this suggests, the RRDCs themselves are responsible for purchasing and monitoring research and facilitating the dissemination, adoption and commercialisation of research results (sub. 96, p. 3). In addition, the RRDCs collaborate with each other in order to facilitate coordination and adoption of research. Priority setting, monitoring and evaluation processes share similarities with recent approaches used by the CSIRO and generally involve:

- determining broad R&D priorities;
- program planning;
- ex-ante project evaluation and planning;
- project investment;
- performance monitoring and management; and
- ex post project evaluation.

A more detailed description of these processes is presented in box 10.5.

Key design issues — targeting, consistency

Collective industry-research models can provide an effective means of internalising the externalities associated with R&D without the need for public support when those externalities are specific to a particular group. In situations where there is a small number of producers this can (and does) occur on a voluntary basis. But in industries with many firms that are also geographically dispersed, compulsory levies are often necessary to avoid the problem of 'free riders'.

Australia's rural research corporations are one model of industry-based collectives. In this case, producers vote on whether there should be a levy (and, if so, its size), have a say in selecting the members of the Board for each RRDC and contribute to setting research priorities. Funding issues aside, this serves to align the interests of the producers with both the level and type of research undertaken. But as producer groups dominate the representation on RRDC boards, there is a risk that research priority setting will focus disproportionately on benefits that are appropriable by that group.

Alternative models to fund R&D also exist. In Australia, for example, a number of manufacturing research associations perform similar functions to those of their rural counterparts — albeit without public support. In the mining sector, privately-funded collaborative research bodies (such as AMIRA), providing services to firms located in a number of different countries, have also been established. Such arrangements are also common in other countries. The United States has a system of agricultural research funding based (solely) on industry levies as well as research associations in the electricity and gas industries. In the United Kingdom, there are several research associations (originally established with public support) which function on a self-financed basis.

Box 10.5 **RRDC priority setting, management and evaluation criteria**

According to the Council of Rural Research and Development Corporation Chairs (CRRDCC), typical features of priority setting processes across industry-specific RRDCs involves a bottom-up approach with beneficiaries, end-users and co-investors determining priorities for relevant jurisdictions, industries and enterprises. Funding proposals are assessed and ranked by advisory bodies and considered by each RRDC Board. Program planning is undertaken in consultation with governments, industry, other stakeholders and research providers to focus strategic direction and avoid duplication. Ex-ante project evaluation is judged against both attractiveness and feasibility criteria. *Attractiveness criteria include:*

- Is the application relevant to the RRDC's R&D programs?
- Is the need and planned outcomes well-defined and relevant to R&D priorities?
- Is the application a priority of the potential beneficiaries?
- Does the application demonstrate user and beneficiary support and a commitment to utilise the outputs?
- Does the application describe the scope and pathway by which the nation will capture the benefits of the research?
- Is the applicant, potential beneficiary or other entity making an appropriate financial contribution to the project?
- Will the planned outcomes, if achieved, provide a high benefit-cost ratio of a sound return on investment for money?
- Is there an appropriate level of collaboration between researchers and between researchers, industry managers and industry interests?
- Is the application innovative? Does it add value to previous R&D?

Feasibility criteria include:

- Are the planned outputs well described and is the strategy for extending the outputs sufficient to achieve the planned outcomes?
- Are the objectives clearly specified and consistent with planned project outputs?
- Are the methods well described and consistent with the project's stated objectives?
- Does the applicant have the capacity and commitment to produce planned outputs?
- Are the principal investigator and other researchers to be engaged on the project competent? Have they performed well in the past?
- Is there a strategy for managing data arising from the project so that they will be easily accessible to others in the future?

R&D management mechanisms include:

- project management systems that integrate technical, financial and administrative data and monitor the status of projects when key project milestones are not met.
- technical evaluations by external advisers reporting on milestone achievement.
- audits of financial and risk management, compliance with agreed project conditions.
- a range of external information sources to monitor projects between reporting periods including workshops, management advisory committees, advisory bodies and other parties involved in research. This may prompt intervention when projects are not meeting their reporting schedule or other agreed performance indicators.

Source: Sub. 96.

Given these alternatives, a major issue in considering the design of Australia's rural research arrangements is to determine the right balance between industry levies and public subsidies. As the Industry Commission noted in its earlier report on R&D (IC 1995), levies act to influence the behaviour of producers and consumers beneficially by:

- encouraging producers to focus on how their own contributions are used to finance research projects;
- reducing incentives for wasteful lobbying to attract public funding; and
- providing incentives for consumers to make more efficient choices (as the total cost of research is incorporated into the cost of products).

Once an industry has formed a binding arrangement among members to contribute to jointly-beneficial R&D, the risks associated with underinvestment are significantly reduced. The usual rationale for government funding would now rest on whether there were spillovers outside the industry.

In the case of RRDCs undertaking significant public good research, such as the environmental research sponsored by Land and Water Australia (LWA), strong grounds for large public subsidies remain because that research is unlikely to take place in their absence.[27] However, for industry-centred RRDCs this is less certain despite the evidence presented by the Council of Rural Research and Development Corporation's Chairs (CRRDCC) that 42 per cent of total R&D expenditure by industry-centred RRDCs was devoted to research with strong public good elements (sub. DR172, p. 13). This is because the level of benefits accruing to producers from that research may well be sufficient to motivate its conduct (see below).

Currently, the actual funding formula provides contribution rates per dollar of industry R&D that are between three and ten times that for eligible R&D in the manufacturing, mining and services sectors (table 10.1). To be supportable, this implies there should be either:

- commensurately greater prospects for additionality; or
- significantly higher spillover rates than other industries.

The Commission noted in the draft report that the first seemed unlikely to the extent that joint R&D arrangements, generally, have been successfully formalised to allow the internalisation of spillovers. However, in contrast to the depth of empirical evidence regarding inducement rates associated with other business programs (in particular R&D START and the tax concession), the Commission acknowledges the

27 The CRRDCC (sub. DR172, p. 15) noted that natural research management is an important cross industry issue and that LWA tends to collaborate with most of the RRDCs on this subject.

lack of such definitive evidence (currently) in this specific area. It also observes that inducement rates may vary across individual RRDCs for reasons other than the ability of producers to capture spillovers — such as, simply, the R&D investment price elasticity.

That said, the CRRDCC took issue with the Commission's view regarding the extent to which spillovers are internalised on the basis that it failed to distinguish between the spillovers associated with different types of rural R&D. It said:

> The RRDCs invest across the entire supply chain, where investments are often categorised as either on-farm or off-farm programs or projects. There is general consensus that producers share a greater proportion of the [benefits from] on-farm R&D than off-farm R&D (Zhao et al. 2001, Alston and Scobie 1983, Verikios 2006). The degree of producer benefits from off-farm R&D is highly dependant on the nature of shifts in supply and demand and the elasticity of factor substitution. (sub. DR172, p. 6)

The CRRDCC went on to suggest that as commodity markets at the producer or early-stage level faced highly elastic demand conditions, the benefits to agricultural R&D off the farm are likely to be more beneficial for consumers than producers. On this basis, it was argued that a reduction in Government support (as proposed by the Commission in the draft report) would lead to a reduction in what they considered were spillover benefits to consumers (manifest in a greater diversity of cheaper, safer food and fibres) and be contrary to the stated objective of the PIERD Act that ' … the levy funds collected must be spent for the benefit of the levy payers <u>and</u> the Australian community…'. (sub. DR172, p. 4)[28]

While the Commission does not take issue with the existence of community benefits associated with much rural R&D, the key question is the appropriate magnitude of public support required (or justified) to underwrite that activity. Firstly, as around two thirds of Australia's agricultural production is exported (PC 2005e), there is a valid question to be asked as to why Australian taxpayers should fund benefits that accrue to foreign consumers. In this context, the Western Australian Department of Food and Agriculture suggested that around 20 per cent of the benefits of Australia's rural R&D effort went to that group.[29] It said:

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28 The Commission questions whether such benefits can actually be considered spillovers as they simply reflect the outcomes of normal competitive processes where the costs of R&D (as with any other input to production) has to be recovered from consumers but where consumers also reap the part of the gains (through an increase in consumer surplus). It draws a parallel here with innovation in other sectors where consumers reap a large share of the gains from innovative activity. A good recent example is provided by the retail sector where the cost savings from major supply chain initiatives have largely been passed on to consumers.

29 As discussed in appendix G, the Commission considers that the aggregate benefits from rural R&D cited by the Department are likely to overstate the actual benefits.

> It is possible that almost half the value of agricultural output in Australia in 2003 can be attributed to new technology generated by domestic R&D since 1953. At a real rate of interest of 4%, the compound value of the stream of benefits from domestic research from 1953 to 2003 is $878 billion (in 2004 $s). It is likely that Australian producers, processors and consumers have retained about 80 per cent of all benefits generated by this national agricultural R&D. (sub. 44, p. i)

Secondly, as discussed elsewhere in this report (chapter 3), the mere existence of benefits to others is not sufficient, of itself, to signal the under-provision of research effort. In that context, the Commission considers that many of the specific examples of off-farm R&D provided in the CRRDCC submission are likely to increase the desirability of agricultural products to consumers and hence increase the demand for those products (box 10.6). They will also maintain the competitiveness of Australian producers compared with foreign suppliers. Accordingly, producers would appear to have an interest in conducting such research whether or not it is supported by public funding.

Moreover, even in cases where this argument may not hold, such as in research related to human health, there is a broader question of why such research needs to be sponsored through RRDCs as opposed to a dedicated health research funding body such as the NHMRC.

That said, it is clear that there are other mechanisms for spillovers from industry-centred RRDCs. For example, a new grain that reduces pesticide use not only lowers costs and improves productivity, but also reduces pesticide residues in water systems, with environmental benefits.[30] Therefore the question is whether these spillovers warrant R&D subsidy rates for industry-centred RRDCs of the present magnitude. The CRRDCC maintained that returns were high and could be about double the 30 per cent rate suggested by the Commission in the draft report (sub. DR172, p. 13). But it is unclear that the prospects for high returns even from industry-centred RRDCs warrant support levels of 10 times that of general R&D support arrangements.

30 Although a valid question in this example is why the polluter should not pay for the R&D required to reduce the environmental costs they impose on others through pesticide use.

Box 10.6 **'Benefits' from off-farm R&D**

- Human health and welfare R&D conducted by virtually all of the RRDCs, such as:
  - Research and promotion of the health benefits of eating more fresh fruit and vegetables (Horticulture Australia Limited).
  - Health benefits of dairy products and dairy consumption (Dairy Australia);
    - … Conjugated Linoleic Acid (CLA) research to develop an experimental model to determine the potential of CLA as a dairy functional food to prevent arterial disease.
    - … Research to better understand the contribution of dairy products, lifestyle factors and response to stress to levels of blood pressure.
    - … Research to improve the nutritional status of institutionalised elderly with the aim of reducing fragility fractures in nursing home and hostel residents.
    - … Research into the role of dairy food consumption in the first year of life in the development of asthma and other allergic disorders in genetically predisposed children.
  - Health effects of red meat consumption (Meat and Livestock Australia) including the development of the CSIRO Wellbeing Diet book;
  - Health effects of seafood consumption (Fisheries Research and Development Corporation);
  - Health effects of egg and poultry product consumption (Australian Egg Corporation and the Rural Industries Research and Development Corporation);
    - … Research to determine if total egg avoidance is necessary for egg allergy treatment;
    - … Research into the rapid detection of virulent Salmonella in egg and poultry products;
    - … Research into the development of eggs with increased arachidonic acid for infant formula;
  - Other industries
    - … Honey research projects including research towards effective diet management for consumers of honey, including researching the antioxidant attributes of a range of Australian honeys and producing information on the glycemic index of a range of honeys; and
    - … Tea tree oil research projects to enhance understanding of the efficacy of tea tree oil for various medical uses, including researching the anti-bacterial and anti-inflammatory effects of tea-tree oil, and researching the impacts of tea tree oil on Staphylococcus aureus and the development of tea tree hydrogel dressings in wound care.
- Food safety and bio-security;
    - … Food safety risk management research by the Australian Pork Limited, such as research into the evaluation of molecular techniques for assessing Salmonella 'flow through' from farm to carcase evaluating the sensitivity of ESAM sampling against new culture/sampling methodologies for Salmonella; and investigating the use of pooled sera to improve the value of the Australian mix-ELISA as an indicator of on farm Salmonella infection.

Source: Sub. DR172.

The Department of Agriculture, Fisheries and Forestry focused on a different point in arguing that significantly high rural productivity growth compared with other industries over the last thirty years '… is likely to be attributable in large part to the effectiveness of the government co-contribution scheme' (sub. DR190, p. 11). Accordingly, it cited the results of a modelling exercise that indicated:

> … losses of agricultural production and gross domestic product (from removing government co-contributions) of around $266 million and $368 million a year respectively. Compared with government co-contributions in 2004-05 ($204.7 million), the rates of return on government co-contributions would be around 30 per cent for the agricultural sector (dividing $266 million by $204.7 million and subtracting the result by 1) and close to 80 per cent for the Australian economy as a whole. These results indicate a net social rate of return of around 50 per cent on government R&D co-contributions… (sub. DR190, p. 12)

However, the Commission considers that this analysis may be flawed because it appears to assume that rural R&D is the main driver of rural productivity. As discussed in appendix G, the sources of rural productivity growth are much broader than R&D alone.

In conclusion, while the Commission continues to see a strong case for continuing compulsory levy arrangements it has not been convinced that the level of social benefits associated with aspects of rural R&D justifies the extent of public support collectively provided to the sector. Accordingly, it has not changed the thrust of its draft finding.

The extent to which government support should be reduced will depend on the level of *induced spillovers* associated with that support. This would serve to clarify '… whether the extent to which public resources are implicated in applied [rural] research is commensurate with the strength of public good characteristics and market failure in applied [rural] research' (Frontier Economics 2006, p. 27). This will vary from one RRDC to the next.

The Commission considers it would be appropriate to conduct an independent assessment of the relative magnitude of induced spillovers on a case-by-case basis before public funding is scaled back. To the Commission's knowledge, no such independent assessment has previously been undertaken — a surprising outcome given the quantum of public funding involved in this area. As discussed earlier in the context of business programs, responsibility for commissioning and acting on the results of that work should rest with a third party.

Moreover, in considering changes to current arrangements, it will be important to provide producers with ample notice of such changes to allow an orderly adjustment to their introduction.

FINDING 10.13

There are strong grounds for significant public co-funding of RRDCs that provide spillover benefits beyond industry members where that research would not proceed in the absence of support. But the present substantial co-funding of some industry-centred RRDCs should be scaled back. The extent to which public funding is reduced should be determined by an independent assessment of the induced spillovers associated with that support. The intention to make changes should be announced well in advance.

10.8 Automotive Competitiveness and Investment Scheme

Key features

The Automotive Competitiveness and Investment Scheme (ACIS) was established to provide transitional assistance and encourage competition and innovation in the Australian automotive industry during the move to a lower tariff environment (AusIndustry 2006a). The first stage of the scheme operated from 1 January 2001 to 31 December 2005 and delivered a similar quantum of support to the assistance arrangements that preceded it but in a manner that was considered consistent with Australia's obligations to World Trade Organisation (WTO) subsidy agreements.

The scheme provided eligible participants with tradeable import duty credits based variously on their production, R&D and investment activities. As such, assistance took the form of forgone tariff revenue with the duty credits used to offset customs duty obligations on vehicles and components. Under the scheme, only automotive component and tooling producers and service providers were able to earn duty credits on the basis of their R&D expenditure. The earning rate was set at 45 per cent of eligible investment in R&D and was capped at 5 per cent of the participant's previous year's sales (to comply with WTO subsidy guidelines).

Importantly, the definition of eligible automotive R&D was much wider than eligible expenditure under the R&D tax concession. In particular, it included the 're-engineering and modification of existing products and processes' (Minchin 2000). These activities are explicitly excluded from access to the R&D tax concession as they are not considered to be sufficiently innovative or to involve a high level of technical risk. In practice, the bulk of automotive R&D activity claimed under the ACIS was for just these types of activity.

As the Commission noted in its recent review of automotive assistance (PC 2002a), this could include, for example, the production of variants of a vehicle based on the same platform and research into making work stations more productive. It also noted that while these activities may have applications to other industries (the spillover argument), it was also possible that firms would appropriate enough of the benefits from this type of development work to proceed without the need for public support.

Following that review, the Australian Government announced that the ACIS would be extended through to 31 December 2015. Support for R&D under the new scheme mirrors the arrangements described above with the exception that motor vehicle producers now also earn duty credits (at a rate of 45 per cent) for eligible R&D. For this group, however, a competitive merit-based scheme has been introduced with stricter requirements on eligible activity including technical risk and level of social benefits (such as environmental amenity).

The funding allocation for the vehicle producers under the MVP R&D Scheme was initially set at $150 million. According to DITR (sub. DR185, p. 29), following the distribution of around $143 million in two grant rounds the relevant Minister has decided to establish a Supplier Development Program (SDP) with the balance of the MVP R&D Scheme funding allocation. The initial focus of the SDP is on enhancing supplier capability development and support arrangements to be mentored by the vehicle producers.

In combination with the funding allocation for vehicle producers, total R&D funding support under ACIS is estimated to double in the two years to 2006-07. By that time it will be equivalent to around 40 per cent of the funding provided to Australian industry in total under the R&D tax concession.

Key design issues — targeting, inducement, consistency

Australia's automotive manufacturing industry accounts for less than 0.5 per cent of total economy production and employment. In comparison, the level of assistance provided to automotive R&D accounts for 13 per cent of total business sector innovation support (and will rise to 20 per cent in 2006-07). However, the extent of resource misallocation resulting from this favourable treatment will depend on the level of R&D induced by the subsidy.

As mentioned above, the type of automotive 'R&D' activity that has been supported by public funding — modification of existing products, processes and production systems — is likely to have been undertaken without public support as the majority of benefits from this kind of development work are captured by either individual automotive firms or the wider automotive industry.

However, definitive conclusions regarding the extent of inducement are difficult to draw. Complications are also presented in attempting to separate the impacts of the R&D subsidy from other elements of the ACIS package (such as the significant production subsidy provided to the vehicle producers) and the more competitive business environment as tariff protection declined.

A survey conducted on behalf of the automotive industry associations in 2002 suggested that had ACIS not been implemented, R&D expenditure by component producers would be around 40 per cent lower over the period 2002 to 2005 (PC 2002a). However, these results need to be treated with caution as the magnitude of the impact is considerably greater than R&D projections provided by the component sector to the program administrator around the time the scheme was introduced.

A comparison of pre- and post-ACIS R&D expenditure (including by vehicle producers) does reveal strong growth in R&D spending. In the three years preceding the scheme's availability, annual growth in R&D averaged just 2 per cent while in the three years after its introduction annual growth averaged around 30 per cent (ABS 2005c). However, this trend was also reflected in the experience of the manufacturing sector as a whole with comparative figures of -1 per cent and 17 per cent respectively, and thus ACIS may not have been the sole catalyst for higher automotive R&D. Further, the transfer from taxpayers to firms had an associated economic cost equivalent to $25 million in 2004-05 (assuming a marginal excess burden of taxation of 20 per cent).

The Commission acknowledges, however, that the support provided by R&D and other incentives need to be weighed against the economic benefits to Australia associated with the transition to a lower automotive tariff environment.

10.9 Public-private partnerships

Public-private partnerships have become increasingly popular features of innovation systems in a number of countries over the last two decades. While they have taken a variety of different forms they share the same underlying goal — to reap broader benefits from investment in public research. As such, these structures are explicitly viewed as more effective means of addressing perceived gaps in innovation systems than other policy instruments. By bringing together researchers and research users from markedly different backgrounds to pursue genuinely challenging projects these types of arrangement have the potential to deliver outcomes with high spillover benefits that would not otherwise be pursued. But cultural differences in terms of the respective aims and approaches of the different partners also means that the transaction costs of these relationships can potentially be very high.

In Australia, a suite of partnership initiatives have been implemented since the mid-1980s — some more successful than others. The main programs currently operating are the ARC Linkage Grants (chapter 12) and the Cooperative Research Centres (CRC) program. The latter stands out in terms of the size of the financial commitment by the Australian Government (around $2.7 billion since the program's inception); the long-term and open-ended nature of that commitment; and a requirement for all core participants to commit to the collaborative venture for a substantial length of time.

Since its introduction, the CRC program has developed into an emblematic feature of Australia's innovation system. It has also been heralded internationally as a pioneering example of collaborative research arrangements — variants of which have been adopted in a number of other OECD countries. As discussed below, while the program incorporates a number of desirable program features, the Commission considers there are important areas where the program's effectiveness could be significantly improved. The most pressing issues involve the shift in focus of its stated objectives and the respective contributions of the main beneficiaries of the program.

Cooperative Research Centres (CRC) Program

Introduced in 1990, the CRC program focuses on the perceived need to improve the economic, social and environmental benefits from Australia's extensive public research effort. The program calls for (on a biennial basis) and supports applications to establish partnership arrangements that bring together researchers and research users. Research groups in the same or complementary fields from universities and public research agencies are linked with users (typically but not exclusively private firms) that can apply research outcomes through commercialisation or other forms of adoption (a relevant distinction for CRCs focused on 'public good' research). The program also provides for postgraduate and undergraduate education and training opportunities through individual CRCs.[31]

All fields of physical and life sciences are eligible and there is considerable flexibility in the range of participants and organisational structures of the Centres.

31 DEST noted that in 2004-05, more than 2000 full time equivalent postgraduate students were studying through a CRC. In addition, some 4550 undergraduate students were receiving education and training through CRCs in the same year (sub. DR205, p. 6).

Public funding support is provided for up to seven years (although existing CRCs may re-apply for funding of genuinely new research proposals) after which it is anticipated that the collaboration will become self-financing. Nine completed selection rounds have established 158 CRCs (100 new CRCs and 58 new from existing CRCs) since 1991. In 2005-06, some 72 CRCs operated across six sectors: manufacturing technology; mining and energy; agriculture; information and communications technology; environment; and medical science (annex box 10.1). In 2006-07, 57 CRCs are operational.

Although there is considerable diversity in organisational structure and research focus among CRCs, there are three broad models of application and use of research outcomes (Howard Partners 2003). The nature of these models has implications for optimal financing arrangements. The CRCs can be classified as follows:

- CRCs that operate primarily as national benefit centres (which historically have accounted for around 20 per cent of total program resources) — with a strong focus on public good research in areas including resource sustainability, maintenance of biodiversity, environmental health and national disaster research.
- CRCs involved in industrial research (60 per cent of total program resources to date) with a strong focus on collective industry outcomes concentrating on mature, commodity-based industries with research aimed at raising productivity, product quality and international competitiveness.
- CRCs that focus on commercial benefits through expanding and creating new businesses based on the transfer or sale of intellectual property and reflected in new products or services (20 per cent of total program resources to date).

Funding contributions (cash or in-kind) vary across participants with the share of benefits from each CRC (including ownership of intellectual property and income from royalties) notionally determined on the basis of respective resource commitments. The only exception is the Australian Government — it does not participate directly in the benefit-sharing arrangement. Yet over the life of the program, one quarter of all resources have been provided directly from that source (tables 10.5 and 10.6).[32, 33]

32 Program participants that themselves receive funding from the Australian Government (such as the CSIRO, DSTO and universities) generally participate in the revenue sharing to some extent, or at least have access to the research outputs of the CRC.

33 Interestingly, direct Commonwealth funding accounted for more than 60 per cent of total cash resources devoted to CRCs over this period. In-kind payments dominate the contributions from other CRC participants and this raises issues regarding valuation methodologies (particularly the treatment of overheads). It may also have implications for CRC governance arrangements.

Table 10.5 **CRC program contributions — 1990-91 to 2001-02**
Per cent

Funding source	*Share of total CRC resources*	*Share of own resources in-kind*
CRC Program — Australian Government	25	0
Universities	22	92
CSIRO	14	98
Industry	17	59
State Government	8	82
Other Australian Government	5	78
Other participants	7	74
Other funding	2	14
Total	**100**	**60**

Source: Howard Partners 2003.

Table 10.6 **CRC program contributions — 2004-05**
Per cent

Funding source	*Share of total CRC resources*	*Share of own resources in-kind*
CRC Program — Australian Government	20.2	0
Other Australian government	14.0	na
Universities	28.9	na
State Government	12.2	na
Industry and industry associations	20.7	65.1
Other[a]	4.0	na
Total	**100.0**	**66.7**

[a] Includes local government, research institute/organisations, uncategorised, other. na not available·

Source: Sub. 87.

The relatively minor contribution by industry partners (around 20 per cent in 2004-05) means the effective subsidy to this group can potentially be very high compared with support provided by other science and innovation programs.[34] In addition, CRCs are not restricted from access to other innovation support measures (such as the R&D tax concession) for which they may be eligible and some participants (such as automotive firms and a number of RRDCs) also receive substantial assistance under other programs (see earlier).

Notably, the user-contribution to CRCs in Australia is also at the lower end of international experience with funding arrangements for public-private partnership

34 DEST noted that the figure for 2004-05 related to CRCs operating before July 2005, the date the objective of the program was changed to give a sharper focus on economic benefits. It also commented that a ‘strong trend of increasing industry contributions over the five years to 2004-05 is continuing.’ (sub. DR205, p. 6)

programs. For example, in many countries including the United States, Norway, Sweden, Finland and France, industry users are required to contribute at least 50 per cent of total program funding (OECD 2005c).[35]

Along with the general shift toward supporting industrial or economic imperatives in the innovation process (both here and abroad) the stated objectives of the CRC program have changed over time. The guidelines for the 2004 and the most recent (2006) CRC selection rounds describe the main objective as being: ‘to enhance Australia’s industrial, commercial and economic growth through the development of sustained, user-driven, cooperative public-private research centres that achieve high levels of outcomes in adoption and commercialisation’ (Nelson 2006).[36]

This is a significant departure from the previously stated objectives, which were evenly balanced across four areas: research excellence; effective collaboration; creation of new educational opportunities for graduate researchers; and the translation of research outputs into economic, social and environmental benefits to Australia. In effect, the recent change means that proposals that focus on outcomes in social and environmental research have been disadvantaged by the policy shift. Currently, 25 of the 72 operational CRCs are involved in these two areas (annex box 10.1 at the end of this chapter). This was confirmed by DEST:

> With the revised focus of the CRC programme the commercial and economic outcomes which can be attributed to the programme should remain high. Nevertheless some concerns have been raised that with the refocussing of the programme long term strategic collaborative proposals that will not generate economic growth are unable to attract funding. While these proposals may be in the national interest, such as reducing health care costs leading to more healthy Australians, reducing loss through the mitigation of risks or result in a healthier environment, they are unlikely to be competitive [for CRC funding]. (sub. 87, p. 70)

CRC proposals are currently selected on a competitive basis against the following four broad selection criteria (the detailed criteria are presented in box 10.7):

- outcomes will contribute substantially to Australia’s industrial, commercial and economic growth;
- path to adoption (commercialisation/utilisation) will deliver identified outcomes;
- collaboration has the capability to achieve the intended results; and
- funding sought will generate a return and represents good value for the taxpayer.

35 There are also a number of examples where no industry contribution is required such as in Japan or where it is very low, for example, Belgium.

36 DEST emphasised that commercialisation is only one of the recognised paths to adoption for research and that a number of CRCs use direct utilisation and uptake by users to disseminate their research outputs to industry. (sub. DR205, p. 6)

Box 10.7 **CRC selection criteria for 2006 round — full business case**

Selection criteria 1 — Outcomes

- Scale (quantity and value) of the outcomes' contribution to Australia's industrial, commercial and economic growth including, but not limited to:
  - additional economic activity either nationally or for a region(s) within Australia
  - improved competitiveness or productivity of business, eg through improvements in product and service quality, cost savings, reductions in inputs or increased outputs
  - new and improved goods and services and technologies
  - creation of new jobs
  - increased exports or development of import replacements
  - creating new or assisting emerging industries
  - improved capability (including education and skills development) in firms/industry sectors to identify, adopt and adapt technologies.
- Robustness of the estimation of the scale of the outcomes.
- Extent of the contribution of outcomes to relevant NRP Goals. Applications that can demonstrate a substantial contribution will be ranked more highly than those that demonstrate little or no contribution.

Selection criteria 2 — Path to adoption

- Robustness of the assessment of market or other end-use opportunities.
- Quality of planning and resourcing (including use of external expertise) for commercialisation and/or utilisation (including technology transfer) strategies and communication activities.
- Adequacy of the intellectual property management arrangements.
- Strength of commitments by end-users (including through international collaborations).
- Strategies to engage additional end-users during the life of the CRC.
- Strategies to reinvest some of the returns from commercialisation of IP in CRC's activities.
- Approach for engaging small to medium sized enterprises (SME) end-users in the CRC.

Selection criteria 3 — Collaboration

Research

- Innovativeness and achievability of the research.
- Coherence of research programme including balance between the longer- and shorter-term projects.
- Strength and integration of international linkages.
- Time commitment and quality of the key individual researchers.

Adoption

- Quality of staff and industry participants involved in the commercialisation/utilisation of CRC outputs.

Governance

- Effectiveness of the collaborative arrangements and the structure and effectiveness of management and governance arrangements. Applicants are expected to become incorporated entities unless a compelling case can be made for alternative structures.

Education and Training (Skills development)

- Extent and quality of end-user focus in education and training, including industry PhD supervision.

Benefits of Collaboration

- Strategies to maintain the benefits of a CRC collaboration and for the closure or continuation of the CRC after Commonwealth funding has ended.

For 'new from existing' applicants track record including assessment of the economic impact of outcomes; key commercialisation or utilisation outcomes; key achievements of research and education programs; effectiveness of the collaboration (including in maintaining or enhancing participant involvement and contributions); and effectiveness of governance and management arrangements.

Selection criteria 4 — Return

- Return on the investment through increases in Australia's industrial, commercial and economic growth, including the value of the proposed outcomes relative to the costs.
- Appropriateness of the budget and the resource allocations.
- Any strategies for obtaining additional contributions over the funding period.

Source: Nelson (2006).

Research programs to be conducted by a proposed Centre and an initial set of projects to be pursued under each research program form the basis of the formal proposal for funding support. Program development and priority setting for individual projects is a collaborative effort between the CRC participants (ie a bottoms-up approach) with only general guidance (in the form of alignment to the National Research Priorities) dictated by the program eligibility criteria (box 10.7).

Proposals are assessed in a multi-stage process (a recent modification designed to ease the compliance burden) by:

- an external technical expert advisory panel with four sub-panels (Manufacturing and Mining, Medical, Information and Communication Technology and Agricultural and Environment);
- independent local and international assessors (who can comment on scientific value, likely value of research outcomes and the quality of collaborative arrangements); and
- the CRC Committee (which oversights the program and provides advice to the Minister on which applications should be funded) whose membership is drawn from industry, research providers and Australian Government agencies involved in research or research funding.

Governance arrangements are based on a corporatist model with a chief executive officer responsible for the daily management of each CRC. They report to a Board of Directors (with an independent chairman) which, in turn, is responsible for the overall direction of each Centre. Importantly, the Board of Directors must have majority representation by research users (such as private firms or RRDCs). This requirement has been in place since the 1998 selection round to address a concern that the program 'had been too focused on research with an insufficient emphasis upon meeting industry and other end-user needs through attention to adoption and application of research results' (Howard Partners 2003, p. iii).

However, some participants questioned the impact of this change noting there may be consequences for the extent of inducement associated with the CRC program. The Invasive Animals Cooperative Research Centre, for example, said:

> Too much power in the hands of end-users can lead to short-term research that probably would have been done anyway. (sub. 57, p. 5)

In addition, until the 2004 CRC selection round, applicants were not required (although it was strongly encouraged) to establish the CRC as an incorporated entity and the majority (around 75 per cent) did not choose this pathway. All new CRCs must now be incorporated, unless they can persuade the CRC Committee otherwise. This change was expected to reduce internal negotiation and transaction costs and provide greater certainty regarding the legal status of the entity compared with the individual participants.

Once established, progress against contractual obligations to the Commonwealth is mainly monitored through detailed annual reporting requirements that contain a range of information relating to each CRC's progress toward meeting its objectives (DEST 2006e). The qualitative information contained in the annual report are also complemented by financial and other quantitative data required in a Management Data Questionnaire (MDQ). According to DEST:

> The information provided in the Annual Report and data provided in the MDQ will be analysed and used to monitor the performance of individual CRCs over the funding period. … Where there are issues of concern, the [CRC] Committee may direct that a review or audit be undertaken of the relevant CRC. DEST may also independently initiate a review or audit of the relevant CRC. (DEST 2006e)

In addition, the Commission understands that a performance review of CRC research activity is conducted after three years (originally two) of operation by a panel of mainly international experts in the particular field of research conducted by each CRC.

As discussed below, the Commission considers that despite these requirements, the incentives facing both the program administrator and CRC participants may be such that individual research projects with limited scope to produce worthwhile benefits are allowed to continue beyond the point justified by a prudent approach to project risk management. It proposes a possible mechanism that could provide improved incentives for participants to cease project funding in those instances.

Key design issues — targeting

The shift in focus of the CRC program in 2004 to industrial, commercial and economic objectives assumes that the community benefits associated with research activity in this area (which depends on the extent of inducement and the level of spillovers) are considerably higher than that in social and environmental research. However, as discussed in chapter 4, there are compelling reasons for public support in these latter areas including: the significant impacts from social and environmental research activity (including economic); its fundamental role as an input to public policy; and increasing Australia's preparedness to deal with a wide range of environmental and social concerns.

In addition, as previously stated in this chapter, the emphasis on supporting the commercialisation stage of industrial research as opposed to the earlier R&D stage is much less defensible from an economic efficiency perspective. Such a focus can also adversely bias the behaviour of selection committees toward collaborations that pursue less risky project outcomes involving lower levels of spillover benefits — precisely the type of research that a firm or industry collective would undertake anyway. And it can also interfere with the wider adoption or utilisation of research results, especially important in areas where the research is generic to a large number of potential beneficiaries (such as in agriculture). In this context, the submission by the Department of Agriculture Fisheries and Forestry noted:

> The current emphasis on commercialisation as a key mode of innovation delivery can also reduce the freedom to operate of R&D providers through their need to seek formal IP rights such as patents, copyright and plant breeders' rights. This can ultimately reduce the rate of adoption of IP-dependent R&D products. (sub. 100, p. 20)

Accordingly, the Commission's draft report concluded that the original objectives of the CRC program provided a much more appropriate focus for public support. Those objectives did not discriminate between CRC research activity in economic, social or environmental fields and emphasised the broad translation of research results rather than those with a greater chance of being captured by the innovator.

There was near-unanimous support for this finding across academic, business, government and individual interests including by the Australian Technology Network (sub. DR153, p. 9), Rio Tinto (sub. DR142, p. 2), Southern Cross University (sub. DR108, p. 1), Tasmanian Government (sub. DR181, p. 1), Queensland Government (sub. DR203, p. 9), Northern Territory Government (sub. DR194, p. 2), Victorian Government (sub. DR211, p. 5), Australian Academy of Technological Science and Engineering (sub. DR169, p. 7), CHASS (sub. DR171, p. 2) and the Australian Vice-Chancellor's Committee (sub. DR148, p. 8).

Specific comments included those from Don Scott-Kemmis (an academic) who said:

> The proposal to reorient the CRC Program to again include Centres with 'public interest' outcomes is applauded. This is the case for several reasons: such outcomes are every bit as valuable as direct commercial outcomes, some of the most effective CRCs are of this type; the CRC model is often very relevant to research in areas such as health or the environment; and some of our major national challenges can be addressed through coordinated research and capability building in CRCs. (sub. DR183, p. 7)

And the South Australian Government stated:

> There is strong support from the South Australian Government for the call to rebalance the CRC objectives to those which strike a balance across the key goals of research excellence, effective collaboration, creation of new educational opportunities and translation of research outputs into economic, social and environmental benefits, in particular, in making those proposals which may yield a great public good, for example in health care and environmental care, more competitive in the CRC funding allocation process. (sub. DR212, p. 4)

While emphasising its view that the CRC program '… does currently generate considerable economic, social and environmental benefits that are not privately captured by industry participants…' the CRC Association also agreed:

> The CRCA supports the call for the CRC Programme to re-emphasise the focus on the translation of research outputs into economic, social and environmental benefits and also welcomes the call for greater flexibility to be built into the CRC Programme. (sub. DR150, p. 2)

At a more detailed level, the Commission also noted that a number of the considerations behind the four CRC selection criteria outlined in box 10.7 — including the creation of new jobs, increased exports, expansion of import replacement activities or assisting emerging industries — are not valid objectives for government policy aimed at influencing science and innovation activity. The most appropriate policy action involves promoting competition and maintaining a stable and conducive macroeconomic policy environment (see the Commission's report on National Competition Policy).

Inducement

Given that the CRC structure aims to overcome the challenges with collaborative ventures involving research partners from diverse professional cultures; the significant associated administrative and compliance costs confronting prospective participants; and the level of public support; it would be surprising if the CRC program did not induce considerable additional research activity (including through the enhancement of existing projects). The most recent evaluation of the program surveyed both researchers and user groups to gauge the extent of additionality and found evidence in support of this expectation. From the research user perspective, around 50 per cent of respondents noted a high or very high program impact on stimulating new research projects and accelerating or improving existing research projects (table 10.7).

These results were reinforced by the researcher cohort with around 75 per cent of CRC managers (primarily university partners) indicating a high or very high program impact in these areas (Howard Partners 2003). In addition, 80 per cent of this group also indicated a very high impact on the introduction of new or improved products and processes, although for research users only around half of this proportion agreed with that assessment.

Table 10.7 **CRC participant views on research outcomes**

Per cent of respondents

	Research users		*Research managers*	
Outcome	*High or very high impact*	*Moderate to low impact*	*High or very high impact*	*Moderate to low impact*
Accelerating or improving existing research projects	48	36	74	20
Stimulating new research projects	48	44	78	18
Contributing to the development of IP	24	60	62	32
Introduction of new/improved products, processes	44	36	80	12
Improving business/industry profitability	28	52	54	36
Improving public programme or policy performance	na	na	40	36

Source: Howard Partners 2003.

Additionality issues were also canvassed in two recent evaluations of the CRC program. The key finding of the first, by Allen Consulting (2005a), was that the delivered (as opposed to prospective) program benefits cumulatively increased GDP by 60 cents for every dollar of direct public funding. The study required that the benefits put forward by the CRCs to be included in the modelling must have been unlikely to have occurred in the absence of the CRC 'in the timeframe under consideration'. More recently, Insight Economics (2006) estimated an economic impact almost twice as great as the earlier study with a cumulative increase in economywide output of $1.16 for every dollar invested in the CRC program.

The main reason for the much higher magnitude of benefits compared with the earlier study was due to the identification and quantification of a number of additional delivered benefits. Both evaluations are discussed in greater detail in appendix I (and different estimates of benefits derived).

However, the implications of these empirical findings need to be viewed in light of recent amendments to the program. As noted above, the lower level of satisfaction with outcomes by research users has led to specific changes in CRC governance arrangements including the requirement for majority user-group representation on CRC Boards (in place since the 1998 CRC selection round) and a complete shift in focus to commercial objectives.

For reasons outlined above, the Commission noted in the draft report that these changes increased the risk of providing support to projects with low potential spillovers and those that would be undertaken in the absence of public subsidies.

But Rio Tinto questioned the validity of this claim on the basis that a large firm would not '… choose to enter into collaborative arrangements with its competitors and take on the additional administrative and reporting overheads of a CRC structure.' (sub. DR142, p. 2)

The Commission generally agrees with Rio Tinto's logic that firms are unlikely to enter into such collaborative arrangements given the costs unless there was a significant prospect of additionality. But the question at hand is whether the change in CRC governance arrangements will have reduced the additionality 'gap' between support for cooperative versus independently conducted R&D. This seems likely. It also notes that the higher the level of public support provided to a CRC research program, the less likely compliance costs will act to deter firms seeking support for projects that would have been conducted anyway.

In a different context, recent OECD evaluations of partnership programs have noted that additionality has an important behavioural dimension. This refers to the desire to create long-lasting linkages between researchers and research users to ensure persistent beneficial effects (OECD 2005c). The CRC selection criteria specifically reflect this aspiration in calling for strategies to maintain the benefits of the CRC once Commonwealth funding has ceased. This was expected to result from either the generation of sufficient revenue from licensing or other commercial activities (contracting) as a substitute for program funding, formation of 'start-up' companies based on the intellectual property generated by the CRC or an injection of resources from commercial partners to allow a continuation of the cooperative venture.

In practice, however, there is very little evidence supporting the attainment of this objective. Over the life of the program, revenue streams generated via licensing and royalty arrangements have been quite modest, examples of company 'spin-offs' are rare and examples of CRCs continuing operation successfully outside the CRC structure beyond the funding period are even rarer. In fact, most CRCs have sought repeat funding support for at least a second seven year duration (to pursue new research proposals) with some now in a third phase.

Funding arrangements

The actual subsidy provided by the CRC program to firms and other research users (such as the RRDCs) depends on the share of benefits appropriated by those groups. With the exception of the public good CRCs, these benefits have typically been assessed in terms of the value of intellectual property rights (the share of which is based on the respective resource commitment of each partner) and the establishment of 'spin-off' companies created by the CRC venture. As noted above, revenue from these sources has been very modest over the life of the program.

But there are other avenues for delivering program benefits. Indeed, as noted by the recent review of the impact of the CRC program:

> Most benefits from the CRC Programme have come from industry application of research rather than through narrowly defined 'commercialisation' events such as spin-off company formation and licensing of IP. (Allen Consulting 2005, p. 40)

The CRC Association was more specific in its submission to this study noting that:

> Measured benefits from the Programme have primarily been delivered through the application of research by industry to reduce costs and increase productivity and through the sale of new products (by existing or new companies) that are based on CRC research. (sub. 11, p. 15)

The University of New England (sub. 17, pp. 12–14) presented quantitative evidence on the beneficiaries of CRC research. It noted that based on modelling results, 75 per cent of the expected benefits from the Australian Sheep Industry CRC (which commenced in 2002) would accrue to Australian sheep producers because they could directly access the new technologies. Similarly, of the expected benefits from an investment in the Invasive Plants CRC (which is currently in the advanced stage for CRC program funding consideration), around 60 per cent would accrue to the beef and grains industries.

This evidence led the Commission to conclude in the draft report that many of the benefits were in fact captured by firm and industry partners and that, accordingly, the subsidy rate to user-groups was much higher than that provided under most other innovation programs. The subsequent submission by CSIRO (which was participating in 48 of the 68 centres operating at March 2006) heightened the Commission's concerns in this area by pointing to inadequate CRC reporting arrangements. It said:

- Official DEST figures may under-report the level of total contributions made by public sector research providers so that the support provided to the end-user is even higher than the Commission suggests. This is because the research infrastructure overheads for CRC-funded staff are in almost all cases borne by the research provider and the CRCs generally do not report them to DEST. The amounts involved are roughly equal to the Commonwealth funding to CRCs (around $200m pa).
- Current practices may result in less than full cost reporting by CRCs and this can result in the CRC community under-pricing research.
- On average, publicly funded research providers bear around 70% of the full CRC project costs with the remainder shared by the Commonwealth CRC grant and the research users roughly in equal proportions. (sub. DR184, p. 12)

However, the CRC Association disputed the Commission's contention including on the basis that much of the work conducted within CRCs is focused on generating community benefits and the benefits accruing to industry only accrue after it spends considerable resources in further developing and applying the CRC research outcomes. For these reasons, the CRC Association '… believes that the rates of subsidy to private industry suggested by the Commission in the draft report are overstated.' (sub. DR150, p. 8)

While the Commission has not been in a position to assess the costs and benefits of individual CRC research projects, it considers that the arguments put by the CRC Association are not inconsistent with its view in the draft report that cost-sharing arrangements should reflect the benefits derived from research.

A number of participants concurred including CRC business collaborators such as Rio Tinto which said '…we agree that there is scope for reviewing the existing cost-sharing mechanisms associated with CRCs, and particularly the incentives that support genuinely new and industry-changing projects' (sub. DR142, p. 3). The company emphasised, however, that this task was complicated in areas where public good research also offered industrial and commercial benefits (even where those benefits may be unclear or difficult to quantify). It provided, as examples, environmental research in areas such as climate change, water management and sustainable energy.

Accordingly, this raises the question of what an optimal cost-sharing ratio should be and whether financing arrangements should be changed to improve the level of induced spillovers. In practice, optimal cost sharing ratios should aim to provide differential funding support dependent on the nature of the research undertaken and the extent of expected social benefits from that research. This is not the basis of current CRC funding arrangements (table 10.8). Those research areas that, prima facie, would appear to involve relatively higher levels of social benefits (such as environmental and medical research) have in the past received lower proportional public support than areas where the benefits of research are likely to accrue to individual firms or industries (such as in the rural and manufacturing sectors).[37]

In the Commission's view, alongside a return to the original objectives of the program across economic, social and environmental research, a better match between funding levels and the specific mission of the various CRCs would involve:

- a higher share of public funding in areas where the social benefits are likely to be the greatest — the national benefit CRCs;

37 Note that significant public support for environmental and medical research is provided through other means such as the CSIRO and grant funding by the ARC and NHMRC.

Table 10.8 **Australian Government contribution to CRCs by sector**

CRC sector	*Total program funding*	*Share of total CRC resources*	*Round 9 funding*	*Share of total CRC resources*
	$ million	Per cent	$ million	Per cent
Manufacturing	398.7	27.4	103.9	35.0
Information and communication technology	285.5	21.6	0.0	–
Mining and energy	358.9	22.2	20.0	26.0
Agriculture and rural based manufacturing	615.3	28.3	129.4	26.0
Environment	620.7	23.4	99.9	30.0
Medical science and technology	379.7	21.1	47.9	36.0
Total	2658.8	24.0	401.1	30.0

Source: Sub. 11.

- a lower level of support in the industrial research CRCs that focus on pre-competitive research (innovation in industrial processes and business practices). The concentrated nature of benefits from this activity suggests that levy systems would be more effective means of dealing with the potential for under-provision of research effort (see the earlier discussion on RRDCs); and
- an even lower level of funding for Centres aimed primarily at commercialising research outcomes such as the business development CRCs.

There may also be a case (particularly for the business development CRCs) for introducing repayment mechanisms for successful projects in the form of a share in the royalty stream of successful projects. Given the distinct legal status of the CRCs (especially under the new incorporation requirement) and the finite number of research projects likely to be commercially viable, the royalty stream alternative would appear less problematic in its application compared with entities with multiple revenue streams (an issue raised in the earlier discussion on avenues to improve business programs).

Performance management

Despite the requirements on CRC participants to report against the achievement of research milestones on an annual basis, there is a risk that 'marginal' projects may continue even when beneficial outcomes are unlikely because of inappropriate program incentives.[38] This is especially significant given the duration of the funding agreements and because CRC participants have more information regarding

38 While program participants can request variations in their contractual obligations, the Commission understands this has primarily been used to deal with the exit and entry of CRC partners once they have been established.

likely research outcomes than the program administrator and an understandable interest in maintaining funding continuity. In addition, although the program administrator has the power to intervene in a CRC's activities, it may be reluctant to do so because it will highlight a failure in the approval processes used to select successful participants.[39]

Given the substantial amounts of funding involved, it may be worth trialling an approach to improve the flexibility of CRCs to manage their project portfolio through offering incentives to CRC partners to terminate projects (or the CRC) early if they consider research objectives are unlikely to be met. This could take the form of payment of part of the contribution by the Australian Government to the CRC as either compensation for resources devoted by the participants to a project (or CRC) that is terminated early or to conduct collaborative research in another area (with appropriate safeguards to avoid abuse).

FINDING 10.14

The CRC program could be improved in two ways:

- *the original objectives of the program — the translation of research outputs into economic, social and environmental benefits — should be reinstated. This is likely to produce greater community benefits than focusing public support on the commercialisation of industrial research; and*
- *the share of public funding should be aligned to the level of induced social benefits provided by each CRC, thereby reducing some of the large rates of subsidy to business collaborators.*

More flexible arrangements

While not reflected in many written submissions to this study, several concerns were raised about the CRC program during discussions with participants (despite or in some cases because of the recent governance changes). In particular, some within the university sector were concerned about the shift in research focus toward commercial objectives and the methodology used by the program administrator to value the overhead component of in-kind contributions. Equally, some business groups commented they were losing confidence in the ability of the program to deliver outcomes of value to them. AusBiotech, for example, said:

> The large number of academic contributors and sometimes complex governance arrangements in CRCs means that the pace of activity is slower than industry would like. (sub. 95, p. 30)

39 The Commission understands that previous interventions have been relatively rare and that they do not appear to have been on the basis of failure to meet research objectives.

Criticisms about excessive and burdensome compliance and administration costs were widespread.[40] Graeme Pearman (a former CSIRO division head and member of the executive with experience in CRC operations) commented in this regard:

> My rough estimate is that these inefficiencies (proposal planning, start-up costs and termination costs), probably account for effective cost of at least one year's of resources (approximately 14% of the investment over a seven year life of a CRC) (sub. 86, p. 18)

In its submission to the draft report, the CRC Association called for a sense of perspective to be maintained when considering these issues:

> A final point that is worth noting is that there does need to be a degree of realism in expectations regarding how streamlined and low cost genuine, collaborative, research endeavours can be. … collaborative activity does inherently involve higher administrative and transaction costs than do single participant activities. (sub. DR150, p. 10).

The Commission agrees with these sentiments but notes that rather than comparing the costs of collaborative ventures vis-a-vis independent research effort, a more appropriate benchmark is to compare current CRC outcomes with those of other collaborative funding mechanisms — a point taken up below with respect to the ARC Linkage program.

Graeme Pearman also detailed a range of other problems he considered to be present in the CRC model and asked whether a better approach deserved consideration:

> Significant unhappiness exists over the limitations of this CRC approach, yet in a climate of budgetary constraints, the benefactors are reluctant to too openly discuss the real shortcomings. These include vagueness about the balance between knowledge generation and knowledge application, the neglect of public-good activities and the incredibly inefficient way of expending money through relatively small institutional arrangements with enormous overheads. This is compounded by the lack of continuity that does not reflect the real timescales of knowledge generation or application research, the real costs associated with CRCs driven by costly start-up and close-down, a ridiculous level of internal review and governance and related demands of overheads on research staff. Serious questions should be asked about whether some of these targeted areas of research and application could not have been better approached through investment in existing research organisations (albeit with contractual

40 The survey conducted as part of the recent CRC program evaluation revealed that the share of resources devoted to administration by all CRCs averaged around 8.5 per cent of total program funds between 1998-99 and 2001-02. Combined with the compliance costs associated with the detailed and lengthy CRC application process (which can take up to 12 months to complete), reporting requirements and the program administration costs borne by the program administrator, the level of resources consumed in these areas appears to be very high in comparison with other competitive funding programs such as ARC and NMHRC grant funding.

> expectations regarding corporation) or through an alternative model of funding. (sub. 86, p. 7)

Similarly, Melbourne Ventures Pty Ltd noted that:

> … its involvement in the 2004/05 round (in which it was involved with 4 successful applications, although it ultimately only participated in 3 CRCs) took more than 900 hours of negotiation of complex, voluminous legal documents which if outsourced would have cost in the order of $0.75M. (sub. DR138, p. 3)

Against that background, the Commission considers that there is considerable scope to improve the effectiveness of the CRC model by introducing more flexibility into the types of arrangement that are supported by the program. Currently, the system is geared toward large-scale, longer-term research programs, which are more suited to big research users, with relatively cumbersome avenues for CRC partners to enter and exit the venture and a heavy compliance burden — points acknowledged by the Business Council of Australia (sub. DR204, p. 6). The substantial financial and in-kind commitments required of CRC participants also effectively exclude a range of potential beneficiaries from participation and this may well act to reduce the potential for inducement from the program.

GlaxoSmithKline, for example, in commenting on the inflexibility inherent in the seven year timeframe of CRC funding (although DEST noted that CRCs could be funded for less than seven years but it is not clear whether any had been) said:

> … there is no doubt that there are inherent tensions within the program. For example, the seven year timeline is often too long for SME participation, yet the government continues to seek greater SME involvement. On the other hand, seven years is often too short a timeline for particular forms of R&D, such as pharmaceutical R&D. (sub. DR154, p. 5)

Giving consideration to complementing the CRC program by also supporting smaller-scale, shorter-term collaborative research proposals would also fill a gap that currently exists in Australia’s innovation space (even though there are programs such as Commercial Ready that play some role in this area). But the benefits to be had from such a move could be counterbalanced by the high fixed costs associated with the existing application, approval and governance processes. The Commission recognised that there is a range of challenges involved in the design of a less costly and more flexible program — not least of which is the need to guard against the inappropriate use of taxpayer’s funds.

In that context, there is a number of different approaches available to introducing a more flexible collaborative mechanism, each of which will involve particular tradeoffs between the desirable design criteria outlined at the beginning of this chapter (see below). Regardless of the approach chosen, in order to maximise the level of inducement from a new complementary program the eligibility criteria would appropriately restrict access to multi-firm collaborative proposals either undertaking research within the group of firms or in conjunction with universities and public sector research agencies. Another advantage of restricting access on this basis is that spillover benefits are likely to be higher because the research will be aimed at applications that are generic to multiple potential beneficiaries. The promotion of these aims could also be enhanced by linking the level of public support to the potential for diffusion of those spillovers.

Of course, the program would not compel universities and public sector research agencies to participate in specific collaborations but opting to do so would provide them access to a supplementary source of income in much the same way that current contracting and consulting arrangements operate.

Various different mechanisms are available to deliver more flexible collaborative support, some of which could be likened to voucher-style entitlements. The potential mechanisms include:

- an entitlement-based program such as a tax concession (or credit) where all proposals that meet the eligibility criteria receive support but with ex post safeguards in place to guard against abuse (in the same way that the ATO polices the present tax concession scheme). This approach has the advantages of funding continuity and allowing decentralised decision-making on the type of research to be undertaken but its open-ended nature will increase the potential revenue cost of the program.
- a grant program for collaborative research proposals where support is made available at regular intervals throughout the year and allocated on a ‘first-come-first-served’ basis (subject to eligibility). This would also allow for decentralised decision-making, places a cap on the cost to revenue and allows for considerable flexibility in the timing of research.
- applications are invited and assessed on an individual basis to determine whether they have sufficient merit to receive a grant. Proposals could either be disallowed at this initial stage if they did not meet the merit or other eligibility criteria or at a later date (with a requirement to repay the grant) if applicants failed to meet their obligations. This would involve lower administrative costs than the current CRC process but also increase the potential revenue cost.
- a competitive program is introduced with proposals ranked against each other and grants awarded to the best proposals. This is similar to the current CRC assessment process and, accordingly, would raise similar concerns in relation to administrative and compliance costs.

The scope for introducing a complementary arrangement received considerable attention from participants.

While the combined submission by seven existing CRCs[41] argued there was no need for a complementary program because the flexibility provided by the CRC model '… can meet the broader collaboration goals proposed by the PC…' (sub. DR164, p. 11), this opposition was not typical of the views put by other participants.

For example, the CRC Association, while noting that it '… has been making considerable efforts towards facilitating shorter/more flexible interactions' also recognised that more needed to be done in this area. (sub. DR150, p. 2)

DITR offered conditional support provided '… the rules of the current CRC program were changed to focus it more on public good, DITR would support the establishment of a complementary program for business …' (sub. DR185, p. 30) Business participants also agreed. Rio Tinto, for example, said it '… would welcome any initiatives to support more flexible collaborative arrangements with universities and across research agencies.' (sub. DR142, p. 3)

Southern Cross University noted the need for a funding initiative that falls between the project-based ARC Linkage program and the theme-based CRC program:

> We have identified numerous opportunities in the past for collaboration with industry, especially SMEs, that would fit into this category, but have not progressed in the past due to an absence of an appropriate scheme. (sub. DR108, p. 2)

The ARC itself submitted that expanded funding for the larger components of the Linkage program would provide an obvious complement to the CRC arrangement. It highlighted what it viewed as the greater flexibility offered by the former:

> The CRC and Linkage schemes differ chiefly in the arrangements under which the collaborations develop. While CRCs provide a defined *structure* within which research collaborations can develop around broad themes, Linkage schemes provide an umbrella under which flexible, more tightly focused, generally support project-based research collaborations of relatively short duration (typically three years) can emerge. (sub. DR167, p. 7)

Roy Rose was a strong advocate for an expanded Linkage program noting that it also shared many of the broader CRC objectives. He said:

- The programme supports the acquisition and application of new knowledge as opposed to supporting R&D that would occur anyway via the tax concession;

41 These were the CRC for Beef Genetic Technologies; CAST CRC; CRC for Innovative dairy Products; CRC for Forestry; CRC Mining; CRC for the Australian Poultry Industries; The Australian Sheep Industry CRC and Vision CRC.

- The programme supports the development and maintenance of linkages between the university sector and industry;
- The programme provides viable employment opportunities in industry for our best practising scientists which in turn increases the technological skills of our leading companies;
- In every sense the programme is aimed at skewing industry towards an improved knowledge economy by leveraging the research outcomes of the academic sector. (sub. DR198, p. 5)

He went on to suggest that the additional funding for the program '… could be financed from the savings made by scrapping the existing R&D tax concession and would support the diffusion and transfer of new knowledge from the academic and public research sectors to industry.' (sub. DR198, p. 6)

The CRC Association, on the other hand, argued that an expanded CRC program was the most appropriate vehicle to support more flexible engagement with smaller end user groups on the grounds that '… leveraging of existing CRC Programme administrative structure in this way will be a more cost effective mechanism for supporting flexible research collaborations with SMEs than incurring the expense of establishing a completely new complementary program …' (sub. DR150, pp. 2–3).

Others thought either organisation could play this role. GlaxoSmithKline, for example, said:

> GSKA supports [the] finding that a program be implemented to assist SMEs in collaborating with the research sector if such a program does not already exist. However, the ARC linkage program could very well fill this gap. Alternatively, existing collaborative programs could be reformed to fill this gap in government support. (sub. DR 154, p. 5).

CSIRO also saw merit in the proposal as it '… would help provide the dynamic element in the national innovation system, leaving the universities and the research agencies to provide the base support' (sub. DR184, p. 12). It went to suggest such a program could be run out of CSIRO and research intensive universities (a model similar to that used in the Institute Affiliate Program of Belgium's IMEC Institute).

The Commission sees a number of advantages in using that ARC to give effect to its proposal to establish a complementary program. These include:

- incorporation within an existing funding mechanism would be a much less costly and less risky alternative to establishing a completely new structure;
- the competitive processes currently employed in ARC grant funding decisions;
- the similarities with the broader objectives of the CRC model;

- experience with managing a broad range of small and large scale projects across a diversity of research themes and durations;
- the ARC's standing among the general research community as an arbiter of research quality; and
- apparently much lower administrative expenses compared with the CRC program (ARC administrative costs accounted for just 2.7 per cent of total grant funding in 2005-06).

There may also be some disadvantages, however, including the length of time taken to reach funding decisions and the historically narrower focus of ARC funding on academic research (using quality metrics) as opposed to research with stronger impact/utilisation objectives.

In summary, in light of the strong support for the draft finding, the Commission is firm in its view that a more flexible arrangement should be introduced. However, it still considers that it would be prudent to conduct a pilot program and independently evaluate the outcomes of that pilot (using the criteria set out in chapter 8) before broader introduction was contemplated. Funding for the new arrangement could be sourced from the savings made available by implementing the proposals canvassed earlier for improving the effectiveness of the R&D Tax Concession.

The development of other forms of intermediation between business and research organisations was raised in chapter 7.

FINDING 10.15

A complement to the CRC program with broader collaboration goals should be introduced that supports smaller, shorter and more flexible arrangements between groups of firms either independently or in conjunction with universities and public sector research agencies. As a pilot for further evaluation, this should be achieved through an enhancement of the ARC Linkage program.

Annex box 10.1 **CRCs operating in 2005-06 (including those selected in the 2004 selection round)**

Manufacturing technology

- CRC for Advanced Composite Structures
- CRC for Bioproducts
- CAST CRC
- CRC for Advanced Automotive Technology
- CRC for Construction Innovation
- CRC for Functional Communication Surfaces
- CRC for Wood Innovations
- CRC for Intelligent Manufacturing Systems and Technologies
- CRC for MicroTechnology
- CRC for Polymers
- CRC for Railway Engineering and Technologies
- CRC for Welded Structures

Information and communication technology

- Australian Photonics CRC
- Australian Telecommunications CRC
- CRC for Enterprise Distributed Systems Technology
- CRC for Satellite Systems
- CRC for Sensor Signal and Information Processing
- CRC for Smart Internet Technology
- CRC for Spatial Information
- Capital Markets CRC
- Australasian CRC for Interaction Design
- CRC for Integrated Engineering Asset Management

Mining and energy

- Parker CRC for Integrated Hydrometallurgy Solutions
- CRC for Clean Power from Lignite
- CRC for Coal in Sustainable Development
- CRC for Landscape Environments and Mineral Exploration
- CRC for Predictive Mineral Discovery
- CRC for Sustainable Resource Processing
- CRC for Greenhouse Gas Technologies
- CRC Mining

Medical science and technology

- CRC for Aboriginal Health
- CRC for Asthma and Airways
- CRC for Chronic Inflammatory Diseases
- CRC for Cochlear Implant and Hearing Aid Innovation
- CRC for Diagnostics
- The Vision CRC
- CRC for Vaccine Technology
- CRC for Oral Health Science
- CRC for Biomedical Imaging Development

Agriculture and rural-based manufacturing

- Cotton Catchment Communities CRC
- Australian Sheep Industry CRC
- CRC for Beef Genetic Technologies
- CRC for Innovative Dairy Products
- Molecular Plant Breeding CRC
- CRC for Sustainable Aquaculture of Finfish
- CRC for Forestry
- CRC for National Plant Biosecurity
- CRC for Tropical Plant Protection
- CRC for Value Added Wheat
- CRC for Viticulture
- Australian Biosecurity CRC for Emerging Infectious Disease
- CRC for Australian Poultry Industries
- CRC for Innovative Grain Food Products
- CRC for Sugar Industry Innovation through Biotechnology
- CRC for an Internationally Competitive Pork Industry

Environment

- CRC for Australian Weed Management
- Invasive Animals CRC
- CRC for Catchment Hydrology
- CRC for Coastal Zone, Estuary and Waterway Management
- CRC for Water Quality and Treatment
- CRC for The Great Barrier Reef World Heritage Area
- CRC for Greenhouse Accounting
- CRC for Plant-based Management of Dryland Salinity
- CRC for Sustainable Tourism
- CRC for Tropical Rainforest Ecology and Management
- CRC for Tropical Savannas Management
- Environmental Biotechnology CRC
- eWater CRC
- Desert Knowledge CRC
- Bushfire CRC
- CRC for Irrigation Futures
- CRC for Antarctic Climate & Ecosystems
- CRC for Contamination Assessment and Remediation of the Environment

Source: DEST (personal communication).

11 Public sector research agencies

Key points

- The principle objective of public sector research agencies is to perform socially beneficial strategic and applied scientific research that would not, or could not, be conducted by other research providers and, wherever appropriate, widely diffuse the results from that research.
- Australia devotes a relatively high proportion of its total science and innovation budget to public sector research agencies compared with other countries. It also has a multiplicity of such agencies, although CSIRO and the DSTO dominate the research funding allocated to these bodies.
- Recent changes to CSIRO's research investment processes have improved its research focus and provide a framework for ensuring that the organisation does not perform research that the private sector would otherwise undertake. Given the scale of CSIRO activity and the dominance of small and medium sized firms in Australia's industrial structure, it is also unlikely that CSIRO crowds-out private sector research effort.
- Block appropriation funding for CSIRO needs to be sufficient to enable the organisation to make appropriate strategic investment decisions and to maintain its research capability in a range of areas. The share of CSIRO's revenue from that source has declined considerably over the last few years. The real level of block funding should not be reduced.
- Aspects of CSIRO's approach to priority setting and performance management may have wider applicability to other parts of Australia's innovation system (for example, other Federal and State public sector research agencies and the CRC program). The aim of adopting such an approach would be to reduce the risk of unnecessary duplication of research effort and increase accountability across that system.
- The effectiveness of research conducted by the DSTO depends critically on the procurement practices and research directions set in *consultation with* its principal customer, the Australian Defence Organisation. An option to improve the effectiveness of defence-related research is to raise the share of research funding distributed by the users of DSTO research. This would allow users, if they wish, to allocate funds to external providers.

11.1 Introduction

Public sector research agencies (PSRAs) are a central feature of national innovation systems in many countries. Public funding of these bodies is premised on the need to ensure that research that has direct significance to national issues is undertaken. This particularly relates to strategic and applied scientific research that would not, or could not, be conducted by other providers (for example, due to the inability to design suitable incentive mechanisms for effective private sector provision).

Rationales for provision within public sector institutions compared with contracting-out include the advantages of building research capacity to flexibly deal with emerging priorities, lower transaction costs compared with selecting and monitoring private sector providers and the ability to diffuse research results widely and cost-effectively or, in some cases, to constrain dissemination of results in areas where research tasks are focused on sensitive issues — such as in defence and national security areas.

There is no clear-cut delineation, however, between the respective research roles of public research agencies, private firms, higher education or hybrid arrangements involving public-private partnerships. The most appropriate institutional setting for the conduct of research may also change over time (for example, as research capability develops in different parts of the innovation system). That said, there is a set of core issues to be considered in determining the appropriateness of conducting research in public sector research agencies. These include:

- the potential to perform research that private firms would otherwise undertake;
- the ability to identify research projects with a high net social return (which places a critical importance on effective priority setting processes);
- the scope and desirability of broader or restricted diffusion of research results; and
- the desirability of public sector provision compared with contracting-out (which has implications for the nature of funding arrangements including the balance between block and competitive funding).

Compared with most other countries, Australia devotes a relatively high proportion of its total science and innovation budget to PSRA research, with these agencies accounting for around 23 per cent of total Australian Government support in 2005-06. The two main organisations — the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Defence Science and Technology Organisation (DSTO) accounted for 70 per cent of total public sector research agency funding in that year (see table 11.1).

Table 11.1 **Australian Government funding for Public Sector Research Agencies (PSRA)[a], 2005-06 (estimated actual)**

Agency	*Appropriation funding*	*Share of total PSRA funding*
	$ million	Per cent
Commonwealth Scientific and Industrial Research Organisation	593.9	44.2
Defence Science and Technology Organisation	349.1	26.0
Australian Nuclear Science and Technology Organisation	138.1	10.3
Geoscience Australia	107.4	8.0
Antarctic Division	94.6	7.0
Australian Institute of Marine Science	23.1	1.7
Bureau of Meteorology Research Centre	11.7	0.9
Environmental Research Institute of the Supervising Scientist	7.5	0.6
Australian Animal Health Laboratory	6.9	0.5
Great Barrier Reef Marine Park Authority	6.1	0.5
Anglo-Australian Telescope	4.6	0.3
Total	**1 343.0**	**100.0**

Note: [a] Not all funding is dedicated to operational research and can include significant allocations for supporting capital and other expenditure items. See Appendix B for a discussion of the treatment of agency funding in this table.

Source: Australian Government 2006d.

Importantly, portfolio responsibility for public sector research providers is spread across a large number of different federal and state/territory departments. This raises issues regarding effective coordination and the scope for duplication of research effort (see below). The submission by the Department of Agriculture, Fisheries and Forestry highlighted differences in reporting systems across research providers as a major impediment to improved coordination (and collaboration):

> The cost and management effort of implementing collaborative approaches can be a significant impediment to better coordinating R&D. R&D providers operate under widely diverse conditions and in very different sectors and the reporting, evaluation and project management systems they have developed for their own purposes and to provide accountability to their stakeholders can impede efforts to develop more common systems and approaches. (sub. 100, p. 27)

Commonwealth Scientific and Industrial Research Organisation

As an introductory comment, the Commission is mindful that CSIRO has been the subject of a multiplicity of reviews throughout its recent history. Current priority setting, performance management and evaluation processes reflect its reaction to those investigations, the response by Government and other changes in the external environment. The revised processes (and the organisation's current view of its role) have been in place for a relatively short period of time and thus firm conclusions cannot as yet be drawn regarding their impact. The scale of the change to the way CSIRO operates was recognised by some participants to this study with the Business, Industry and Higher Education Collaborative Council, for example, saying:

> CSIRO has undergone a massive change program over the last four years which is only now delivering results. CSIRO initiatives such as the new Science Investment Process, which is specifically designed to avoid a mismatch between the research environment and market, and the Flagship program, which is aimed at supporting engagement and collaboration, have resulted in major cultural change and an organisation with greater collaborative capacity. The impact of these changes have not yet been fully realised, and sufficient time needs to be allowed to fully establish their impact on developing and supporting ongoing partnerships with other research focused institutions, and enhancing knowledge transfer and innovation. (sub. 55, p. 20)

But there has also been considerable recent criticism of the organisation's research investment decisions in other forums. However, there was very little coverage of these issues or of alternative decision-making approaches either in discussions or submissions to this study. That said, the Commission acknowledges the potential for problems to emerge in any organisation (either in the public or private domain) where the incentives facing those tasked with delivering outputs diverge from their principals — the principal-agent issue.[1] This is amply borne out in the Commission's discussion regarding governance arrangements for the Commercial Ready program (see chapter 10).

Key Features

CSIRO is Australia's peak scientific research agency. It operates as an independent statutory authority and performs a broad range of functions in accordance with the *Science and Industry Research Act 1949* (amended in 1998). Its primary tasks include conducting research to: assist Australian industry; further the interests of the Australian community; and encourage or facilitate the application or utilisation of scientific research results. It also performs a number of subsidiary roles such as the training of researchers and the interpretation and dissemination of scientific and technical information.

In contrast to the curiosity-driven nature of some university research, CSIRO's role is mission-based. In line with its mandate, the bulk of its research activity is at the

1 This problem can occur at different levels. For example, at one level the CSIRO Board and management can be viewed as the agent of Government and at another level research divisions, teams or individuals can be viewed as the agents of the CSIRO Board and management.

applied and strategic end of the research spectrum. It devotes very few resources to experimental development (the domain of the business sector) or to pure basic research — a major focus of activity in higher education institutions — (see table 11.2).[2]

The organisation also has a very wide charter with research projects spread across a range of activities including advanced materials, ecosystem management, mineral exploration and processing, plant and animal sciences, climate science and water management, information and communication technology and astronomy (sub. 50, p. 10). The organisation's scale (it has 6500 employees and 17 research divisions located across 57 sites throughout Australia and overseas) also provides considerable scope for multidisciplinary research to be conducted 'in-house'.

CSIRO emphasised certain beneficial aspects of this capability in its submission:

> Achieving [solutions to complex problems] usually involve multiple stakeholders, multiple, intricate social interactions, and the bringing together of a wide range of technical skills and expertise from a range of disciplines. The transactions costs in trying to implement this approach across many different organisations, each with its own culture, process, procedures and objectives can be considerable. In many cases CSIRO can achieve this from within its own resources. (sub. 50, p. 54)

In a broader context, the Commission also notes that combined with other features of CSIRO's operating environment, this capability is likely to involve lower transaction costs compared with either competitive grant funding arrangements or the contracting-out of research activity by a central purchasing agency (see below). Public support is provided via a single block grant currently under a triennial funding agreement as well as through dedicated resources for the recently introduced Flagships program (see box 11.1).[3,4] Total Australian Government support accounted for 63 per cent of CSIRO's budget in 2005-06. Significantly, nominal growth in the organisation's public appropriation has been very modest over the last decade, leading to claims that the agency is under-resourced.[5] This issue is discussed below.

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2 In 2004-05, CSIRO devoted around 47 per cent of its research expenditure to applied research, 38 per cent to strategic basic research, 9.5 per cent to experimental development and 5.5 per cent to pure basic research (CSIRO sub. 50, p. 38).

3 The Government recently announced that CSIRO will move to a four year funding cycle from 2007-08 (Bishop 2007).

4 This differs from the dual funding arrangement in higher education research which involves both block funding for institutions (on the basis of allowing greater flexibility to set their own priorities) and competitive grant funding for teams and individual researchers (to encourage excellence through merit criteria).

5 Between 1997-98 and 2005-06, CSIRO's public appropriation increased at a nominal rate of just 3.0 per cent annually. CSIRO's share of Australian Government support for science and

Table 11.2 **CSIRO's expenditure and revenue, 2005-06[a]**

Expenditure	*$ million*	*Share of total*
Core roles		
Advancing frontiers of science[b]	91	9.2
Creating new or significantly transforming industries	147	14.9
Solving major national challenges	129	13.0
Delivering incremental innovation for existing industries	157	16.0
Science-based solutions for the community	60	6.1
Satellite roles[c]	128	13.0
Other		
Research support services	242	24.5
Enterprise strategy and governance	33	3.3
Total expenditure	**985**	**100.0**
Revenue	*$ million*	*Share of total*
Appropriation	593.9	62.7
Co-investment	210.1	22.2
Services and consulting	61.9	6.5
Intellectual property	37.1	3.9
Other[d]	43.8	4.6
Total revenue	**946.8**	**100.0**

[a] Expenditure figures relate to budgeted outcomes at the beginning of the period while revenue figures relate to actual outcomes at the end of the period. [b] According to CSIRO, this element is directed at improving capabilities in other areas of CSIRO's research rather than being purely curiosity driven research. [c] Satellite roles include providing technical services, supporting post-graduate and post-doctoral development, outreach and education, managing national collections, managing national facilities and scientific publishing services. [d] Includes revenue from asset sales and interest.

Sources: CSIRO 2005b, 2006 and sub. 50.

Under its funding agreement, CSIRO is required to meet and report on an extensive range of outcome-based performance criteria over the life of the funding cycle (see annex box 11.1 at the end of this chapter). As discussed later, some participants (for example, the submission from the CSIRO staff association, sub. 78, pp. 12–13) were critical of the administrative burden associated with these reporting requirements claiming that they were diverting resources away from research functions.

innovation declined from 12.6 per cent to 10.0 per cent over the same period (Australian Government 2006d).

Box 11.1 **CSIRO's National Research Flagships**

According to CSIRO, the Flagship programs (officially launched in 2003) represent some of the largest directed research efforts ever undertaken in Australia and the largest ever redirection of CSIRO funding. They involve partnerships with other research providers and users of research outputs including leading scientists, research institutions, firms, government agencies and selected international partners. They aim to help shape the future of an industry or sector in Australia or address a major national challenge by identifying opportunities that require a research solution. Total Flagship funding (including external and in-kind) is estimated at $240.4 million in 2006-07.

The programs are based on: tackling Australia's biggest national challenges; delivering high impact, high quality science in pursuit of those challenges; delivering effective outcomes by working with partners; achieving long-term goals by a combination of short, mid and long-term science outputs; introducing a new way of doing science (multidisciplinary, multi-agency, transformational science to make a difference); investing significant resources from CSIRO and its Flagship partners; and delivering high standards of accountability through rigorous governance controls.

CSIRO currently manages six individual flagships each with an explicit goal (there is also a Flagship Collaboration Fund that purchases research from other organisations).

- Energy Transformed
– To halve greenhouse gas emissions and double the efficiency of the nation's new energy generation, supply and end use, and to position Australia for a future hydrogen economy.
- Food Futures
– To transform international competitiveness and add $3 billion annually to the Australian agrifood sector by the application of frontier technologies to high-potential industries.
- Light Metals
– To lead a global revolution in light metals, doubling export income and generating significant new industries for Australia by the 2020s while reducing environmental impact.
- Preventative Health
– To improve the health and wellbeing of Australians and save $2 billion in annual direct health costs by 2020 through prevention and early detection of chronic diseases.
- Water for a Healthy Country
– To achieve a tenfold increase in the economic, social and environmental benefits from water by 2025.
- Wealth from Oceans
– To position Australia by 2020 as an international benchmark in the delivery of economic, social and environmental wealth based on leadership in understanding ocean systems and processes.

Sources: Sub. 50, sub. DR184 and CSIRO 2006.

This funding is supplemented by external consulting, co-investment (with a range of public and private sector research user groups) and contract revenue. Although a formal external revenue target (set at 30 per cent of CSIRO's budget) aimed at increasing collaboration and engagement with research users was removed in 2002 due to a range of associated problems, the share of funding from this source has actually increased since that time.[6,7] In effect, if CSIRO is to maintain its pre-2002 gross funding budget, it must still meet an implicit external revenue target. Thus far, income from royalties and intellectual property (IP) rights accounts for a relatively minor share of total revenue (around 4 per cent in 2005-06).

As a statutory body, the CSIRO Board decides how its public funding appropriation is directed to specific research areas (though there is very general guidance provided by the National Research Priorities).[8] In determining that research agenda, the agency has developed what many consider to be a rigorous, flexible and robust priority setting framework that has generated interest from other parts of Australia's research community (including some universities and science program administrators). As discussed later, CSIRO also considers its framework is more widely applicable to other parts of Australia's innovation system (sub. 50, p. 18).

Priority setting (known as the Science Investment Process) is based on an assessment of CSIRO's capabilities (scientific strengths) and an analysis of the potential impacts of different areas of research (that is, it asks which areas would deliver the greatest benefits to Australia — see box 11.2). Broad consultation with stakeholder interests is also a feature of the process. This allows research activity in other parts of the innovation system, both domestically and abroad, to be specifically considered in determining project funding. This is relevant, inter alia, to addressing issues regarding additionality and the potential for CSIRO research to crowd-out activity by other research providers (see below).

6 The increasing trend toward collaborative research is highlighted by CSIRO being the largest single participant in the CRC Program. It was involved in 48 of the 68 CRCs operating as of March 2006.

7 According to the review of the external revenue target (Batterham 2002), these included encouraging short-termism at the expense of longer term planning, focusing effort to areas more likely to provide a financial return, limiting collaborations with SMEs, restricting optimal performance in CRCs and creating difficulties in building the value of intellectual property.

8 Research priorities for externally generated revenue are influenced by industry and collaborative partners.

Box 11.2 The selection and management of CSIRO research

According to CSIRO, the allocation of research funding is based on the principles of science excellence, relevance and impact. The organisation uses a variety of methods to promote these goals including what it terms the organisation's Science Investment Process (SIP), Performance Management Framework and Science Assessment Process. Formal stakeholder engagement (such as Sectoral Advisory Councils and Flagship Advisory Committees) allow user groups to participate in developing CSIRO's overall research strategy and the priority setting process in order to align its activities with the needs and capacities of user groups and to improve the utilisation of CSIRO's research results.

Science excellence encompasses research quality and the extent to which research achieves its intended outcome (its fitness for purpose). The two main tools used to assess research quality are: peer review of science quality and its importance to users (used in the science assessment process described below); and citation performance relative to other national and international research institutions. Fitness for purpose is measured via customer value surveys and indicators of repeat business.

The **Science Investment Process** is forward looking and aims to ensure the relevance and impact of CSIRO science. It represents a systematic approach to managing the research portfolio and is based on an extensive range of indicators across 18 different socio-economic areas. These indicators are used to determine *research relevance* (with broad investment criteria based around value from R&D; whether CSIRO should be engaged and its role; and the relevance of R&D) and *research impact* (with broad investment criteria based around the likelihood of adoption; R&D productivity/potential and CSIRO research competitiveness). In turn, they help to prioritise decisions regarding resource allocations. A listing of the indicators used to assess research relevance and impact is presented in annex box 11.2 at the end of this chapter.

The **Performance Management Framework** is both forward and backward looking and aims to manage research to achieve impact and underpin accountability within CSIRO and with stakeholders. It involves tri-annual reporting of: strategy implementation; program performance; science highlights; outcomes (adoption and use of outputs) and organisational health. Performance monitoring and reporting is conducted against a detailed set of indicators in order to maximise the return on investment. The framework allows individual projects to be stopped or accelerated depending on changes to external conditions (such as the development of competing technologies or changes in community attitudes) and provides for the reallocation of resources to projects offering greater potential.

The **Science Assessment Process** is backward looking and periodically evaluates the work conducted within, and by, each division. It draws on peer review through expert external committees (predominantly comprising international experts and including end-user representatives) to review the quality, relevance, capability development and impact of each division.

Source: Sub. 50.

A feature of the operational management of CSIRO research (the Performance Management Framework) is that regular monitoring of progress against science outcomes and path-to-market milestones allows for a redirection of resources should progress fail to meet specified targets (at so-called stage gates). CSIRO noted that an example of its ability to shift resources in response to changes in the internal and external environment is reflected in a recent decision to replace an intelligent transport research stream with a transport fuels stream in response to escalating global oil prices. Another example was the ‘fast-failing’ of 14 research projects in the Light Metals Flagship for not meeting technical, economic or partnering performance criteria (sub. 50, p. 84).[9]

Another element of CSIRO’s research management framework, the Science Assessment Process, has similarities to the proposed Research Quality Framework (RQF), which is discussed in chapter 12.

At a broader level, the application of this approach to research governance is also reflected in expenditure shifts of up to 10 per cent across core research roles such as occurred between 2005-06 and 2006-07 (CSIRO 2006). This flexibility contrasts with the operation of other parts of Australia’s innovation system (notably ARC and NHMRC grants and the CRC program) where ongoing research management is largely a matter for the individual researcher or team and funding continuity is guaranteed for the life of the research project with much less rigorous monitoring of whether research objectives are being met.

Research priorities are guided by sectoral advisory committees spanning seven broad socio-economic areas: 1) agribusiness; 2) energy and transport; 3) environment and natural resource management; 4) health; 5) information, communication and services; 6) manufacturing; and 7) minerals resources. In addition there is an external advisory committee for each National Research Flagship (see box 11.1). The committees provide stakeholder input (from industry, government, higher education institutions and community groups) about strategic research needs and the utilisation of research results and assist in the evaluation of performance against planned outcomes. The organisation also draws on the expertise of eminent international scientists in determining research priorities and evaluating the outcomes of CSIRO’s research activity.

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9 CSIRO noted in discussions that the scale of the organisation’s research portfolio generally allowed the affected research scientists in these situations to be diverted to other projects in their existing disciplines, thus enabling the organisation to maintain research capability in these areas. This was contrasted with the operation of alternative organisational models such New Zealand’s Crown Research Institutes (discussed later) which were involved in a much smaller number of research projects and hence risked losing capability should a project be terminated.

11.2 Are CSIRO's processes effective in targeting the right research projects?

As noted above, a core rationale for sponsoring research within public agencies is to meet socially valuable research needs that would not, or could not, be effectively performed by other providers even if funded by government. In principle, this type of research primarily involves strategic and applied work with strong (though not necessarily exclusive) public good characteristics in areas such as managing the environment, improving the quality of life and, more generally, providing input to government policy setting processes. Private firms would not participate in these areas if they could not capture sufficient benefits (subject to the magnitude of government subsidies) while university researchers (whose incentive structure is based on furthering the frontiers of knowledge and academic reputation) would often abstain because such pursuits may lack sufficient originality.

As shown in table 11.2, CSIRO's research spending in areas that appear, prima facie, to reflect relatively strong public good outcomes across social, environmental and economic spheres (advancing the frontiers of science, solving major national challenges and science-based solutions for the community) accounted for just over 50 per cent of research activity in 2005-06. While the rationale for public funding in these areas is relatively clear cut the justification for CSIRO's involvement in industrial research (creating new or significantly transforming industries and delivering incremental innovation for existing industries) is less so because these activities are likely to involve both private benefits and public good elements.

The submission by Graeme Pearman, a former CSIRO division head and member of its executive committee, effectively questioned whether the organisation's current emphasis on performing industrial research was appropriate:

> With respect to CSIRO's current focus on capturing scientific knowledge for economic benefit it is argued that this is a huge, potentially dangerous experimentation with a national and publicly supported asset that is being undertaken on what are basically ideological grounds, in a vacuum, devoid of open debate concerning the overall benefit of this approach for Australia. (sub. 86, p. 6)

This highlights the importance of putting in place rigorous priority setting processes to avoid committing appropriation revenue to areas where beneficiaries are likely to have sufficient incentives to perform and/or fund the research themselves (the additionality issue). A prominent historical example is CSIRO's involvement in agricultural R&D where the organisation's strong record of achievement in that field has delivered significant benefits to primary producers, sometimes without a requirement for the beneficiaries to contribute proportionally to the cost of research or for CSIRO to share in the income streams that resulted (see chapter 4).[10]

The Commission considers that CSIRO's ongoing involvement in its core research area of delivering incremental innovation to existing industries poses the greatest potential risk of encroaching on activity that private firms would otherwise undertake because that research is likely to involve considerably lower levels of technical and commercial risk than other industrial research. As CSIRO itself noted in the context of generating interest from potential users:

> … it is easier to attract external funding for incremental improvement work than for research aimed at major transformations of industry, which is much riskier and long term. Yet CSIRO's major responsibilities fall into the major transformation area. (sub. 50, p. 64)

Importantly, the wording of the CSIRO Act does not provide specific guidance on the type of industrial research activity that CSIRO should undertake — only that it carry out scientific research to assist Australian industry. It is therefore up to CSIRO itself to determine the most appropriate use of its public funding. Of course, this does not mean that CSIRO should be precluded from performing contract research (on a full cost-recovery basis) for industry as the associated interaction with research users achieves a number of outcomes including that: it can provide a valuable 'relevance check' for research; it has the potential to trigger public good research grounded in practical problems; and it can also lead to more effective utilisation of CSIRO's research infrastructure.

As discussed below, the Commission considers that the recently introduced priority-setting process provides a framework for systematic and robust evaluation of research areas that warrant investment of CSIRO appropriation revenue. An element of that framework asks whether CSIRO should be engaged in specific research and the respective role the organisation should play (see annex box 11.2).

However, as the Commission said in the draft report, questions remain about the nature of its involvement in certain areas. In particular, a review of the impact of recent CSIRO research noted that the R&D program in light metals and cotton research had a strong commercial emphasis and that a key factor underpinning CSIRO involvement 'is its legislative requirement to carry out scientific research to assist Australian industry and the extensive light metals [and cotton R&D] capability already held by the organisation.' (ACIL Tasman 2006e, pp. 5–6)

10 CSIRO's research activity in the mining and elements of the manufacturing sector has similar potential. The Commission recognises the organisation's recent efforts to move resources away from these areas in the face of criticism from the groups benefiting from past investment decisions.

As discussed in chapter 4, even where a small number of large firms are the potential beneficiaries (such as in the light metals industry), there may be a case for CSIRO involvement in the early stages of a research project on the grounds that the project is so technically risky that it would not otherwise proceed. However, that involvement would need to be re-assessed as the project evolved and the prospects for full private funding increased. In the case of cotton research, on the other hand, the Commission sees a much weaker argument based on additionality grounds (see chapter 10).

CSIRO's response to the draft report noted that broader political and practical considerations were part of the environment within which research organisations operated and this could present challenges for it in funding decisions.

> As an example, CSIRO's role house model, business models and science investment process all explicitly build on the reasons for public support and the circumstances under which research services require full private funding, a balance of private and public funding, or full public funding. However, putting these principles into practice can be quite challenging – as when the business sector expresses concern about the requirement to cover the full costs of research, the benefits of which will flow to an individual firm; or when shifting effort to longer term, riskier work leads to a decrease in private sector funding and consequent cost pressures for the organisation, or to complaints from industry that CSIRO is becoming less responsive to its needs. (sub. DR184, p. 5)

That said, the earlier submission by CSIRO emphasised the organisation's position is that it 'does not fund research that the private sector is likely to support itself' (sub. 50, p. 64) and that a decreasing proportion of its appropriation revenue was directed to the incremental innovation for existing industries role (the area it also viewed as having the greatest potential to encroach on work private firms would fund).[11]

In seeking to give effect to this goal, CSIRO also commented it had moved toward a co-investment approach where the benefits from the application of research were shared by collaborative partners. This is, in essence, a form of incentive subsidy in that it acts to dissuade firms from seeking support for research they would have conducted anyway (see chapter 10). CSIRO noted:

> If the private sector view is that the research has a high level of certainty and will produce significant benefits, it is less likely to agree to co-investment proposals, preferring to pay the full costs of the research upfront and retain for itself all of the

11 While incremental research activity represented the largest single core role in 2005-06 (see table 11.2), the relative importance of that component has declined in 2006-07. At a disaggregated level, resources allocated to incremental innovation decreased by 5.8 per cent in the Agribusiness Group in 2006-07, 3.0 per cent in the Information, Manufacturing and Minerals Group and 6.7 per cent in the Sustainable Energy and Environment Group (CSIRO 2006).

> expected returns. The greater the level of uncertainty and risk, the more likely firms will be to agree to share the costs, risks and benefits. (sub. 50, p. 64)

Evidence of the adoption of this approach is provided by the increasing share of CSIRO's total revenue from co-investment activity (see table 11.3).

The Commission said in the draft report that it considered that there may still be some value in reinforcing CSIRO's stated aim by appropriately amending the wording of its Act to target high spillover research that would not otherwise take place and explicitly incorporating a more specific set of ex-ante evaluation criteria to improve CSIRO's current processes (see below).

But CSIRO considered this would be a cumbersome process and instead offered an alternative:

> Changing the legislation is a political process requiring parliamentary scrutiny and is a matter for government. There is also another, perhaps less onerous, route through which the government could make its intentions clear regarding CSIRO's responsibility to support industry. This would be to use the Statement of Expectations that ministers will provide under the Uhrig reforms. (sub. DR184, p. 13)

While the Commission considers that legislative change would be a more powerful and, accordingly, preferred instrument it would countenance the suggestion put by CSIRO if it were shown to be effective.

The organisation also highlighted its planned *Australian Growth Partnerships* model that would provide competitive funds to SMEs who have a track record of commercialisation success but who are unwilling to accept the full risk associated with a particular new project. Its aim will be to transfer CSIRO technology and provide the technical assistance needed for successful commercialisation. In that event, CSIRO would require repayment of the funding it provides. One participant, AusBiotech (the representative association for Australia's biotechnology sector) supported this type of arrangement on the grounds that it would improve the accessibility of CSIRO research although it also noted potential risks:

> CSIRO is currently exploring some schemes, such as the Australian Growth Partnership model which could result in deferred payment for contract research in exchange for a share of the IP generated. This would make CSIRO services more accessible particularly for SMEs.
>
> Until this model gains approval, CSIRO has been trialling a similar scheme, using the resources of the Division of Molecular and Health Technologies. The approach is to offer scientific resources on the basis of flexible business models, using a risk-adjusted mixture of up-front payment, IP sharing, royalties, milestone payments and equity options, depending on what suits particular SMEs and their investors. There is however a risk for CSIRO that in deferring some or all of its returns, these returns may not materialise. (sub. 95, p. 29)

Table 11.3 **CSIRO's co-investment, consulting and services and IP revenue, 2002-03 to 2006-07**

	2002-03	*2003-04*	*2004-05*	*2005-06*	*2006-07*[a]
Co-investment	179.8	194.0	209.4	218.1	235.6
Services and consulting	83.7	78.7	60.9	61.9	65.0
IP revenue	13.8	22.0	20.4	37.1	37.2
Total[b]	**275.4**	**296.2**	**280.9**	**309.1**	**337.8**

[a] Figures in this column are CSIRO budget estimates and include work-in-progress and deferred revenue adjustments and for this reason are not strictly comparable to previous years. [b] Except for 2006-07, total revenue includes work-in-progress and deferred revenue adjustments, but individual components do not.

Sources: Sub. 50 and CSIRO 2006.

As discussed in chapter 10, the Commission strongly endorses the use of instruments that dissuade firms from unnecessarily seeking financial assistance. However, it considers that the use of a royalty sharing arrangement would be far more effective in achieving this aim compared with a requirement of just repaying the funding received by the firm. In this context, the Commission considers the flexible funding and royalty approach adopted in the trial scheme cited by AusBiotech as a more preferable funding mechanism.

Finally, in reviewing potential improvements to CSIRO's investment processes, the Commission judged in the draft report that incorporating an explicit set of quantitative and qualitative criteria to assess the case for, and extent of, CSIRO involvement in research where public and private benefits co-exist would be valuable. In this regard, the investment criteria used by the Victorian Department of Primary Industries for agricultural research, development and extension (RD&E) was instructive. The main principles (some of which are already reflected in CSIRO's investment process) used in that process involve an assessment of:

- *Role of Government*: A market failure test is used to help determine the role of government in future RD&E investment and the beneficiaries and funders test is applied to help determine who benefits and therefore who should be funding the work;
- *Alignment with strategic direction and investment priorities*: Scanning the environment (external and internal) to identify the key drivers and emerging issues that might inform setting strategic direction as well as annual investment priorities. Project proposals need to align with the strategic direction and priorities to be considered for funding.
- *Equity in funding:* Investors should make a quantum of investment proportionate to the benefit of the output to that investor using the market failure test. Some projects should be fully funded by industry, some fully funded by government, and others a mix of both government and industry.
- *Impact of investment and value for money:* The success of government investment in RD&E through DPI will be underpinned by demonstrated achievements in relation to

economic impacts for the agri-food sector and benefits to the natural resource base and regional communities. (sub. 84, p. 34)

CSIRO confirmed that current Science Investment Process (SIP) criteria already reflected many of these principles but agreed that in some areas they could be made more explicit:

> It would not be a major change to ensure that issues relating to the role of government and to equity in funding become explicit rather than implicit criteria. These are already embedded in the business models that support SIP process. (sub. DR184, p. 13).

Finally, the organisation also commented that while it accepted the importance of examining the rationale for public support, it was not always possible to make a clear-cut assessment of the issue because of: uncertainty regarding the data on which decisions are based; the level of potential spillovers; and about possible outcomes. It went further in suggesting that the potential for firms to move their research effort overseas and for public funding to facilitate the faster and more widespread diffusion of a technology (compared with proprietary use by a firm with sufficient incentive to fund the work themselves) were also relevant considerations.

The Commission acknowledges the (often significant) uncertainties involved in these areas. As mentioned earlier, there is no clear-cut delineation between the respective research roles of different players in the innovation system and the most appropriate setting for the conduct of research may change over time. However, it cautions that the potential to make inappropriate funding or cost-sharing decisions will be lessened through the application of a robust, risk-based priority setting framework compared with one that allocates funding on the grounds of the potential for missed opportunities — for example, whether a firm alleges it would move overseas in the absence of funding support (see chapter 10).

Crowding-out

A closely related issue to the inducement question is whether public sector research ‘crowds-out’ or substitutes for activity that might otherwise have been conducted by the private sector (an issue more widely discussed in appendix M). This may occur where, for example, in the face of supply constraints in the market for scientists and engineers, public sector demand acts to raise salaries and make research uneconomic for private firms. In that respect, CSIRO noted it was unlikely that its industrial research activity (specifically its core role of creating new or significantly transforming existing industries) substitutes for business funded R&D due to the scale of research effort in that area.

It argued that the absence of large corporate laboratories in Australia (in contrast to countries like the United States) meant that major research efforts aimed at developing breakthrough technologies would simply not be undertaken here. As an indicator it presented comparative data on the distribution of research effort by firm size in four countries showing a much higher proportion of research conducted by small firms in Australia (see table 11.4). It also noted that this feature of Australia's research landscape also precluded most private firms from managing risk across a broad portfolio of projects.

The Commission notes empirical evidence both from Australia and internationally lends a degree of support to this contention. For example, a recent Commission study into the relationship between R&D and productivity (Shanks and Zheng 2006) found a strong positive relationship between government and business sector R&D (a 1 per cent increase in public R&D raised business R&D by 1.9 per cent over the long run). For the OECD as a whole, on the other hand, there was evidence of modest crowding-out, though this appears to be isolated to countries with large public sector defence R&D (appendix M).

Similarly, in a recent review of international studies sponsored by the Department of Employment, Science and Training, Dowrick (2003) noted that while crowding out of private sector research was a common finding for the United States (where more than 50 per cent of industrial R&D is conducted in very large firms with more than 10 000 employees), the majority of studies for other countries found a degree of complementarity between public and private sector research activity. In other words, public R&D raised private sector productivity.

Finally, subject to the caveat above, the Commission acknowledges the point made by CSIRO that even where private sector research is crowded-out, public sector provision may be more effective if it leads to greater spillovers (for example, because research outcomes can be more widely disseminated).

Table 11.4 **Research effort by firm size, 1999 — selected countries**
Per cent of total business R&D

	Firm employment size			
Country	*Less than 100*	*100-499*	*500-999*	*Greater than 1000*
Australia	29.2	20.7	12.3	37.8
Canada	16.8	15.8	10.1	57.4
United States	10.4	8.3	3.8	77.5
Korea	4.1	8.8	8.2	78.9

Source: Sub. 50.

11.3 Are CSIRO's funding arrangements appropriate?

As noted above, the bulk of CSIRO's research budget is provided through a block appropriation grant. Block funding offers significant advantages for mission-based research agencies like CSIRO: it provides greater flexibility to make strategic decisions about research direction; it creates opportunities to respond to emerging priorities; it allows the organisation to plan and build multi-disciplinary research capability; it provides scope to engage in larger scale and longer-term research; and it involves lower administrative and compliance costs compared with competitive funding processes such as grant funding or contracting out. From the community's point of view, these features also deliver potentially valuable contingency or option benefits relating to the capacity to reduce a range of social (eg public health) and environmental risks and a preparedness to deal with future uncertainty. In the words of CSIRO:

> … one reason why the government provides a (largely) one line appropriation to CSIRO [is that] this buys capacity rather than projects from CSIRO – it is in effect an insurance policy, supporting a preparedness to deal with possibilities that flow from CSIRO's more directed activities that result from an expert analysis of Australia's needs and challenges conducted in the context of existing and emerging scientific opportunities. (sub. 50, p. 56)

But there are also potential disadvantages associated with block funding including: reduced external accountability (at least over the term of the funding cycle and especially given the diffuse and uncertain nature of public good research outcomes); less direct involvement in research investment decisions by stakeholders; and lower incentives to maintain or improve research quality and impact compared with more 'at risk' funding sources.

However, the Commission considers that current research investment and research governance processes employed by CSIRO provide a degree of reassurance against these risks. Firstly, the science investment process involves an element of internal contestability as research scientists and research divisions are required to compete for available appropriation funding. Research proposals are assessed and ranked on merit against detailed relevance and impact criteria in the science investment process framework (see annex box 11.3). Broad stakeholder consultation will also help to shape research strategy from a top down perspective.

Secondly, a much greater share of funding now comes from competitive sources with external revenue estimated to account for just under 40 per cent of the organisation's total budget in 2006-07 (CSIRO 2006). Accordingly, interaction with research users has, by necessity, increased significantly over time (with the strength of these linkages reflected in the responses to CSIRO's regular customer value survey). Finally, accountability will also be enhanced by the performance management system that redeploys resources if agreed objectives (science excellence and impact) are not met and outcome-based performance reporting requirements under the triennium funding agreement.

Importantly, the breadth of that engagement includes research applications in areas with strong public good characteristics. In particular, direct government grant and contract funding (with research outputs used to address policy responsibilities in areas such as environmental management) accounts for the largest share of external revenue (see table 11.5). The submission from CSIRO highlighted the mechanism through which that funding influences the direction of its research effort:

> … a grant is one means through which external public bodies can draw on CSIRO's appropriation funding and affect its overall research strategy. Because grants originate from public sector organisations, involve public funding and generally aim to produce public good outcomes in the public interest, the necessary subsidy of grant-supported work from appropriation funding does not result in any conflict with CSIRO's roles and objectives. However, grants do reduce some of the flexibility that CSIRO has to allocate its appropriation funding purely according to its internal assessments. (sub. 50, p. 61)

In effect, this means that the actual share of funding determined on a competitive basis is considerably higher than that indicated by external revenue sources alone.

Moreover, this raises a broader question of whether these government bodies could play a more direct role in decisions regarding how CSIRO's appropriation funding is allocated or, alternatively, whether a central purchasing agency could be involved in determining research directions such as occurs in New Zealand (see below). CSIRO argued strongly against a move away from current arrangements highlighting both the advantages of block funding and the consequences of relying too heavily on external bodies in allocation decisions. It said:

> The budget appropriation … provides for a degree of certainty and stability. This facilitates the strategic planning of research and investment in longer term, challenging projects, as well as the maintenance of capability. Appropriation funding supports basic infrastructure, including facilities, equipment and expertise. Just as importantly, it provides an essential base from which it becomes possible to invest resources into the development of long term research projects requiring the assembly of large teams of experts from several disciplines across different organisations. Grant schemes do not support such planning or cover the considerable overheads required to manage such projects. Neither do grant schemes provide the single point accountability within one organisation which is necessary for the effective management of this kind of large scale program. (sub. 50, p. 58).

Table 11.5 **Sources of CSIRO's co-investment, consulting and services revenue, 2005–06**

Source	*Revenue*	*Share of total*
	$ million	per cent
Government	86.7	31.9
Private sector	71.2	26.1
RRDCs	44.3	16.3
CRCs	35.2	12.9
Overseas entities	35.0	12.9
Universities	7.7	2.8
Work in progress and deferred revenue	-8.0	-2.9
Total	**272.1**	**100.0**

Source: Sub. 50.

In considering the issue of funding balance, the Commission notes the operating environment of New Zealand's Crown Research Institutes (CRIs). The CRIs are separated along similar divisional lines to that of the CSIRO and are required to compete against each other, universities, private firms and research associations for public good research funding administered by a centralised research purchasing agency (see box 11.3).[12]

In principle, there are a number of potential advantages of centralised purchasing including a lower risk of duplication across the public research sector (including State research bodies) compared with multiple funding models such as that operating in Australia; greater consistency in selection processes across research providers; more responsive priority setting to community expectations (ie targeting projects with high social benefits); and greater transparency and accountability.

But there may also be disadvantages. As discussed in chapter 9 in the context of considering an increased emphasis on National Research Priorities, these include the higher transaction costs involved with collecting and assessing information from competing bidders; a greater risk of purchasing errors compared with decentralised decision-making models; higher administrative and compliance costs for research providers; wasteful lobbying effort; adverse incentive effects from a less certain funding environment (such as gaming); and the potential loss of capacity building and the other advantages of block funding.

12 In 2004-05, 53 per cent of the available funding was allocated to the CRIs, 23 per cent to higher education institutions and 23 per cent to business.

Box 11.3 **New Zealand's Crown Research Institutes**

The establishment of Crown Research Institutes (CRIs) in 1992 represented a new approach to public sponsorship of scientific research in New Zealand. Prior to their introduction, public research activity was conducted within portfolio agencies including the Department of Scientific and Industrial Research and the research arms of the Ministry of Agriculture and Fisheries and Ministry of Forestry. The CRIs were established as independent statutory bodies subject to the New Zealand Companies Act (requiring the payment of dividends and corporate tax). They are expected to be commercially viable (with a strong focus on financial performance), compete for public and private sector contracts, exhibit a sense of social responsibility and undertake research for the benefit of New Zealand.

There are currently nine separate institutes aligned to research in the following economic, environmental and social fields: agriculture; horticulture; crops; industrial research; forestry; geological and nuclear science; landcare; water and atmospheric research; environmental science; and social research and development. The CRIs undertake both basic (mainly strategic) and applied research with most effort focused on the application of research results over the medium to long-term. They are required to produce science and technology of both high quality and relevance to end users including industry and government.

Public funding is primarily provided under the Public Good Science Fund and allocated by the Foundation for Research, Science and Technology (FRST) — established to act as the main public purchasing agent — on a contestable basis. The CRIs compete against universities, private firms, research associations for funding from FRST and other purchasing agents who then contract to the successful bidders for the research. Unlike universities, CRIs receive very little block funding from government, and are instead dependent on FRST funding, private sector contracts or generating commercial revenue. CRIs also receive non-contestable public funding to build and maintain research capability required for the provision of public good science. In 2004-05, 60 per cent of CRI revenue was sourced from government, 20 per cent from private firms and around 8 per cent from 'own funds' (commercial revenue).

Sources: MoRST (2003, 2006), OECD (2004a).

In practice, these and a number of other problems have been associated with New Zealand's move to a more centralist approach. While recent evaluations of the research funding arrangements in that country noted strongly beneficial impacts in certain research fields (mainly industrial and environmental research), improved linkages with research users and better performance against financial benchmarks, there was a range of concerns identified by the CRIs and other stakeholders (purchasing agents, policy makers and end-users) about the impact of the contestable funding model (MoRST 2003).[13] These included:

- grant funding duration compromising the management of long-term research;
- tensions between public good and commercialisation objectives;
- inappropriate purchasing decisions with respect to the core role of the CRIs;
- reduced ability to maintain core competencies in certain areas;
- encouraging game playing to secure funding (at the expense of other CRIs) making collaboration with universities more difficult; and
- imposing an unnecessary administrative burden in terms of securing funding and a legal burden in dealing with intellectual property issues.

While there were no specific recommendations in relation to funding, the latest evaluation noted that the range of suggested solutions from stakeholders 'were mainly variations on the theme of reducing the amount of funding allocated on a contestable basis.' (MoRST 2003).

The Commission recognises that adoption of this model, as a whole, would represent a radical departure from Australia's approach to funding CSIRO and other public sector research agencies. The associated risks of causing abrupt and significant costly disruption to that part of the innovation system need to be taken into account. As discussed in chapter 8, there is also no certainty that a more directive funding model would be more effective than Australia's current processes. In particular, important aspects of the present approach (such as allowing those with expert working knowledge of particular science and innovation issues to make decisions) would be hampered by such a move. Accordingly, the Commission considers there is not a strong case for moving to a centralised purchasing model.

The level of appropriation funding

A related issue involves the adequacy of the *level* of CSIRO's public funding. As noted above, appropriation funding has been static in real terms over the last decade and now accounts for a smaller of share of overall Australian Government support for science and innovation (down from 12.6 per cent in 1997-98 to 10.0 per cent in 2005-06). Some participants highlighted the adverse consequences of the increased emphasis on attracting external funds in the face of stagnant appropriation revenue. Graeme Pearman said in this regard:

13 In 2004-05, around 50 per cent of the public research funding pool was allocated to the CRIs (down from 85 per cent in 1998).

> The process and other cultural changes have led to early retirements, redundancy of productive and experienced senior staff and most importantly failure to attract young and mid-career scientists from overseas and the loss of mid-career scientists to Europe and North America. (sub. 86, p. 7)

A range of different problems associated with the increased reliance on external funding (and reflective of issues to be considered in contracting-out) are also possible. These include an inappropriate focus on short-term research at the expense of medium- and longer-term outcomes; greater emphasis on the needs of large firms at the expense of SME's (due to higher transaction costs); the resource-intensive nature of managing intellectual property; and the potential for cross-subsidisation of contract research from appropriation funding (though CSIRO's submission asserted that this practice had been eliminated by 2004-05).

While CSIRO said it was not appropriate for it to discuss the quantum and nature of specific funding proposals because they were part of the (current) budget process it emphasised that:

> … future funding levels for CSIRO will greatly influence Australia's ability to address successfully many of the major challenges it faces in areas such as water resource management, climate change adaptation, low emission transport fuel security, agricultural sustainability, rising levels of childhood and adult obesity, mineral resource exploration and niche manufacturing. (sub. DR184, p. 9)

The initial submission from CSIRO's staff association (sub. 78, pp. 15-16), on the other hand, focused on the impact of past funding decisions and argued that an 'inadequate increase in government funding' was responsible, among other things, for insufficient scientific research capability (including the ability to respond to emerging challenges) and significant problems with staff satisfaction including issues associated with job security.

Subsequently, the CSIRO staff association (sub. DR176, p. 5) also responded to the statement in the draft report that there had been no hard evidence presented to the Commission on where current capability gaps existed (either within CSIRO or across Australia's public research sector). It noted that the organisation had lost significant capability in the following areas over the last five years: sheep, wool and textiles research; steel and alumina research; wildlife ecology and conservation; soil and landcare research; forestry research; atmospheric research; and taxonomy. It also commented that capability gaps were emerging in: water and natural resource management; energy research, including renewables; and mathematics and information technology.

Accordingly, it called for a substantial increase in CSIRO's public funding to expand its research capability.[14] It also highlighted that the actual costs of delivering research needed to be taken into account in considering the appropriate quantum of funding. A similar issue was raised by CSIRO:

> The cost of science is increasing beyond the usual indexation rates applied by governments. Technological developments themselves lead to more sophisticated and expensive facilities and equipment — and leading edge equipment is necessary not only to do leading edge science but also to maintain the quality and relevance of scientific outputs. (sub. DR184, p. 7)

Against that background, the Commission sees considerable merit in maintaining sufficient block funding so that effective strategic choices can be made by CSIRO. This places a limit on the extent to which the level of appropriation funding can or should be reduced in real terms. As noted above, appropriation funding is already being used to augment competitive funding. This means that more than 40 per cent of the organisation's total funding is subject to competitive influences. Notably, this is around the same proportion as that for higher education institution funding where a stronger relative case for competitive funding may exist given the nature of the of the research in that environment (see chapter 12).

Following the release of the draft report, the Government announced the new funding arrangements to apply to CSIRO over the four years to 2010-11 (Bishop 2007). The funding quantum is equivalent to nominal growth of about 2 per cent per year compared with the previous four year period. Considering CSIRO's statement regarding the rate of growth in the cost of research inputs, the quantum would represent a considerable decline in real terms. This is likely to require meaningful adjustments to the organisation's operating environment in the absence of either supplementary external support (that may limit strategic flexibility) or large productivity improvements.[15] On the other hand, the announcement also represented a move to a longer funding horizon than was previously the case. The greater certainty provided by this change will improve the organisation's ability to plan and develop its research program and is to be welcomed.

14 It also said that CSIRO's public appropriation would need to increase by 6 to 7 per cent per annum for the organisation to sustain its current research capacity. (sub. DR176, p.2)

15 CSIRO itself focused on the latter in saying that 'maintaining the current level of activity would be possible only if two conditions were met: first, that there is slack in the system such that it is possible to capture sufficient efficiencies through improved management and/or the redistribution of the existing level of funds; second, that the improved management and/or reallocation of funding takes place.' (sub. DR184, p. 8)

11.4 Are there any lessons from CSIRO's approach for other parts of Australia's research sector?

CSIRO's current approach to priority setting, performance management and assessment is a distinctive feature of Australia's innovation system. It incorporates both ex-ante and ex-post appraisal processes, combines bottom-up and top-down input to research planning, involves broadly-based consultation with potential users and other stakeholders and actively manages projects against performance benchmarks. It is also relatively transparent in comparison with some other public sector research agencies and the higher education sector (at least in terms of the allocation of block funding by institutions).

In part, the approaches used in different components of the innovation system reflect differences in purpose and function. For example, the focus of much higher education research is on advancing the stock of scientific knowledge where impacts are difficult to measure. Mission-based research organisations, on the other hand, are outcome focused as they primarily aim to solve applied problems. Despite these differences, some participants considered that divergent research management and governance processes and a lack of clarity regarding organisational roles among various components of Australia's research system were resulting in unnecessary duplication and a lack of accountability and transparency. Against that background, CSIRO noted:

> … a number of the changes CSIRO has made to the way it operates would also generate greater benefits in applied more widely across the [National Innovation System]. (sub. 50, p. 18)

As noted earlier, an important feature of CSIRO's priority setting involves taking account of research activity in other parts of the innovation system. Performed properly, this means that CSIRO can avoid duplicating research conducted by other private and public sector research performers. While competition among research organisations can provide strong incentives to improve quality and efficiency there is also a risk that resources may be inefficiently devoted to solving identical problems. Potentially, this could be avoided by adopting similar priority setting processes in those parts of the system where this is feasible. Another advantage of a more consistent approach to project selection is a greater likelihood of undertaking research that would not otherwise be conducted by the private sector.

The most obvious area of adoption would be in applied public research organisations at both federal and state government level with agricultural research being a specific example where the Commission sees a heightened risk of duplication. Past problems in this area were acknowledged by the Department of Agriculture, Fisheries and Forestry which said in its submission:

> Institutionally, difficulties in prioritising, coordinating and collaborating on R&D between different actors in the agrifood innovation system have previously led to duplication in some areas and gaps in others. There are also concerns about the potential for a decline in research provider skills and capacity. (sub. 100, p. 4)

The Department also noted that specific initiatives in train to improve the effectiveness and efficiency of public investment in this area included a review of rural research and development priorities and implementing a national framework to improve national collaboration. In acknowledging these efforts, the Commission considers that there may still be value in applying CSIRO-type decision processes to agricultural research activity more broadly. This is already a feature of the RRDC model (see chapter 10).

Another area of potential adoption is in the applied research work of the industry-oriented Cooperative Research Centres where ex-ante appraisal of impacts are more readily identifiable (see chapter 10). On the other hand, it might not be well suited to basic research in the higher education sector because impacts are more diffuse and applications can take much longer to be realised. But even here there may be opportunities to improve on current arrangements such as those funded through the ARC (see chapter 12). In that context, CSIRO emphasised the importance (broadly) of considering the pathways through which research can have an impact throughout the life of a project:

> One area that the [draft report] might have considered in more detail is that of the need to incorporate 'path to impact' issues into research management processes. It is generally not possible to maximise impact through simple one-off effort at the end of the research. Managing research to achieve impact, whether commercial or otherwise, has to be a continuous process. Significant outcomes are the result of complex interactions involving continuing engagement with diverse players over a long period. Especially with major innovations, this requires engagement to start early in the research process and preferably at the planning stage. (sub. DR184, p. 4)

Similarly, other features of the project management system used by CSIRO appear to offer particular advantages compared with the approaches used in other areas. As noted earlier, research management within CSIRO involves ongoing monitoring against set performance criteria across the organisation's research portfolio. This provides considerable flexibility in allowing the redeployment of resources at various stages throughout the life of a project, should agreed objectives not be met. These features contrast with the processes used in grant-funded higher education research where ongoing project management is largely a matter for the investigator. Accordingly, the ability to change research direction is limited to when a project is completed. That said, the curiosity-driven nature of basic research means that application of an effective forward looking performance management system may be more problematic than in other areas.

However, this appears to be less of an obstacle for CRCs which receive significantly higher levels of public funding (the average was around $20 million for successful partnerships in the latest selection round) than the typical grant awarded to a university researcher. These application-focused entities also operate for much longer time periods (of up to seven years) without, in practice, the same degree of scrutiny regarding the achievement of project objectives as occurs in CSIRO (see chapter 10). It is in this area that the Commission sees the most useful role for adopting elements of CSIRO's performance management system. As discussed in chapter 10, while CRCs are subject to detailed annual reporting requirements and a comprehensive technical review after 3 years of operation, there may be a case for providing financial incentives to encourage CRCs to change research direction if it becomes apparent that research objectives are not being, or will not be, met.

The Commission acknowledges that CSIRO's approach is resource intensive and that, inevitably, there is a tradeoff between improved accountability and administrative burden. It also notes that the compliance and administrative costs faced by CRC applicants (whether successful or not) are already significant. In this context, there was some criticism of the onerous nature of CSIRO's performance management system. The organisation's staff association claimed that the associated increase in administrative expenses had, in the context of an essentially flat appropriation budget, meant there was less scientific capability for the organisation's research agenda. It went further in saying:

> We believe CSIRO may have gone too far in introducing project management bureaucracies following the findings of the Auditor General's Report (No 51, 2002). This has resulted in increased reporting requirements on researchers in both appropriation and externally-funded projects. … There is little analysis to suggest greater productivity and efficiency with the recent adoption of project management bureaucracy, and even less clarity that the organisation is more accountable because of it. More accountability is not always better accountability. (sub. 78, pp. 11–12)

However, the staff association's response to the draft report also acknowledged some of the benefits from these processes:

> CSIRO's priority setting and performance management, although not perfect, affords good accountability to the investment of public research funds … (sub. DR176, p. 3).

Overall, the Commission sees merit in exploring mechanisms of this type to improve the operation of CRCs and other research bodies given the substantial amounts of public funding involved (see chapter 9). And the CSIRO's processes provide a useful guide.

FINDING 11.1

The current real level of public appropriation funding for CSIRO should not be reduced. Aspects of its approach to priority setting and performance management may have wider applicability to other parts of Australia's innovation system.

11.5 Defence Science and Technology Organisation

The Defence Science and Technology Organisation (DSTO) is the principal science and technology advisor to the Australian Defence Organisation. As such, its mission-based research effort is far more concentrated than that of the CSIRO and focuses on 'providing specialist advice to the Government and Defence to ensure the efficient and effective operation of defence and the development of Australia's future defence capability' (sub. DR179, p. 1). Its activities also support national security goals through an involvement in counter-terrorism and defence against chemical and biological threats. Specific functions supporting the organisation's goals include:

- influencing the framing and implementation of defence policy through the use of science and technology;
- providing advice and support to ensure that Australia is an informed buyer of its defence equipment;
- developing new niche capabilities, especially where there are special national demands such as those related to Australia's unique circumstances;
- providing smart user advice and support to existing capabilities in increasing their performance and reducing costs of ownership;
- assisting industry to become better able to support the capabilities needed to defend Australia, and through industry contribute to national wealth creation; and
- strengthening the national security technology base through collaboration nationally and internationally to support Government's broader national and international objectives. (sub. DR179, p. 3)

Australian Government funding is provided though a single block grant from the Department of Defence budget allocation (accounting for 89 per cent of the $384 million of revenue in 2005-06) which is supplemented by external funding derived primarily from cost recoveries for the provision of services to private industry (about 3 per cent) and for work performed for non-Defence Government agencies (around 8 per cent). Commercial arrangements include the licensing of DSTO's intellectual property and contracts for the purchase of technical services.

With respect to intellectual property, the organisation has noted that its philosophy is not to earn revenue, but to provide its IP to industry to enhance defence capabilities (DSTO 2006, p. 8).[16]

A number of characteristics distinguish the DSTO from other public sector research agencies. These include the organisation's integration with the Department of Defence, the direct link between its funding and Australia's defence, and its role as Australia's lead research agency responsible for the science and technology aspects for safeguarding Australia's national security.

Importantly, the organisation does not operate across the whole of the science and technology spectrum, with the organisation generally involved at the conceptual end (Technology Readiness Levels 1 to 4).[17] According to DSTO, this end of the research spectrum is generally 'not serviced or provided for by industry' (sub. DR179, p. 4). In that case, crowding-out of private sector research activity would not be an issue for the bulk of DSTO's research effort.

Industry engagement is primarily focused on developing technologies further along the science and technology spectrum (Technology Readiness Levels 5 and 6). According to the DSTO, one of the principal mechanisms through which this occurs is the Capability and Technology Demonstrator (CTD) Program that acts as a 'capability bridge with industry'. Since its inception in 1997-98, total CTD program funding has been around $140 million with around $26 million of that amount allocated in 2005-06 (sub. DR179, pp. 8-11).

Increasing DSTO's engagement with industry has *previously* been identified as an important government policy objective (Hill 2003). According to a recent organisational review, while the DSTO does have extensive industry linkages — including through technology and skill transfer and international technology links — this was an area that offered scope for significant improvement (Trenberth 2004). It also raises the issue of the most appropriate balance between in-house, co-investment and contracted research.

However, the majority of DSTO's research continues to be conducted internally. It is structured around three groups — Platform and Health Sciences, Information and Weapon Systems and Policy and Programs. In delivering its research outputs, the organisation employed around 2380 scientists, engineers and support personnel in

16 The Commission has been unable to establish the magnitude of the technology transfer involved.

17 The DSTO (sub. DR179, p. 4) noted that Technology Readiness Levels (TRLs) are measured along a scale between one and nine from paper studies of the basic concept (TRL1) through to a technology that has proven itself in actual usage on the intended product (TRL9).

2004-05. External expenditure accounts for just over 10 per cent of DSTO's budget and includes: collaborative projects and liaison with other agencies and government departments; participation in a number of CRCs, Centres of Expertise and research agreements with universities; and scholarships and fellowships provided to students and scientists.

The overall framework that determines DSTO's research activity is based around an assessment of short-term and emerging defence priorities articulated in the Defence Capability Plan 2006–2016 (Australian Government 2006e). In 2005-06, research expenditure was distributed between projects that supported the operations of the Australian Defence Force; the development of Defence capabilities over the next ten years; and research associated with developing enabling science for long term capabilities (comprising 10 per cent of DSTO's internal research effort (sub. DR179, p. 5).

According to DSTO, research priorities are set by a process of negotiation between DSTO and its Defence clients (sub, DR179, p. 1). The criteria used to determine research directions include the importance to national security, contribution to the operational effectiveness of the Australian Defence Force and defence technology trends to determine the appropriate level of funding for each project.

This purchaser-provider arrangement is, therefore, considerably more formal than the funding model employed for the CSIRO vis-à-vis its relationship with the Australian Government. It also implies that any flaws in the decision-making processes of DSTO's principals will affect the quality, nature and magnitude of its research effort. The Commission notes that those processes are outside the scope of this study.

Like CSIRO, the organisation is currently undergoing 'significant reorganisation and renewal' with the redesign of its planning, reporting and management framework that is aimed at improving the match between client requirements and capability and financial and operational accountability (sub. DR179, p. 5).

11.6 DSTO's role

Given Australia's ability to competitively source state-of-the-art defence equipment and proven designs that have been developed by the world's leading providers of defence research — notably the United States and Europe — as well as its privileged access to other areas of defence and security including defence planning, intelligence, science, tactical applications and training (Thomson 2006), this raises some meaningful questions regarding the appropriate nature and size of an indigenous defence R&D capability in Australia.

The case for such a capability has typically been argued on the basis, at least in part, of Australia's unique geographic and strategic circumstances and the sensitive nature of defence issues. For example, a former Chief Defence Scientist recently articulated four broad criteria against which to consider the need for a domestic defence R&D program. These involved situations where:

- Australia has critical needs that are so different from those of other nations that their products do not come sufficiently close to what Australia requires. An example provided was the need to develop a broad-area surveillance network to deal with Australia's strategic geography (the Jindalee over-the-horizon-radar).
- there are sensitive and compelling national security considerations such as where science and technology is applied to security classification (cryptography being an illustration);
- not even Australia's closest allies are prepared to share sensitive information or equipment. An example is the development in Australia of acoustic tiles for the Collins-class submarine designed to reduce the vessels acoustic signature where Australia's allies would not share the relevant technology. The Commission notes in this respect that that particular technology may not have been required had Australia met its submarine needs through a foreign supplier. This raises issues regarding procurement policy and practice (see below).
- a new idea has emerged with potential benefits so compelling that it would be inappropriate not to take it further, with a prominent example being the development of the Australian Mine Sweeping System that is now in service with the navies of several other countries and has earned significant domestic and export sales revenue. (Brabin-Smith 2006)

More broadly, the Australian Government's stated objectives for a domestic defence industry reinforce the need for an indigenous R&D capability. Those objectives were recently enunciated by the Minister for Defence in the following terms:

> We must have a local industry base that can maintain, repair and modify the equipment we purchase from overseas, and design, manufacture and adapt equipment to meet the unique requirements of the ADF. (Nelson 2007, p. i)

Accordingly, the nature and size of DSTO research will depend on decisions regarding the mix of defence equipment spending (both the type and level) sourced either domestically or overseas.[18] As a defence industry analyst recently noted, the choice between local and overseas sourcing will often involve a tradeoff between

18 The Commission notes that during the 1990s the average share of defence equipment spending in Australia increased dramatically to around 60 per cent (more than double the average of the preceding decade). While the domestic share has since declined to around 45 per cent in 2004-05, it remains significant.

the perceived strategic and economic advantages of local purchase against the potentially lower risk and cost of foreign purchase. And in the past, there have been numerous examples of domestic defence projects where cost blowouts, schedule delays and compromises on materiel effectiveness have focused attention on decisions to source locally (Thomson 2006). [19]

The effectiveness of Australia's defence-related research spending needs to be seen in this light. This feature may also be enhanced if:

> Rather than flirting with exotic acquisition strategies or interventions to shape the local defence industry market, the government should simply sort out the strategic capabilities it needs to keep in-country and then use open competition on the global market to equip the ADF for the rest. (Thomson 2006)

11.7 Should DSTO contract-out more research?

While the DSTO contends that its research program is supported by engagement with external agencies, it devotes a relatively minor share of its overall financial resources to such arrangements. These interactions include:

- collaboration with other Australian research agencies, universities, a number of Centres of Expertise, CRCs and industry to broaden Defence's science and technology (S&T) base;
- collaboration with international defence S&T agencies, particularly in the US and UK, which is also an important component of the wider government to government military alliances; and
- partnerships with Australian industry to transition Defence's research into military capability and to contribute to national wealth (DSTO 2004a).

As noted above, external expenditure accounted for just over 10 per cent of the total budget in 2004-05. Although this represents a doubling over the last decade it remains very low by international standards.[20] For example, 75 per cent of the UK defence research budget is spent externally. Similarly, the scientific research arm of the US Air Force contracts around 70 per cent of its budget to external providers. In a more extreme example, the US Defence Advanced Research Projects Agency commits its entire research funding allocation to industry, universities and other research bodies. And Canada's military research laboratory (Defence Research and Development Canada — Suffield) spends around half its research budget externally (Trenberth 2004).

19 The Commission recognises that overseas purchasing has not been problem-free in the past.

20 This doubling in external funding was in fact a stated objective of the DSTO at the time of the Commission's 1995 R&D inquiry.

Arguments cautioning against the use of international experiences to benchmark the level of defence research contracting in Australia have previously been put by the DSTO (IC 1995). They highlighted a number of differences between Australia and other countries that made such comparisons problematic. In particular, they noted that:

- Australia's strategic circumstances and industrial structure differs from that in other countries;
- Australia [was at the time] primarily an importer of defence equipment rather than a designer, developer and manufacturer of that equipment (as are the United States and United Kingdom);
- The size of Australia's defence science budget makes it difficult to contract-out a meaningful amount of research to universities, industry and other research providers and still maintain an intramural defence technology knowledge and hence an impartial advisory capacity to government.

In addition, the Trenberth review of DSTO's external engagement noted that the modest external spending reflected a need to maintain a complete set of skills to service its clients internally; its desire to ensure those skills were not eroded by external spending; and the limited ability of Australian industry to undertake the majority of the type of R&D that DSTO conducts. The review also highlighted the complicating security issue, given the classified nature of much defence-related research. That said, it found there was a case for increasing the proportion of research funded externally (although it did not nominate a target).

In arguing for a greater share of DSTO research to be outsourced to academic institutions, Professor Donald Sinnott (sub. DR168, pp. 1–2) queried the extent to which national security may be compromised by moving away from in-house provision:

> Without detailed inside knowledge, which security considerations would normally preclude, it is difficult for an 'outsider' to challenge such agency judgments. But circumstantial evidence points to the fact that the 'security/confidentiality' flag is all too readily used to ensure research is kept in-house. For example, in other countries defence research, some of it heavily classified, is carried out in many universities to a far greater extent than in Australia. In the US, as the draft research report notes, the Defence Advanced Projects Agency (DARPA) spends all its massive research budget externally. (sub. DR168, p. 2)

The Commission considers that while it may not be appropriate to aim for a similar share of contract research as that in other countries, the value of contestability in providing a discipline on efficiency in resource use and fostering creativity in the development of ideas suggests that more emphasis should be placed on this avenue of defence research provision. That said, it acknowledges that contracting-out will involve higher transaction costs because information about potential providers, assessment of bids, determination of prices and monitoring quality is more resource-intensive than in-house provision. In this context, Professor Donald Sinnott (sub. DR168, p. 2) noted that in his experience the monitoring of contract research involved a 30 per cent overhead compared with in-house provision.[21]

The Commission accepts that the science and technology activities of DSTO require a level of technological sophistication that can limit the scope to increase the level of external engagement. The Commission also notes the recommendation of the recent review of DSTO to create a Defence Science Access Network (DSAN) that would improve external engagement with DSTO's science and technology portfolio (Trenberth 2004). That recommendation is currently being implemented (DSTO 2004b).

Finally, the Commission suggested in the draft report that another option to facilitate greater contestability might be for the Australian Defence Organisation to review the potential for providing a component of research funds directly to the users of DSTO research (the three services, joint commanders, intelligence agencies, the Defence Materiel Organisation and strategic policy and information groups), allowing them to allocate these funds to the DSTO or to contract with other external providers. This could also include academic institutions.

In responding to this proposal, the DSTO commented:

> It is important to note that approximately 10% of the DSTO budget is paid at the discretion of users, frequently using Defence project funds, to support user-defined activities and timescales. In addition, some funds go to other providers (including CSIRO) sometimes directly and sometimes with DSTO participation. Consequently, it should be recognised that DSTO already operates a hybrid funding system with some of its budget coming direct from the portfolio and some from its clients. (sub. DR179, pp. 1–2)

The Commission welcomes this advice, but continues to question whether a higher level of user-driven funding may facilitate a more effective defence research effort.

FINDING 11.2

The effectiveness of DSTO research is dependent on the appropriateness of the procurement practices and the research directions set in consultation with the Australian Defence Organisation.

21 He also commented that on-costs and overheads of research programs in public sector agencies tended to be 'submerged in accounting systems' and this gave the appearance that in-house provision was much less costly than outsourcing to an academic research provider.

Annex box 11.1 **CSIRO performance reporting**

Focussing CSIRO science investment

- Share of CSIRO investment in National Research Priorities
- Assessment of science capability
- Share of CSIRO science budget in Flagships initiative
- Number of Flagship programs operating successfully
- Percentage of Flagship annual performance goals achieved
- Total external revenue for Flagships (including private sector element)
- Major cross – divisional programs operating successfully

Delivering world class science

- Staff Commitment and Engagement
- Number of postgraduate students supervised by CSIRO researchers
- Number of Post-docs with excellent credentials
- External/internal audit findings on project management practice
- Customer Value Survey (CVS) rating on process/people
- Citations of publications (citations per paper — cpp — as measured by ISI)
- Citations of publications (CSIRO's institutional ranking as measure by ISI)
- Citations of patents (as measured by CHI Inc's Patent Impact Index)
- Number of publications (by type)
- Number of publications, excluding client reports, per Research Scientist/Engineer
- Australian positioning on Square Kilometre Array (SKA)
- Initiatives to establish international science facilities

Partnering for community impact

- Partner feedback from collaboration with Unis, CRCs, other agencies
- Partnerships with Unis, CRCs, other agencies focused on clear strategic goals
- Co-location of major new facilities
- Engagement with the federal and state/territory governments
- Partnerships with other agencies to advance Australia's global development contributions
- More focused and effective international effort (number/value/spread of overseas projects)

Serving as a catalyst for industry innovation

- Number of significant commercial relationships with rural RDCs ($10 m threshold)
- Value of commercial relationships with RDCs
- Customer Value Survey results — RDCs (comparative score)
- Number of significant commercial relationships with states/territories ($10m threshold)
- Value of commercial relationships with commonwealth, state and local governments
- Number of significant large corporate relationships ($2m threshold)
- Value of commercial relationships with large companies
- Customer Value Survey results — large companies (comparative score)
- Number of significant relationships with SME growth stars ($0.1m threshold)
- SME investment in CSIRO projects (Value of SMEs engaged with CSIRO)
- Customer Value Survey results — SMEs

Building one-CSIRO capabilities and commitment

- OH&S injury indicators (Lost Time Incident and Medical Treatment Frequency, Average Time Lost)
- External assessment/benchmarking of relevant processes
- External recognition for CSIRO practices
- OHS positive performance indicators (induction, investigation, training, assessment)
- Management of performance (Insight Survey results)
- Proportion of projects completed on time, on brief and on budget
- Number and proportion of projects discontinued under the fast failure approach (by type)
- Working relationship and Work Organisation and Efficiency
- Inter-divisional collaboration in CSIRO-wide support

Securing a financial foundation for growth

- Intellectual property revenue
- Subsidy in consulting service activity
- External revenue and total expenditure (co-investment; consulting and services; exploitation of IP)
- External revenue by source (market segment)
- Overhead and support costs
- Overhead ratio

Source: CSIRO personal communication.

Annex box 11.2 **Indicators used in CSIRO's Science Investment Process**

Relevance

Value from R&D

The intent is to assess how much value the successful completion, adoption and use of R&D might create, taking into account the full range of potential economic, social and environmental benefits. Assessment does not confine itself to Australia or to CSIRO's traditional research activities. It compares what would happen with successful completion, adoption and use of R&D with what would happen with no additional investment in research. Indicators/ data include:

- Industry Community Area (ICA) size (industry/market size, growth, employment, exports)
- Addressable benefit to Australia
- Trends in distribution of CSIRO investment (appropriation and external funding by ICA)
- Distribution of CSIRO ICA spend compared with Australian public and private R&D spend
- Contribution of ICA to the economy, looking at both GDP and environmental risks
- Key environmental challenges relating to each ICA
- Projected GDP growth and historic OECD change in ICA contribution to GDP
- Contribution of ICA to employment and changes in this measure over recent years
- World trade trend
- Resource use by ICA (water and greenhouse gas emissions)
- Trends in greenhouse gas emissions

Whether CSIRO should be engaged and the role it should play

Even if research has the potential to make a major contribution to the development of the ICA, it is still necessary to consider whether there is a role for CSIRO. Assessment considers:

- • CSIRO's mandate
- – Whether CSIRO has any specific responsibilities or restrictions relating to the ICA.
- – Whether government policies or obligations bear upon level or kind of effort in CSIRO.
- • Australia's National Research Priorities
- • CSIRO's role compared with that of other members of the national innovation system
- – Whether the nature of the users or potential users of CSIRO's research results has any implications for the role of public sector R&D generally and CSIRO's role in particular.

Possible data include:

- Australia's total R&D spend for each ICA
- Ratio of public/private expenditure for each ICA
- R&D spend ratio between CSIRO, other PSRAs, higher education, states/territories
- CSIRO spend relative to economic contribution of ICA (eg, value added and employees)
- CSIRO spend compared with each ICA's contribution to GDP
- Australian challenges and opportunities
- Trends in the balance of trade for each ICA

Relevance of R&D

Assesses relative importance of R&D in creating value for each ICA and whether science and technology are key to the development of the area. Assessment considers relevance of R&D to the problems and opportunities presented by the ICA. Possible indicators/data include:

- An industry sector's own investment in R&D.
- Global business expenditure on R&D (BERD) intensity for major countries for each ICA
- Australian BERD trend for each ICA
- Aust R&D intensity: Total $ spent on R&D per $m of value generated
- Aust R&D intensity: Industry $ spent on R&D (BERD) per $m of value generated
- OECD intensity in Business R&D Expenditures as a % of Industry Value Added
- USA R&D Intensity: R&D Expenditures as a % of Industry sales
- Industry innovation focus: Industry action agendas
- Business innovation

(continued next page)

Annex box 11.2 continued

Impact

Likelihood of adoption

Assesses likelihood research users will adopt successful research, develop it if necessary, and put it to use. Requires analysis of state of 'receptor' system for CSIRO's research. Considers:

- Willingness of partners/receivers (eg firms, resource agencies) to adopt or use results.
- Ability of likely partners/receivers to convert successful R&D into commercial or other value.
  - Identification of what will be necessary to realise the benefits from successful R&D. (eg capital investment; distribution networks; marketing skills; changed enterprise processes)
- Identification of what factors would drive adoption of the research results.
  - Whether these driving forces are short-term or long-term?
  - Whether factors (eg community acceptance) are likely to promote or impede uptake.

Possible data include:

- Proportion of external revenue to total expenditure by CSIRO for each ICA
- European Industry Innovation: New products (last two years) % of total sales

R&D productivity/potential

Intent is to assess how much technical progress would result from R&D investment. Purpose is to identify: areas of science and technology that are most productive in enabling new applications or advances in applications; number of highly productive areas for an ICA; and breadth and size of impact across the ICA. Assessment evaluates R&D productivity/potential as global measure independent of particular research group or organisation. Takes account of:

- Scope for technical progress (or technically-based improvement in performance).
  - The larger the scope the higher the R&D productivity/potential for the area.
- Likely cost of achieving this progress.
  - The higher the cost, the lower the R&D productivity/potential for the area.
  - Whether technical progress is likely to be quick or slow (as a proxy for cost)
- Technical progress measured in terms of parameters important for use of R&D in the ICA.
- Assessment considers uniformity and rate of technical progress in core areas of science and technology. This is important as if there is a significant mismatch between progress in one area and in those complementary areas needed to deliver value to end-users then overall rate of technical progress will be viewed by the users of research results as relatively low.

Indicators/data include:

- Global science and technology 'hot spots'
- CSIRO research competitiveness (now and future networks)
- CSIRO's ability to make scientific or technical progress in a timely and competitive way

CSIRO research competitiveness

The intent here is to assess CSIRO's ability to make scientific or technical progress in a timely and competitive way. In conducting this assessment, CSIRO takes into account its existing and potential research collaborators. Factors taken into account include:

- Skills and experience needed and how CSIRO's capability compares with elsewhere.
- CSIRO's track record.
- Whether CSIRO can assemble internationally or nationally competitive research teams.
- Whether necessary infrastructure (equipment, other facilities) is or can be put in place.

Measures of CSIRO's research competitiveness include

- CSIRO citations per paper compared with selected Australian institutions
- Ranking of CSIRO research in areas that are ranked in the Global Top 1%
- CSIRO divisional 'quality' as measured by customer value surveys
- CSIRO divisional Intellectual Property positions

Source: Sub. 50.

12 Funding of higher education research

Key points

- The rationales for dual streams of funding of higher education research are sound.
  - An appropriate balance of block and competitive funding should be maintained. Block funding levels should be sufficient to enable meaningful strategic choices to be made at the individual institutional level. Accordingly, block funding should not be reduced, either in absolute terms, or in relation to Australian Government competitive funding.
- Differing block funding allocation methodologies — for example formula-based approaches and peer review-based approaches — should be evaluated in a cost–benefit framework against relevant criteria.
- There is no clear objective evidence pointing to systemic deficiencies in the quality of research currently funded through the formula-based block grants.
- The Australian Government has announced that it will implement the RQF, and has supported the model recommended by the RQF Development Advisory Group.
  - There is evidence that the RQF will bring costs as well as benefits — UK and NZ experience suggests that the benefits would have to be substantial to offset the significant administrative and compliance costs.
- The continuing detailed development of the RQF should aim to achieve the benefits intended at the minimum possible administrative and compliance cost.
- The first round RQF 2009 evaluation should consider the merits of other, less costly, ways of promoting quality and impact in higher education research.
  - These would include risk minimisation auditing based approaches.
- If the RQF is to continue beyond 2008, then consideration should be given to bringing forward the 2014 round and/or conducting a partial round in the intervening period — this would provide an earlier basis for assessing the effects of the RQF in promoting quality and impact improvement.
- The maximum benefit from the 2008 RQF round could only possibly be obtained if its provisions allow scope for significant change in funding outcomes compared with the existing block funding formulae. Accordingly:
  - safety nets should be minimal; and
  - scales should be set so that there are significant penalties for achieving low quality and impact grades — a linear funding scale could be counterproductive.
- In regard to competitive funding, little, if anything, would be gained through amalgamating the ARC and the NHMRC.

Funding of higher education research accounts for over 40 per cent of total Australian Government financial support for science and innovation. This highlights the importance of such issues as: aligning funding arrangements to different activities such as basic research, applied research, commercialisation, strategic capability building, and risk minimisation; program design, including administrative and gaming issues; and performance evaluation and monitoring.

This chapter does not address funding levels but focuses on the *allocation* of Australian Government higher education research funding and, in particular, on block and competitive funding. (As noted below, higher education research receives substantial support from other funding sources as well.) The term *higher education* in this chapter refers to the university sector. It includes higher education course providers, but excludes such entities as separately constituted medical research institutes.

The chapter does not cover all issues of relevance to higher education in a science and innovation context. Some issues, such as those relating to collaboration and to commercialisation, are covered elsewhere in the report. The Commission has also judged that some issues are beyond the scope of this study. In particular, this report does not cover issues relating to the quality of higher education teaching nor related funding issues, even though the Commission acknowledges that quality higher education teaching is essential to Australia's future. Nor does it consider the merits, or otherwise, of changing funding arrangements so as to encourage greater specialisation by particular institutions in teaching or research. And the chapter is not examining the strengths and weaknesses of peer review processes for existing programs.

The Commission is very aware that conclusions on funding issues necessarily involve considerable judgment (chapter 9), and that even small changes in arrangements can have important financial and operational implications for individual institutions.

12.1 Current funding arrangements

In 2004, higher education research funding totalled some $3.3 billion (table 12.1). This compares with total Australian expenditure on R&D in 2002-03 of some $12.8 billion.

Even though funding from other sources is significant, Australian Government funding accounts for the majority of higher education research funding — nearly 75 per cent in 2004, for instance.

Table 12.1 **Higher education research funding 2004[a]**

Includes funding from government and non-government sources

Category	*Funding ($m)*	*Proportion of total (%)*
Imputed share of Australian Government operating grant for teaching-related research (2004-05)	***587***	***18***
Australian Government Research block grants[b]		
Research Training Scheme	540	16
Institutional Grants Scheme	284	9
Research Infrastructure Block	160	5
Australian Postgraduate Awards	89	3
Regional Protection Scheme	6	..
Total	***1 079***	***33***
Research income		
Australian competitive grants[c]	734	22
Other public sector	300	9
Industry and other[d]	459	14
CRC research income[e]	113	4
Total	***1 606***	***49***
Total	**3 272**	**100**

[a] The latest year for which comprehensive data are available. [b] Excludes the Systemic Infrastructure Initiative and International Postgraduate Research. [c] Includes Australian Government funding of $697 million — ie not all Australian competitive grants are Australian Government funded. [d] Includes other non-government funding including from donations, bequests and foundations as well as international income. [e] Includes Australian Government funding of $74 million.

Source: DEST Higher Education Research Data Collection (from internet) and DEST Science and Innovation in the 2006-07 Budget.

This chapter concentrates on Australian Government block funding ($1079 million in 2004 for the schemes in table 12.1) and Australian Government competitive funding ($697 million in 2004) for (non-teaching related) higher education research. Block funding accounted for about 59 per cent of that combined total in 2006. But there has been a significant decline in the share of block funding in recent years at least, with that share in 2001 being over 70 per cent (albeit in the context of a lower total) — a decline of nearly 12 percentage points over five years.

The share of the operating grant shown above is merely an imputed or notional amount, representing the component of that grant estimated (by DEST) to be applied for teaching related research in aggregate. Separate amounts are not indicated for particular institutions in line with their teaching related research activity — individual institutions can spend more or less. Indeed, to an extent, operating grant monies may be spent on non-teaching related research just as block funding for research could, to a degree, be spent on teaching or on teaching related research. Given its nature, this teaching related research funding is not considered further.

‘Performance based’ block funding

Leaving aside some smaller programs, block funding is provided through a number of ‘performance based’ arrangements — the Research Training Scheme (RTS), the Institutional Grants Scheme (IGS), the Research Infrastructure Block Grants scheme (RIBG) and the Australian Postgraduate Awards scheme (APA) — with funding in 2006 totalling almost $1.1 billion. These arrangements are known as ‘performance based’ because allocations to each institution depends on its past ‘performance’ as assessed by various formulae (administered through DEST) — see box 12.1. In effect, institutions ‘compete’ for this block funding, which they can then allocate according to their own priorities (but see below).

Box 12.1 **Allocation of performance based block grants: criteria and weightings for 2006**

Research Training Scheme (2006 funding of $563 million) A ‘performance index’ is calculated for each relevant institution on the basis of its higher degree by research (HDR) student completions (weighted 50 per cent), its research income (40 per cent) and its research publications (10 per cent). Research income is the total of Australian competitive grants income, other public sector research income, industry and other research income, and CRC research income. Publications comprise books (weighting of 5), book chapters (1), journal articles (1), and conference papers (1). A ‘pre-safety net’ grant is then determined on the basis of the formula: (A x 0.5) + (B – (0.75 x A)) + (C x performance index), where A = the institution’s 2004 grant indexed to 2006 prices, B = the institution’s 2005 grant indexed to 2006 prices, and C = total 2006 RTS pool x 0.25. A safety net applies so that no grant will fall below 95 per cent of the previous year’s grant indexed to current prices.

Institutional Grants Scheme ($296 million) A ‘performance index’ is calculated for each institution on the basis of research income (60 per cent), student load (30 per cent) and publications (10 per cent). Research income and publications are determined as for the RTS above. A pre-safety net amount is then calculated on the basis of available IGS funds and the institution’s performance index. No grant will fall below 95 per cent of the previous year’s grant indexed to current prices.

Research Infrastructure Block Grants ($200 million) The grant is calculated directly on the basis of each institution’s share of Australian competitive grants income over the most recent two years for which data are available.

Australian Postgraduate Awards ($93 million) The grant is based on the number of places allocated to an institution in the current and previous three years. In turn, the number of allocated places is based on research higher degree completions (weighting of 50 per cent), research income (40 per cent) and research publications (10 per cent).

Source: DEST documents (from internet).

The objectives of particular arrangements are as follows.

- Research Training Scheme. Its objective is to strengthen Australia's knowledge base and research capabilities by enhancing the quality and effectiveness of research training environments (DEST 2004c). Funds are allocated to individual higher education providers to support training for students undertaking PhD and Masters Degrees by research (in the form of HECS-exempt scholarships).
- Institutional Grants Scheme. This shares the same underlying aim as the RTS. But, in contrast to that scheme, higher education providers have the discretion to use IGS funding for any activity related to research.
- Research Infrastructure Block Grants Scheme. This is allocated to higher education providers to enhance the development and maintenance of project-based research infrastructure. Institutions have discretion to distribute it as they see fit.
- Australian Postgraduate Awards. Their objective is to assist students of exceptional potential undertaking a higher degree by research with general living costs. Institutions are, in effect, awarded a number of APA places and the associated funding.

Some information about how higher education institutions allocate their block funding is provided in section 12.5.

The methodologies associated with the block grants shown in box 12.1 act to allocate funding continuously, rather than discretely — that is, a marginal change in an institution's 'score' would result in a marginal change in its funding. Further, the extent of change from one year to the next in the proportionate distribution of funding to individual institutions from each of the schemes is affected by a number of factors, such as previous years' funding, income and activity, and the operation of safety nets. Nevertheless, significant change — up or down — can arise from one year to the next in the funding levels allocated to particular institutions.

'Competitive' funding

In terms of Australian Government funding, the two main sources of 'competitive' funding are the ARC and the NHMRC, which both allocate funding at the project and sub-institution level. The ARC funds research in all fields except clinical medicine and dentistry, with specific funding for medical research administered by the NHMRC. Funding levels have increased significantly over the past few years (table 12.2), but with considerable variability from year to year.

Table 12.2 **ARC and NHMRC funding**

	ARC[a]		*NHMRC research grants*[b]	
Year	Funding	Annual increase	Funding	Annual increase
	$m	%	$m	%
1997-98			164.3	
1998-99			177.1	7.8
1999-00			173.6	-2.0
2000-01	247.8		183.3	5.6
2001-02	265.8	7.3	243.0	32.6
2002-03	298.3	12.2	209.4	-13.8
2003-04	399.6	34.0	332.4	58.7
2004-05	480.9	20.3	369.4	11.1
2005-06 (estimate)	546.2	13.6	403.5	9.2
2006-07 (budget estimate)	570.3	4.4	437.6	8.5

a Provided under different arrangements prior to establishment of the ARC as a statutory body. **b** Excludes separate programs and infrastructure funding.

Source: Australian Government (2006d).

ARC

The ARC is an independent statutory agency established under the Australian Research Council Act 2001. Its day-to-day operations are now under the control of the CEO appointed by and reporting to the Minister for Education, Science and Training. The ARC Board was abolished in July 2006 in line with the recommendations of the Uhrig Report to improve governance arrangements. However, according to the ARC — many of the following details are taken from its submission, sub. 73 — the Minister has indicated an intention to appoint an advisory council to provide advice to the CEO.

Responsibility and role

The ARC administers the National Competitive Grants Program under which funding is made available for research conducted in universities and other eligible organisations across all fields outside of clinical medicine and dentistry. The vast majority of its funding is directed towards research conducted in universities. The main streams of funding are:

- *Discovery* – for investigator initiated research and research fellowships; and
- *Linkage* – which supports collaborative research projects, infrastructure, and fellowships undertaken with partner organisations in the private sector and government. A component of this stream also provides funding for several

centres of excellence in research priority areas. Such funding can be valuable in contributing to the utilisation and commercialisation of research outputs.

Ministerial direction

The Minister receives the ARC's recommendations on funding and must approve each proposal before it is funded. In 2003, the ARC targeted over a third of annual funding to four areas of research priority: nano-materials and biomaterials; genome/phenome research; complex intelligent systems; and photon science and technology, following a direction from the Minister (sub. 73, p. 28).

Level of funding

The ARC's estimated program budget for 2006-07 is $551.8 million. Of this, $315.3 million or 57 per cent is for Discovery programs and the remaining $236.5 million is for Linkage programs. The previous year's program budget, 2005-06, was similar, $552 million, and an increase on 2004-05's budget of $481 million. (Note that this information revises that shown in table 12.2.)

For grants commencing in 2005, the average Discovery grant was around $258 000 and the average Linkage grant was around $246 000. Discovery grants and Linkage projects are funded from one to five years (ANAO 2006). In 2005, the ARC's advisory committees recommended a smaller number of proposals for funding to increase the average grant size.

The ARC's operating costs for 2005-06 are estimated at about $15 million, equivalent to about 2.7 per cent of its program costs (ANAO 2006, p. 33). (Of course, to the extent that services are provided to the ARC either gratis or below cost, this figure understates the full administrative cost.)

Success rates

In 2005, there were 3414 applications for Discovery grants and over 1500 applications for Linkage project funding (ANAO 2006 and sub. 73). Fewer than one in four proposals submitted for Discovery projects and just over one in three Linkage proposals were successful (that is, received some funding, not necessarily at the level requested) in 2005.

Up and coming researchers

There are no specific ARC programs for ‘up and coming’ researchers. However, the ARC states that ‘fostering the careers of Australia’s best and brightest researchers is one of [its] key objectives’ (see ARC website). For example, under Discovery-Projects, the ARC identifies targeted funding for early career researchers applying individually or in teams in which all investigators are early career researchers.

How it works

Both the Discovery and Linkage grants operate on an annual cycle that commences with the announcement of the funding rules for applicant eligibility. This is followed by calls for applications, the assignment of applications to assessors, assessment of applications, meetings of college of experts/selection advisory panels, recommendations made to Minister and concludes with the announcement of the funding results by the Minister (ANAO 2006).

Eligibility

The ARC Act sets out that only applications that meet the requirements set out in the approved funding rules are to be recommended to the Minister. For example, Discovery project funding rules for projects commencing in 2006 set out that the researcher cannot hold more than two Discovery project grants, may not be named as a Partner Investigator on more than four Discovery grant projects and that the project must be submitted by an eligible organisation.

In the case of Linkage projects, applications can only be submitted by eligible organisations, which according to the ARC funding rules for Linkage projects are all Australian universities. As partner organisations, the commercial organisations of universities, CRCs, public research agencies, State and Territory Government research agencies or any organisations the ARC considers to be substantially funded for research by the Australian Government are specifically excluded (ARC Funding Rules for Linkage Programs commencing in 2007).

Assessment

Once received by the ARC, Discovery Project applications are provided to two College of Expert members, two Australian readers (assessors) and up to four international readers (international assessors). Australian readers receive a nominal payment of $30 per application and international readers receive no payment for assessing applications. Australian readers completed around 90 per cent of applications sent to them and the response rate of international readers ranged from 20 to 40 per cent (ANAO 2006).

These assessors use the following section criteria for Discovery projects:

- Investigator (40 per cent);
  - track record relative to opportunities; and
  - capacity to undertake the proposed research;
- Project content (60 per cent) made up of:
  - significance and innovation (30 per cent);
  - approach (20 per cent); and
  - national benefit (10 per cent).

The selection criteria for all Linkage projects are:

- Investigator(s)
  - Track record (20 per cent)
- Proposed project content
  - Significance and innovation (25 per cent)
  - Approach and training (20 per cent)
  - National benefit (10 per cent)
  - Commitments from partner organisation (25 per cent).

The assessments of Linkage project proposals are undertaken by members of the College of Experts.

Following assessment, recommendations for both Discovery and Linkage grants are submitted to the Minister for approval.

There is an appeal process for administrative matters only. The ratings and comments of assessors are not appealable.

NHMRC

The NHMRC is an independent statutory agency established under the National Health and Medical Research Council Act 1992. In response to the ANAO review of governance structures in 2004 and the Investment Review of Health and Medical Research in the same year, changes were made to the legislation in June 2006 to alter the governance arrangements. Prior to July 2006, the NHMRC was a statutory body corporate run by the Council. The CEO is now responsible for all the day-to-day operations and is appointed by and reports to the Minister for Health and Ageing. The role of the Council of the NHMRC, which previously was responsible for governance of the NHMRC, is to assist the CEO in implementing the NHMRC's strategic plan and provide independent advice on scientific and technical issues (see sub. 80 and Parliament of Australia Bills Digest NHMRC Amendment Bill 2006). The CEO makes recommendations to the Minister about research funding.

The bulk of NHMRC funding goes to the higher education sector (72 per cent of funding in 2005), but funding also goes to medical research institutes (25 per cent of funding in 2005), and hospitals and other government and non-government research organisations (3 per cent).

Responsibility and role

The NHMRC's role is to:

- raise the standard of individual and public health throughout Australia;
- foster the development of consistent health standards between the various States and Territories;
- foster medical research and training and public health research and training throughout Australia ; and
- foster consideration of ethical issues relating to health.

It also has statutory obligations regarding the research surrounding human embryos and the prohibition on human cloning.

It provides funding under three categories — researcher support, infrastructure support and research support.

Researcher support includes:

- *Training Fellowships* to allow researchers to undertake research that is of major importance in its field and of benefit to Australian health.
- *Career Awards* to provide support for experienced researchers to undertake research that is both of major importance in its field and of benefit to Australian health.
- *Career Development Awards* to build health research skills, increase knowledge and encourage the growth of knowledge-based industries in Australia.
- *Scholarships* to support Australian health and medical graduates early in their career.

Infrastructure support includes:

- *Enabling Grants* to provide support for specific facilities and/or activities to enhance the national health and medical research effort.
- *Equipment Grants* and *Infrastructure Grants* to provide funding for specific equipment and overhead infrastructure.

Research Support includes:

- *Project Grants* to enable individual researchers or a group of researchers to undertake a scientific investigation in the biomedical, clinical, public health or health services field.
- *Program Grants* support teams of researchers to pursue broadly based collaborative research activities.
- *Strategic awards* provide a mechanism by which the NHMRC can respond to opportunities for pursuing innovative projects and national and international collaborations research.

The NHMRC has a number of other award schemes for specific health issues, including:

- palliative care;
- potential avian influenza-induced pandemic;
- preventive healthcare and strengthening social and economic fabric; and
- type I diabetes.

Ministerial direction

The Minister can provide only general direction to the CEO and is 'not entitled to recommend the allocation of research funds to a particular person, organisation, State or Territory'. The Minister is also not entitled to direct the NHMRC's treatment of a particular scientific, technical or ethical issue. Any general Ministerial direction to the NHMRC is to be tabled in each house of Parliament within 15 sitting days.

Level of funding

The NHMRC's estimated expenditure for 2006-07 is around $450 million. Estimated expenditure in the previous year, 2005-06, was about $432 million and actual expenditure was around $420 million in 2004-05 (see sub. 80, pp. 8–9). In the 2006 Budget, the Government announced an additional $905 million for health and medical research to be spent over the next four to nine years. This includes

$170 million over nine years for a new Australian Health and Medical Research Fellowship scheme (sub. 80, pp. 7–8).

By broad research area, in 2005-06, nearly half (49 per cent) of the NHMRC funding was directed to basic science, 28 per cent to clinical medicine and science and 13 per cent to public health. About 5 per cent was directed to health services research and preventative medicine and science and 5 per cent was not allocated (see sub. 80, p. 7).

Of the grants awarded in 2005 and to commence in 2006, 65 per cent went to research support, 24 per cent for researcher support and 11 per cent for infrastructure support (NHMRC 2005a).

Total administrative expenses incurred by the NHMRC (including program and committee support) amounted to some $22 million in 2004-05, equivalent to about 5.6 per cent of research payments made in that year. As with the ARC, this proportion would understate the true amount to the extent that services are provided to it free or below cost.

Success rates

The ‘success’ rates for the NHMRC programs vary. The following rates are for 2003.

Researcher support:

- Research Fellowships — 119 applications were received, of which 46 (38 per cent) were successful. By comparison, in 2002, 123 applications were received, of which 24 (19 per cent) were successful (that is, received some funding, not necessarily at the level applied for).
- Career Development Awards — 148 applications were received, of which 39 (26 per cent) were successful. By comparison, in 2002, 135 applications were received, of which 39 (29 per cent) were successful.
- Training Awards — there were 308 applications for Scholarships, with 159 awarded (51 per cent), and 307 applications for Training Fellowships with 91 awarded (30 per cent). By comparison, in 2002, there were 299 applications for Scholarships with 154 awarded (51 per cent) and 173 applications for Training Fellowships with 82 awarded (47 per cent).

Research support:

- Project Grants — there were 1798 applications for Project Grant funding, of which 407 (22 per cent) were successful.

- Program Grants — there were 27 applications for Program Grant funding, of which 11 (40 per cent) were successful (NHMRC website).

Are up and coming researches provided for?

The NHMRC provides Career Development Awards specifically for researchers in the early stage of their careers and a range of Post-Graduate Scholarships. In 2005, 50 Career Development Awards were granted worth a total of nearly $22 million and there were 155 Post-Graduate Scholarships awarded worth just over $9 million (NHMRC 2005a).

How it works

The NHMRC funding arrangements have been established on a triennial basis, with the current arrangements in place from 2003 to 2006. The applications for grants for the infrastructure support (enabling grants and infrastructure grants), research support (program and project grants) and researcher support (fellowships, scholarships etc.) are processed in an annual cycle with the funding made available in the following year.

Eligibility

NHMRC research funding is open to most researchers in Australia. Applicants must apply through an NHMRC Administering Institution. University registration as an Administering Institution is automatic. Most other institutions are able to 'self-certify' that they meet specific criteria required by the NHMRC to be accepted as an Administering Institution.

The criteria largely relate to the administration and acquittance of Australian Government funds, and having documented procedures in place relating to such matters as ethics clearances, the proper conduct of research and being able to provide appropriate infrastructure support (NHMRC website).

Assessment

Each year the NHMRC establishes panels which are responsible for the review and ranking of NHMRC grant applications. The panel members also have the opportunity to provide advice to the NHMRC on emerging research developments.

Panel members are experts of high standing drawn from the Australian and international research community, from public and private health and medical research organisations, higher education and industry.

The assessment process usually takes around 6 months. From submission of the application, the peer review process can be broadly summarised as follows:

- allocation of each application to a Grant Review Panel (GRP) and to appropriate spokespersons within that panel;
- the spokespersons write a report on the application which is provided to all panel members;
- the GRP meet to review and determine a category for each application and then rank each application in comparison with all others allocated to the GRP;
- the primary spokesperson writes a final report on the application which is sent to the applicant;
- the outcomes of the GRP meetings are considered by the NHMRC and a funding recommendation sent to the Minister for Health and Ageing; and
- subsequent to Ministerial approval, applicants are advised of the outcome of their applications.

The current funding schemes will cease after the 2006 application round and the number of existing schemes will be reduced so as to provide efficiency gains in both peer review and the time researchers are required to devote to preparing applications for different schemes. The initial calls for applications under the new schemes will be in 2007, for funding commencing in 2008. The details of the new schemes are yet to be finalised (NHMRC web site).

12.2 Rationales for separate funding streams

The rationale for Australia's current dual stream funding arrangements was spelled out in the 1999 Knowledge and Innovation policy statement by the Government as follows:

> … a dual system of funding for higher education research [would] both … encourage institutions to be more flexible and responsive in developing a strategic portfolio of research activities and research training programmes, and … secure the benefits to be derived from the endeavours and achievements of individual researchers and teams. (Kemp 1999, p. 9)

Further:

> We need to strike an appropriate balance in research funding among national needs, institutional capacities and individual interests. In doing this, the Government is establishing a dual funding system of competitive research grants for individuals and their teams, awarded on merit, and block funding to institutions to give them flexibility to adapt to new opportunities and to set their own priorities. (Kemp 1999, p. 14)

Such dual funding 'should be competitive in nature, as simple as possible to administer, and be readily intelligible to researchers, institutions, students and the wider community' (Kemp 1999, p. 7).

DEST considered that:

> One advantage of the dual support system is that it offers governments a range of levers to influence the direction and performance of publicly-funded research and research training. Importantly, a dual support system also supports diversity and system robustness, by allowing a focus on national priorities linked to economic and social aspirations, or a focus on research excellence, to be balanced with the ability to support and maintain strategic research capabilities over the long-term, or develop emerging research areas, irrespective of the availability of competitive funding. (sub. 87, p. 24)

And the ARC commented that the dual funding model:

> … provides for both competitive funding and block funding, and so provides incentives for excellence in higher education research as well as scope for higher education institutions to develop particular research strengths and specialties. (sub. 73, p. 24)

Using similar rationales, the UK Government has described such a dual funding system in that country as a 'key strength' which has helped to deliver 'the UK's world class standing in research outputs':

> The logic behind the dual support system is that it provides two distinct, but related sources of income for university research. The Research Councils [similar to Australia's ARC arrangement] … are able to take a national strategic view, ensuring excellence through peer review, and balancing directive and responsive support. By contrast, [QR] funding [similar to Australia's block funding] allows universities to take strategic decisions about their research activities; builds capacity to undertake 'blue skies' research and research not supported from other sources; creates flexibility to react quickly to emerging priorities and new fields of enquiry; and provides a base from which to compete for research funding from other sources. (HM Treasury 2006, p. 29)

Indeed, many countries utilise both block funding and competitive funding arrangements for higher education research, although comparisons of their reliance on each stream are difficult to make.

In the Commission's view, the rationales expressed by then Minister Kemp are sound. Block and competitive funding each have a number of advantages. For example, block funding allows institutions to specialise and develop strategic capability, can have lower transactions costs in project funding allocation, allows easier identification of outstanding and developing talent, makes it easier for resources to be pooled across projects and institutions and makes funding readjustment and reallocation more flexible. Competitive funding, on the other hand, can contribute more readily to the achievement of national priorities, and can place greater emphasis on excellence and impact.

Thus, in principle, continuation of dual funding arrangements in Australia would appear appropriate subject to the caveats that:

- both streams remain contestable;
- an appropriate balance between the two is maintained;
- allocative criteria minimise gaming possibilities; and
- additional administrative costs, if any, are kept to reasonable levels.

In regard to administrative costs, funding allocation mechanisms can range in complexity from the relatively simple and cheap (such as formula-based approaches, or approaches based on tacit knowledge) to the relatively complex and expensive (such as extensive formal peer review). In principle, an *additional* layer of ‘complexity’ arises in the case of block funding, in that funds are first allocated to institutions, before allocation to researchers and research groups can be determined. As discussed below, however, in practice, depending on the methodologies adopted, the total costs of allocating block funding may well be less than those for allocating competitive funding.

12.3 The balance of funding

While there are sound rationales for dual funding, in practice the existing block funding appears to provide individual universities with only limited flexibility and discretion.

First, the internal allocation processes of the higher education institutions appear to direct much of their block funding to the departments which generate competitive funding. As advised by DEST (pers. comm.):

> Based on reports in the 2005 RRTMRs [Research and Research Training Management Reports], the majority of HEPs [higher education providers] follow the broad pattern of reserving a proportion of funds centrally – for infrastructure, capacity building projects, internal competitive schemes, scholarships and awards – and award the remainder to the faculties or departments who ‘earned’ it. DEST states that its research data collection (which records publications and research income) is not intended for use by HEPs as the basis for their own internal funding allocation. Usually the allocation to faculties/departments is done on the **basis of similar indicators that DEST uses to allocate the block grants**, although at a greater level of disaggregation, and often with greater emphasis on certain indicators over others. (emphasis added)

Further, the allocation to individual institutions of block funding significantly relies on research income — which is determined primarily on a competitive project basis. Indeed, the distribution of one particular block funding component to each university, the RIBG, is directly proportional to its Australian competitive grants income; with even its total quantum set by reference to competitive grants funding (sub. 87, p. 26).

Second, the competitive grants schemes effectively lock up a significant proportion of each university's block funds. ARC grants (in aggregate) totalled only 34 per cent of the cost of relevant sponsored research commencing in 2002, with universities contributing 47 per cent, industry 11 per cent and other sources 8 per cent (ARC 2002). Thus, in effect, over 35 per cent of block funding in that year would have been used to support ARC funding[1]. Although the NHMRC scales back grants to a lesser extent than the ARC, a further component of block funding would similarly have been used to augment funding from the NHMRC. The Group of Eight commented that:

> Institutions that succeed in winning competitive grants through the ARC, NHMRC and other schemes must find funding from other sources to match or 'leverage' the funding available under the competitive schemes. In 2003-04 this cost supplementation was estimated at $450 million for the whole sector … (sub. 68, p. 10)

Similarly, DEST noted that:

> Much of the block grant funding is actually being used to underpin the important research being undertaken with support from competitive schemes. (sub. 87, p. 26)

This imposed leveraging could be considered to reflect inadequate funding through the competitive stream and limits significantly the discretionary nature of block funding.

To the extent that the distribution of block funding within institutions correlates with competitive funding and that institutions must allocate block funds to augment competitive funding, a case could be made to discontinue the relevant block funding components and include those funds in the competitive stream. In turn, this would reduce the rationale for implementing an RQF, at least for higher education institutions.

An alternative approach — with greater merit given the rationale for block funding — would be for competitive funding to support fewer projects more fully, thus limiting its draw on block funding. This would then maximise flexibility at the institutional level and, of course, add to the case for more rigorous block funding allocation arrangements.

One participant pointed to the added costs associated with multiple funding sources, but none argued solely in support of block funding or competitive funding. Several,

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[1] Calculated as ((47/34)*265)/1012 per cent, with $265 million and $1012 million being ARC and block funding, respectively, for 2001-02.

however, argued in favour of the importance of block funding and, in some cases, for increases in allocations to it (box 12.2).

Box 12.2 Views on block vs. competitive funding

One of the key purposes of RIBG and IGS is to allow HEPs to build capacity in areas of emerging or strategic strength, rather than in those areas that already have a track record of excellence or support from other sources. There are concerns in the sector that leveraging funds may limit capacity-building in this regard. (DEST, sub. 87, p. 27)

… the direct costs of research are (inadequately) funded by research grants but the funding of researchers' salaries (eg through fellowships) and the indirect costs of the research program (eg through research infrastructure block grants) are funded by completely different schemes so that consistent and full funding of research is difficult to achieve. A business would not run its R&D program this way! (Association of Australian Medical Research Institutes, sub. 41, p. 7)

The AVCC welcomed the increase in funding provided in Backing Australia's Ability I and II. However, these reports allocate increases in funding to competitive funding schemes and each assumes an effective university research base and adds additional demands to this base. There has been virtually no increase in direct public investment in universities' core research capacity … (Australian Vice-Chancellors' Committee, sub. 60, p. 9)

The ATN would strongly oppose any model of allocation that would focus research funding narrowly, given the need to build and grow a broad research and innovation base. (Australian Technology Network, sub. 34, p. 8)

The IRU Australia strongly recommends that a major component of public support for science and innovation in Australia recognise the long term nature of basic research by allowing certainty and stability in the allocation of research block grants to research active universities. (Innovative Research Universities Australia, sub. 54, p. 2)

… increase the base level of research funding provided to institutions, recognising that we need to encourage a modest level of curiosity-driven research to allow new ideas to develop to the stage where larger peer review research funding mechanisms can work to provide further support. (Professor James Trevelyan, sub. 3, p. 5)

… the balance between competitive and base-line research support funding needs to be re-examined in order to encourage universities to offer structured career paths for young, dedicated researchers and attempt to make working at Australian public universities in this capacity, an attractive proposition. (National Tertiary Education Union, sub. 62, pp. 27–8)

As discussed above, the Commission supports the rationale for continuing with dual funding streams for funding higher education research in Australia — but within this framework there must be sufficient block funding so that meaningful strategic choices can be made at an institutional level.

FINDING 12.1

Reductions in block funding levels would further limit the flexibility and discretion of higher education institutions to make meaningful strategic choices. Consequently, Australian Government block funding should not be reduced, either in absolute terms, or in relation to Australian Government competitive funding.

The remaining sections of this chapter discuss funding allocation methodologies in more detail.

12.4 The proposed Research Quality Framework

Background

Current arrangements for Australian Government support for higher education research funding stem from 2000. Prior to that, block funding was essentially allocated in one bucket as a separately identified part of the operating grant, using a formula-based approach.

A 2003 review of these arrangements — the Fell review (DEST 2004c) — concentrated on block funding, essentially recommending little change. It considered that the balance between performance based block funding and competitive funding (ARC/NHMRC) should be retained (rec. 5, DEST 2004c, p. 53) — largely on the basis that universities generally opposed a change and that such block funding was already of a 'competitive nature' (DEST 2004c, p. 53).

As well, that review considered that it was important to enhance the quality of research outputs, and proposed that discussions continue about how 'best to undertake cost-effective research quality assessment' (rec. 6, DEST 2004c, p. 53). These comments were made in the context that such improved assessment mechanisms should apply to 'additional research support funding' (rec. 7, DEST 2004c, p. 53).

An Expert Advisory Group subsequently expressed the view that there are deficiencies in the current formula-based approach to block funding allocation and considered that a method based on peer review would be preferable:

> Currently there is no system-wide and expert-based way to measure the quality and impact of research conducted in universities and PFRAs and its benefits to research and the wider community. For example, the existing distribution of university research block funding is based on inadequate proxy measures of quality, eg numbers of publications, external research income and student completions. Clearly these quantity-

> based measures do not satisfactorily assess the quality of research undertaken in the university sector. The EAG believes that the only assessment process which will enjoy the confidence and consent of the research community is one based on expert review. (RQF 2005, p. 11)

DEST considered that:

> … [the existing] indicators appear comprehensive and have the advantage of being reasonably easy to collect. The major disadvantage … however, is that while they incorporate some element of quality, there are actually quite coarse. There is no way to measure gradations of quality, or to compare actual quality across HEPs and across disciplines. (sub. 87, p. 25)

Stemming from that group's report, work has been proceeding towards developing a Research Quality Framework (RQF) for Australia, to be used in the allocation of (block) funding to universities and public sector research agencies. The overall objective of the RQF, as defined in the EAG's final advice to the Government:

> … is to develop a broad assessment mechanism of research quality and impact that will be relevant across the full breadth of research organisations in receipt of public funding. The RQF will recognise and reward high quality and high impact research wherever and whenever it occurs. (RQF 2005, p. 11)

In effect, the RQF would be used to assess the aggregate research performance of an institution over a *past* specified period of time in terms of both output *quality* and outcome *impact* — the latter broadly defined as 'the extent to which research is successfully applied … to achieve social, cultural, economic and/or environmental outcomes' (RQF 2005, p. 12). The assessments would be based on summary 'scores' at the Research Grouping level, rather than on Research Grouping profiles. Such assessments would then be used in making decisions about *future* funding allocations to the institution. Box 12.3 provides a brief summary of the main features as proposed by the Expert Advisory Group.

In providing its final advice to the Government in December 2005, the Expert Advisory Group recommended that the RQF be implemented in 2007. It envisaged that, initially, one hundred per cent of IGS funding and a minimum of fifty per cent of RTS funding would be allocated on the basis of the RQF. But the advice recognised that a number of 'threshold questions' need to be resolved including taking the size of an institution into account and allowing for variations in the volume and cost of research.

In response, in the 2006 budget the Government announced $3 million in funding to allow:

> … further development of the model and the next phase of the process. The recently appointed RQF Development Advisory Group will advise the Government on how the

RQF model, if adopted by the Government, could be most effectively implemented. (Bishop 2006b)

Box 12.3 Features of the RQF proposed by the Expert Advisory Group

- Institutions to nominate Research Groupings that can be aggregated to Research Fields, Courses and Disciplines (RFCD) Codes, subject to adherence to RQF Guidelines as developed by the RQFIG [RQF Implementation Group];
- Assessment of both the quality of original research outputs and associated impact, within the assessment period for the RQF;
- An expert review-based assessment process overseen by the RQFIG;
- A Research Grouping to provide an Evidence Portfolio (EP), comprising of:
  - A Context Statement detailing the type, composition and focus of the Research Grouping;
  - The 4 'best' outputs of each of the eligible researchers;
  - The full list of Research Outputs produced in the 6 year production period; and
  - Statements of early impact, verified by qualified end-users of research.
- 12 Expert Assessment Panels to develop their own discipline-specific guidelines (consistent with overarching RQF Guidelines) and assess EPs of nominated Research Groupings;
- Panels able to flexibly expand membership and have access to Specialist Assessor Groups to make assessments, as required, particularly for cross-discipline and/or emerging research areas;
- Panels moderated by an RQF Moderation Panel;
- Independent validation of a statistically-significant sample of panel assessments to ensure RQF ratings are appropriately benchmarked both nationally and internationally, coordinated by the RQF Moderation Panel;
- Assessment of quality and impact to be primarily based on the same 'best' four Research Outputs per eligible researcher for each Research Grouping over a six-year period;
- Quality to be assessed against a 5-point scale and impact against a 3-point scale;
- Reporting of RQF ratings of quality and impact by Research Groupings, and discipline areas (including profiles of ratings at either 6, 4 or 2-digit RFCD level) for each institution; and
- Funding distributed to institutions based on quality and impact ratings through an appropriate mechanism.

Source: RQF 2005, pp. 7–8.

Developments since the release of the Commission's draft report

On 14 November 2006, the Minister for Education, Science and Training announced that:

- the Australian Government will implement a RQF;
- the model recommended by the Development Advisory Group 'has received support from the Australian Government'; and
- preparatory work and trialling will continue in 2007, with data collection in 2008 and funding implementation in 2009 (Bishop 2006e).

Subsequently, in December 2006, the Government announced some $87 million in financial support for the implementation of the first cycle of the RQF (Bishop 2006f). Of this, about $42 million will be provided to universities.

It is understood that the RQF will apply initially to 50 per cent of RTS funding and 100 per cent of IGS funding, as proposed by the EAG.

The model recommended by the Development Advisory Group differs in some important respects to that proposed by the EAG in its final advice (box 12.4). Of particular note are the proposed use of metrics; the adoption of a five point, rather than three point, scale for impact; and the possible inclusion for impact assessment of research undertaken up to 12 years before the end of the assessment period.

Even though some progress has been made in fleshing out the RQF, some important matters appear to remain unresolved including: detailed assessment procedures; moderation procedures; information management systems; estimates of administrative and compliance costs; and the linkages of RQF assessments into funding outcomes. Further, although the Development Advisory Group has suggested several funding principles which it considers should apply — see box 12.5 — these leave open a wide range of different funding arrangements in practice.

Participants' views about the RQF

Given its current relevance as a policy issue, it is not surprising that a number of participants commented on the proposed RQF. Many of the views outlined in this section were expressed in the context of the EAG's advice, but are still of relevance in the context of the Development Advisory Group's advice and the Government's decision to adopt the RQF.

Box 12.4 **Revised methodology for the RQF**

The Development Advisory Group has made revisions to the *Preferred RQF Model* of the EAG in several areas.

- *Research Groups:* will form the unit of assessment for the RQF and will define the focus of their research activities by 4-digit Research Fields, Courses and Disciplines (RFCD) codes and appropriate key word descriptors.
- *Attribution:* the research outputs and body of work listed by an academic during the six-year assessment period will be attributed to the institution at which the researcher is employed at the time of the Staff Census Date (31 March 2007), not at the time of production/publication of the outputs.
- *Quality assessment augmented by metrics:* the peer review assessment process will be assisted by the inclusion of relevant and appropriate quantitative measures of research quality which will be applied to a Research Group's 'body of work' (that is, the four best outputs per researcher and the full list of research outputs for the Group). These measures may be a combination of generic and panel-specific measures to be determined by the Assessment Panels and communicated to the sector through the RQF Guidelines.
- *Five-point assessment scale for both quality and impact:* the RQF will produce separate assessment and reporting for Quality and Impact, against a five-point rating scale for each.
- *Accommodating longer-term impact:* work judged for impact must achieve a threshold quality rating of 2. Impact may be related to original research conducted in the preceding six years provided the research can be shown to have a direct relationship with the research being assessed for quality.
- *An additional Assessment Panel* has been created to better cater for the professional disciplines.

Source: DEST 2006g, p. 17.

No participant explicitly argued against the RQF, although the Australian Academy of Technological Sciences and Engineering expressed 'doubts about the value of such an approach' (sub. 27, p. 13). The Australian Vice-Chancellors' Committee was non-committal, one way or the other. The Business Council of Australia considered the additional costs associated with the RQF will be outweighed by the benefits (sub. DR204, p. 7). Many participants offered in-principle support, but raised a number of concerns nevertheless. A prime concern was that funding under the IGS and RTS schemes should be increased if the RQF were to go ahead. Another major issue centred on the proposed assessment of impacts (box 12.6).

Box 12.5 Funding principles suggested by the Development Advisory Group

The Development Advisory Group has agreed to the following principles to determine funding from RQF outcomes:

1. Funding will be allocated using a relative funding model similar to that of the current research block grants, but based on assessed Research Groups rather than at the level of the total Institution.
2. RQF quality and impact ratings for Research Groups will be separately aggregated to the institutional level for RQF funding purposes.
3. In order to reward high quality and impact research, funding will be distributed with higher weighting for higher RQF ratings in a linear fashion (with the precise gradient to be determined).
4. Research groups rated below “2” for quality will not contribute to an institution’s RQF quality funding.
5. Research groups rated below “D” for impact will not contribute to an institution’s RQF impact funding.
6. Funding will take into account the cost of the research assessed, possibly based on either [the UK’s] RAE or [NZ’s] PBRF discipline weightings.
7. Funding will take into account the volume of an institution’s research, as measured by its staff FTE assessed for the RQF.
8. Institutions will retain discretion over the internal allocation of RQF-driven IGS and RTS block funding.

Source: DEST 2006g, p. 25.

The UK’s RAE

It is relevant to note, in the context of considering the relative merits of alternative funding allocation mechanisms (see below), that the United Kingdom has signalled major modifications to its RAE (research assessment exercise) process for assessing block funding based on research quality assessment, which has operated for some 20 years — the reasons are briefly summarised in box 12.7. The UK Minister for Higher Education has expressed the view that:

> … all our combined brainpower must surely be able to find a more efficient way of assessing research quality than convening the 82 separate committees that will feature in RAE 2008. (Rammell 2006)

Box 12.6 A selection of views on the proposed RQF

Assessment of quality and impact

… the RQF criteria of quality and impact are not the only criteria for assessing research, and in some cases are not the most important. (Deakin University, sub. 15, p, 2)

… the allocation of a single ranking based on aggregate scores for 'Quality' and 'Impact' … is confusing, as these different measures protect interests which are of varying relative importance for different kinds of research. 'Quality' protects the integrity of the process of investigation and knowledge formulation, recognising that this may have unforeseen consequences significant in time. 'Impact' recognises the need for some kind of return on science investment within a finite time frame. (Australasian Institute of Mining and Metallurgy, sub. 71, p. 6)

Application to the humanities and social science

… very little macro and micro economic benefit analysis has been performed of the contributions of the humanities and creative arts to national innovation. This … is due to the difficulty of measuring the impact of humanities research in such terms. (Australian Academy of the Humanities, sub. 64, p. 7)

… citation rates should be used with care for all disciplines and especially for many professional disciplines and those focused particularly upon improving the social and economic fabric of Australian society. (CHASS, sub. 52, pp. 12–13)

Peer review is shown … to be essential but conservative in that it favours silo disciplinary review; and thus needs to be supplemented to embrace the challenges of really significant cross-sectoral activity. (CHASS, sub. DR171, p. 8)

Importance of impact assessment

… [the RQF] will focus on research excellence, which will not catch all the important research outcomes. (Deakin University, sub. 15, p. 2)

… [the] lack of incentives for private sector engagement with universities … could become more of a problem with the introduction of the RQF, if quality is seen as more important than impact. (Australian Vice-Chancellors' Committee, sub. 60, p. 37)

If implemented without an impact measure, the RQF will reduce the attractiveness of the CRC program … Full implementation of the RQF may lead Australia to return to its 1980s position of generating a higher than expected volume of knowledge, as measured through historic methods, but having a lower than expected commercialisation output and attendant lack of patents, spin-offs and licensing revenues. (Desert Knowledge Cooperative Research Centre, sub. 29, pp. 7, 8)

… the system must consider impact separate from, and equal to (for the purposes of funding distribution), measures of academic quality. This Academy is most concerned that the importance of impact has been substantially downgraded in the RQF preferred model. (Australian Academy of Technological Sciences and Engineering, sub. 27, p. 13)

(continued next page)

Box 12.6 **(continued)**

Workload for assessors/quality of assessment

> … RQF assessments will be of limited value. Because of the pressure on assessors they will be drawn to processes that offer a quick result … (Deakin University, sub. 15, p. 1)
>
> The ARC … is concerned that the operation of the RQF, and in particular the demands it will place on assessment capability in 2008, may adversely affect the availability of assessors and hence the quality of the assessments which the ARC will be able to undertake itself in that year. It is clear that the assessment task associated with the RQF, however configured, will be substantial and will, in any event, divert research resources from research to assessment in 2008. (ARC, sub. DR167, p. 12)

Six year time affects incentives

> Using a 6-year historical survey … as an instrument to determine any proportion of 'infrastructure support or block funding' could inadvertently result in a loss of momentum … (Australian Technology Network, sub. 34, p. 4)

Unintended consequences; negative incentive effects

> … we are concerned that universities will perceive that they are best able to achieve high RQF ratings and secure funding through separating the teaching and research responsibilities of academic staff. This could result in the creation of teaching only or teaching intensive positions, and undermine universities general research capacity and capability. (National Tertiary Education Union, sub. 62, p. 19)
>
> The IRU Australia strongly cautions against Australia adopting a [RQF] that results in the same unintended consequences of the British RAE on the viability of … [science departments through] a non-linear funding formula … (Innovative Research Universities Australia, sub. 54, p. 8)
>
> The concern of the South Australian Government is that any framework developed to assess research quality will create an environment that will reward universities for existing research strength and stifle the ability to create innovation in new and emerging areas of research. (South Australian Government, sub. 92, p. 8)
>
> … the effect of offering very high salaries to attract a few stars [to boost RQF ratings] could have major distorting impacts on university budgets, and importantly have adverse consequences for the career prospects of post doctoral fellows and junior academic staff. The short term benefits may be outweighed by the longer term costs. (Australian and New Zealand Association for the Advance of Science, sub. DR123, p. 2)
>
> … the RQF may have adverse consequences on the long term sustainability of institutions. It would appear that the RQF might encourage institutions to sacrifice a number of less senior staff positions for a few high calibre researchers. (Tasmanian Department of Economic Development, sub. DR181, p. 1)
>
> … two-thirds of the total number of institutions funded by the NHMRC are non-university organisations … Since these … may not be directed affected by the RQF, the NHMRC will be monitoring whether or not implementation of the RQF creates any disparity. (NHMRC, sub. DR165, p. 10)

Box 12.7 **Research quality assessment in the United Kingdom**

In the UK, the RAE (research assessment exercise) has been used to inform quality-related (QR) research funding for higher education institutions (HEIs) — that is, block funding to institutions based on assessed quality. The next RAE round is scheduled for 2008. As well, funding derives through the Research Councils on a competitive basis at a program and project level.

The proposed Australian RQF could serve a similar role in relation to block funding as does the RAE. A difference to the RAE is that Australia's proposed RQF would explicitly assess outcomes impacts as well as research quality.

It is commonly believed that the RAE has had a positive effect on research quality. For example, HM Treasury 2006 p. 30 states that: 'Over the years since the RAE was introduced, research quality has risen significantly, as the RAE has acted as a driver of competition, focusing institutions on delivering high quality outputs' (but see below and the text).

Nevertheless the UK, after 20 years experience with the RAE in its various manifestations, has announced that greater reliance is to be placed on metrics-based approaches.

The cited reasons for reducing reliance on comprehensive expert review relate to administrative cost, behavioural impacts on the HEIs, deficiencies in detailed peer review procedures, and inability to properly deal with user-focused research. More particularly, a 2003 review of the RAE highlighted:

- the substantial administrative costs of the system (estimated to cost the higher education institutions at least £45 million in 2008);
- difficulties in assessing the less research intensive institutions;
- gaming by institutions in relation to staff recruitment and determining 'active' research staff and publishing to maximise scores; and
- the silo driven approach which has failed to capture the value of interdisciplinary research.

Source: Draws from HM Treasury 2006, RAE Review 2003, DFES 2006.

The United Kingdom is likely to make greater use of metrics-based approaches — in effect, reducing reliance on comprehensive expert review. In broad concept, the RAE can be considered a somewhat *less* ambitious undertaking than Australia's proposed RQF, which has been designed to consider impacts explicitly, as well as research quality.

New Zealand's Performance-Based Research Fund

In New Zealand, new funding arrangements for the Performance-Based Research Fund (PBRF) — block funding allocated directly to tertiary education institutions — are being phased in between 2004 and 2007. The fund has three components: a periodic Quality Evaluation using expert panels to assess research quality based on material contained in evidence portfolios; a measure for research degree completions; and a measure for external research income. In the funding formula, the three components are weighted 60/25/15 respectively. The previous arrangement was based on student enrolments.

The initial Quality Evaluation was conducted during 2003. Of the 45 eligible institutions, 22 participated. A partial round is being conducted during 2006, with the next full round scheduled for 2012. The 2006 round is partial in the sense that updated evidence portfolios will not be required in many cases, with the relevant 2003 assessment being confirmed for 2006. In some cases, however, updated portfolios will be required and in others they will be optional.

In the context of the Commission's present study, of particular note in regard to the New Zealand system is the level of administrative and compliance costs associated with the implementation of the PBRF. It is estimated that the total administrative and compliance costs of implementing the PBRF in 2003 and conducting the 2003 Quality Evaluation is likely to have ranged between $14 and $21 million (NZ) dollars or between 14 per cent and 21 per cent of the total PBRF funding for the period 2004-2006 allocated by the 2003 Quality Evaluation (Centre for Research 2004, p. 78). Of course, that percentage will fall as the funding levels allocated through the PBRF and the time period for which any Quality Evaluation round is applied increase.

12.5 Alternative block funding approaches

Different block funding approaches — for example, formula-based approaches and peer review based approaches — should be evaluated in a cost–benefit framework against relevant criteria. A number of issues are relevant in such an evaluation:

- the appropriate degree of linkage between quality and impact assessment and future funding;
- the extent to which future funding should be in effect a reward for past performance (track record) as opposed to expectations of future performance;
- which methods best assess past performance;
- which methods best offer incentives for enhanced future performance;

- which administrative approaches are best; and
- which perform best against criteria such as the following:
  - appropriate 'neutrality' across disciplines;
  - minimisation of administrative and compliance costs;
  - minimisation of opportunities for gaming and manipulation;
  - independence of assessment; and
  - transparency of assessment.

In terms of such criteria, formula-based and peer review approaches have a number of general strengths and weaknesses. Possible relative advantages of a formula-based system include: objectivity; ease of application at an institutional level; lower administrative and compliance costs; and greater transparency. Possible advantages of peer review include: possibly better assessment of quality and impact (at least at a project level); assessment of 'marginal' rather than 'average' projects; and possible application ex ante and ex post. These issues are explored below.

The existing formula-based approach

The existing approach to allocating block funding is formula-based and backwards looking but nevertheless provides incentives to continue to improve performance, as that will itself influence subsequent rounds of funding. It draws on proxy indicators of the quality and impact of higher education research at an institutional level, albeit indicators considered inadequate by some. Further refinement of formulae could be advantageous, for example to better account for the different potential research income capacities and publication rates of different disciplines and sub-disciplines. Similarly, if there was concern that the existing publication indicators bias research quality downwards, greater weighting could be given to publications in higher 'quality' journals. Even so, an arguable case can be made that, in the absence of objective information to the contrary (see below), the present system already adequately promotes good quality outputs and worthwhile outcomes from higher education research funded through the block system.

This conclusion would be stronger if it could be demonstrated that the universities themselves have robust and effective methods of allocating and monitoring the use of that block funding within their institutions, or that external oversight currently addresses poor performance. In that case, it could be argued that any 'errors' in initial funding distribution to institutions will matter less. Such assurance could come in one of two forms:

- direct assessment of research quality and, where relevant, impact; and/or

- demonstration of appropriate and effective allocation and monitoring procedures, together with effective procedures to address any identified deficiencies.

Direct information about the quality and impact of research funded through block grants is not available. Indeed, DEST commented [pers. comm.] that in regard to research quality and impact, 'it is not useful or possible to consider the block grants and competitive funding in isolation from each other'. Nevertheless, DEST also commented that the use of the quantity of research publications in the funding formulae for the RTS and the IGS:

> … has led to significant changes to the behaviour of researchers in the higher education sector, with the key outcome of encouraging the research community to publish their research wherever possible. Concurrent with these increases in activity is evidence that publication activity has not been coupled with an increase in the *quality* of Australia's publication output. (sub. DR205, p. 10)

However, the data on which this statement is based (DEST 2003c, pp. 56–73) is subject to considerable interpretation. And even if it is accepted as correct, it does not provide conclusive evidence of poor funding methodology, but merely that some adjustment of existing formulae might enhance results (also see section 4.7).

Further, as noted above, a significant proportion of block funding currently goes to support competitive funding. To the extent that this is the case, it could be assumed that the *quality* of block funded research (in particular, research to which block funding contributes) is somewhat correlated with peer reviewed research funded competitively[2]. As noted by the ARC, 'decisions made by the ARC and other competitive grant funding bodies will affect the distribution of funding for research and research training in ways that will tend to reinforce the selection criteria applied by those agencies' (sub. 73, p. 27).

These considerations, however, do not mean that all block funded research is of satisfactory quality nor that overall improvement might not be made through a reallocation of block funding among institutions.

Some procedural information is available through the RRTMRs but, to the Commission's knowledge, there is no published comprehensive evaluation of the adequacy of university procedures for promoting the quality of block funded research.

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2 It could be expected that the quality of projects put forward for ARC funding by the universities would be somewhat better than 'average' as the object is to attract external funding. Therefore, to the extent that they exist, average quality differences between ARC/NHMRC funded projects and those funded from block funds shed little light on the relative merits of peer review and formula-based funding mechanisms.

In regard to a procedural approach, a comparison can be drawn with arrangements for monitoring/ensuring higher education teaching quality. Funding for that is of the order of some $3 billion annually — nearly three times the block funding total. In this case external quality assurance derives from a program of auditing by the Australian Universities Quality Agency (AUQA — see box 12.8) of the self-accreditation that is undertaken by the institutions themselves, rather than from an extensive and detailed program of direct quality and impact assessment.

Box 12.8 **The role of the Australian Universities Quality Agency (AUQA)**

- The AUQA is an independent national agency that promotes, audits, and reports on quality assurance in Australian higher education.
- It has four main objects:
  – Arrange and manage a system of periodic audits — with a current cycle of about five years — of QA arrangements relating to the activities of Australian universities, other self-accrediting institutions (SAIs) and state and territory higher education accreditation bodies.
  – Monitor, review, analyse and provide public reports on QA arrangements in SAIs, and on processes and procedures of state and territory accreditation authorities, and on the impact of those processes on the quality of programs.
  – Report on the criteria for the accreditation of new universities and non-university higher education courses.
  – Report on the relative standards of the Australian higher education system and its QA processes, including their international standing.
- The indicative scope of the AUQA's work includes: organisational leadership and planning; teaching and learning; courses; research and consultancies; internationalisation; staff and staff support; student and academic support; and administrative support, facilities and resources.
- AUQA pays attention to such things as:
  – planning documents, including strategic plans, QAIPs [Quality Assurance and Improvement Plans] and RRTMRs;
  – the rigor and effectiveness of performance monitoring against institutional plans;
  – systematic, internally-initiated reviews, including the rigor and effectiveness of the review mechanisms used;
  – course and program approval and monitoring;
  – research activities and outputs;
  – overseas operations and partnerships, including consideration of quality comparability; and
  – relationships with stakeholders.

Source: AUQA (2004).

The proposed RQF

Although the Australian Government has announced acceptance of the Development Advisory Group's RQF model, it is currently not possible to weigh up the possible advantages and disadvantages of replacing existing block funding arrangements with funding approaches based on the proposed RQF. Many details are still to be finalised and its links into funding remain uncertain. As well, information is lacking about such important aspects as administrative and compliance costs, although the size of the financial support programs announced in December 2006 give some indication (see above).

Indeed, it may be that the tradeoffs between alternative assessment and funding methodologies can only be effectively evaluated in the light of the experience of the first RQF round — that is, in the evaluation proposed for 2009. Even then, some answers will need to rely on informed judgment, rather than on detailed quantitative assessment (see below).

But some relevant observations can be made at this early stage. As a process based on comprehensive peer review, the RQF is likely to be a better indicator of institutional quality than the current block funding formula proxies. (This leaves aside the fact that, as discussed above, a degree of peer review information about quality is already available through the processes of the ARC and the NHMRC and the linkages between block and competitive funding.) Similarly, direct assessment may well give a better indication of impact than the current indirect proxies. Further, it could be argued that adoption of the RQF could inherently promote better research quality and impact through a range of positive incentive effects — almost independently of its detail. And there could be spin-off benefits in terms of providing greater information about quality and impact to research managers and through institutional repositories.

But whether such better comprehensive indicators in fact materialise, whether their translation into funding formulae will better promote continuing improvement in quality and impact than the existing block funding arrangements, and what will be the balance between benefits and costs, including positive and negative incentive effects, depends on a range of factors.

- The robustness of quality measures will depend critically on assessment and weighting methodology — including, for example, the availability and skills of peer reviewers, and the extent to which any metrics used continue the deficiencies that are present in the current formulae (see section 4.7). Sound assessment of impact will also depend on similar factors as well as the time period over which impact is assessed.

– Suitable testing and trialling will be crucial to good outcomes, as the fine tuning of methodology ('fixing mistakes') will be possible, in effect, only every 6 years.

– It appears that some funding could be based on impacts gained up to 18 years previously — that is up to 12 years before the end of the relevant period for influencing funding for the subsequent six years. Such long time lags could have negative and unforeseen consequences.

- How quality and impact measures are incorporated into funding formulae will be crucial. Judgment will be required about the relative weights to give to those measures, as well as to student numbers, cost structures, size of institution, and the nature and extent of any safety nets to apply.

– 'Wrong' decisions here could negatively affect incentives for quality and impact improvement.

- Positive incentives might be offset to some extent by negative downsides. For example, any widespread escalation in academic salaries, due to competition between institutions for high quality researchers to be engaged at or during the relevant census dates or periods, could adversely affect the volume of research which can be undertaken. And, as noted by the ARC, the RQF could place pressure on the peer review process itself, with adverse impacts on the ARC, as well as diverting effort from research towards peer review activities (see box 12.6).

- Most importantly, experience in the United Kingdom and New Zealand shows that such assessment exercises bring significant additional administrative and compliance costs.

– Unless controlled, these could easily outweigh any benefits arising from better assessment of quality and impact.

– Thus, the continuing detailed development of the RQF should aim to achieve the benefits intended at the minimum possible administrative and compliance cost.

The draft report's suggestions

In the draft report, the Commission suggested that the arguments for discontinuing the existing formula-based approach to the allocation of block funding in favour of an RQF approach could not be fully tested.

It proposed that consideration should be given to delaying the adoption of the RQF further, while undertaking the following investigations and analyses:

- continue with limited trials based on RQF peer-review principles, but focus them on providing indicators of the quality and impact of research dependent on block funding;
- systematically examine whether current procedures within institutions are sufficiently rigorous to promote quality and impact of block-funded research;
- examine what fine tuning of existing formulae, if any, might be advantageous in promoting incentives for continuing enhancement of quality and impact of research funded through block funding; and
- examine the merits of externally applied, risk-minimisation approaches to enhancing the quality and impact of block-funded research (applied in conjunction with formula-based funding).

Under the last proposed approach an external auditor, for example, might identify areas of deficiency in institutions, which would encourage them to improve their performance over the period ahead. Failure to do so would result in significant funding penalties. Institutions operating satisfactorily would be subject to less frequent assessment than those with problems. Such a process would appear to have strong advantages over the proposed RQF in terms of both incentive effects and administrative costs.

This process would be somewhat like that currently used by the existing AUQA in relation to auditing the quality of teaching. (As box 12.8 notes, the AUQA already has some role in relation to research.) But it could extend beyond a paper based assessment of procedural documentation, to processes of selective peer review, for example.

In making that proposal, the Commission was not making any inference that the AUQA would, or would not, be an appropriate body to undertake such a role, nor any judgment about the quality of teaching in higher education institutions, nor the processes used by those institutions themselves and the AUQA in monitoring and enhancing teaching quality. The Commission commented that, prima facie, if a risk management auditing approach to ensuring $3 billion annually of teaching expenditure is satisfactory (at least in principle), then serious investigation should be given as to why it would not be satisfactory in regard to $1.1 billion (or less) annually of research block funding.

The Commission suggested that such an investigative process would deliver information about: quality of research currently funded through block grants; administrative, compliance and efficiency costs likely to be associated with full implementation of the RQF or a similar methodology; whether existing formulae can be improved; and the merits of alternative risk based auditing approaches. At that stage, a more fully informed decision about the RQF could then be made.

There was some support for these suggestions from participants in response to the draft report. However, perhaps because of the Government's announcement of ongoing support for the RQF subsequent to the release of the draft report, there was very little substantive comment.

Conclusions

Although the Government has now supported a RQF along the lines recommended by the Development Advisory Group, the Commission remains concerned that the costs of the RQF may well exceed the benefits.

In the Commission's view, the opportunity now lost should be taken up during the first round RQF evaluation proposed for 2009. Thus, that evaluation should not just focus on fine tuning, but should consider the merits of other, possible less costly, ways of promoting quality and impact in higher education research. This should include consideration of risk minimisation auditing based approaches.

A fundamental problem will be that, under the present arrangements, reliable measures of change in quality and impact will not be observable until after the second RQF round planned for 2014. Therefore, if the RQF is to continue past 2008, consideration should be given to the feasibility of either: bringing forward the 2014 round to an earlier year; and/or conducting a partial round in the intervening period. This would provide an earlier basis for assessment of the effects of the RQF and the associated funding formulae on quality and impact.

A second problem is that assessment systems themselves can provide incentives which inherently make comparison of 'real' quality and impact changes over time difficult. This has been noted in the United Kingdom (see box 12.9) which, as a result, is changing the basis of its assessment system for 2008 from summary scores — as will be used in the RQF — to profiles. But, of course, such a change, together with the accompanying necessary changes to funding formulae, will further complicate comparison of change over time. If the RQF is to continue beyond 2008 therefore, unless significant deficiencies become apparent, it would be desirable to leave the major features of the proposed RQF in place at least until the conclusion of its second run.

Similar considerations apply to the question of whether the 2008 round should be merely a 'trial' or whether it should have financial consequences. Southern Cross University argued 'that funding not be tied to the RQF in the first instance to give time for the RQF to be tested' (sub. DR108, p. 2). But given the level of administrative and compliance costs likely to be involved in applying the RQF, it is important, in the Commission's view, that the 2008 round be 'live'. Otherwise considerable expense will have been met for little result and evaluation of the net benefits or costs of the RQF would be delayed possibly until after the third RQF round.

Box 12.9 **Gaming and bracket creep in the United Kingdom**

A review of research assessment issued for consultation in May 2003 made the following remarks in relation to the RAE's grading system:

> '… in recent years, doubts have begun to be expressed about the grading system. Concerns include the following:
>
> a. the consequences of gaining or losing a grade are so great that institutions are obliged to 'play games' in order to ensure that they fall the right side of the grade boundary
>
> b. it is extremely difficult to ensure that grades are comparable across subject areas, especially subject areas between which there is little overlap
>
> c. there is a risk that the grade improvement seen in 2001 may create an expectation of improvement from one exercise to the next, which might itself drive grade inflation
>
> d. grades attempt to capture the absolute performance of departments, although funding must of necessity be dependent on relative performance. …'

Source: RAE Review 2003, p. 10.

Southern Cross University also argued that 'if funding is tied to the RQF, then … appropriate caps and floors to prevent rapid shifts in funding between institutions in the early years [should be introduced]' (sub. DR108, p. 2). But the Group of Eight considered that 'the use of caps to limit the distribution of research funding … would appear to be at odds with the objectives of the [RQF]' (sub. DR158, p. 6). In the Commission's view, the high administrative and compliance costs likely to be consequent on the RQF could only possibly be justified if its provisions allow *scope* for significant change in funding outcomes compared with the existing block formulae. (Allowing scope for significant change does not necessarily mean that significant change will in fact eventuate — this depends not only on the particular RQF funding formulae adopted but also on how well, or how poorly, existing funding formulae differentiate gradations of average institutional quality and impact.) This means that:

- safety nets should be minimal; and
- scales should be set so that there are significant funding penalties for achieving low quality and impact grades. (In this regard, the Development Advisory Group's preference for a linear funding scale could be counterproductive.)

Despite these conclusions, it is obviously important that the lessons learnt from the 2007 trials be fed back into the 2008 assessment procedures. It is also vital that the detailed RQF funding formulae should be finalised and published during 2007 so that institutions can best prepare for those assessments.

FINDING 12.2

The costs of implementing the RQF may well exceed the benefits. The following steps would help to increase benefits relative to costs:

- *The continuing detailed development of the 2008 RQF round should aim to minimise administrative, compliance and incentive costs wherever possible.*
- *The provisions of the 2008 RQF round should allow scope for significant change in funding outcomes compared with the existing block funding formulae. Accordingly:*
  - *safety nets should be minimal; and*
  - *scales should be set so that there are significant penalties for achieving low quality and impact grades — a linear funding scale could be counterproductive.*
- *The first round RQF evaluation proposed for 2009 should not just focus on fine tuning, but should consider the merits of other, possibly less costly, ways of promoting quality and impact in higher education research.*
  - *These would include auditing approaches that uncover those areas with the highest risk of poor performance.*
- *If the RQF continues beyond 2008, then consideration should be given to bringing forward the 2014 round and/or conducting a partial round in the intervening period — this would provide an earlier basis for assessment of the effects of the RQF in promoting quality and impact improvement.*

12.6 Allocating competitive funds

Some participants considered there are a number of deficiencies in existing peer review arrangements (box 12.10). As noted in the introduction, however, the Commission is not examining the strengths and weaknesses of peer review processes for existing programs.

Leaving aside the issue of whether existing competitive funding arrangements can be improved, there is no feasible alternative to expert review or peer review methodology for allocating competitive funds to projects and at the sub-institutional level. Thus, the central issue in allocating Australian Government competitive funding hinges on how many separate programs to establish and, in particular, the advantages and disadvantages of continuing with both the ARC and the NHMRC.

Box 12.10 Comments on ARC and NHMRC assessment processes

Anyone with experience of, for example, assessment processes of the Australian Research Council since work on the RQF began will know that judgments will be strongly influenced by the source of funding for the work including whether there was significant funding through schemes on the Australian Competitive Grants Register. (Deakin University, sub. 15, p. 2)

… concern with the apparent current move to non-external peer review by the National Health and Medical Research Council (NHMRC). Without external influence as part of the review process, peer review runs the danger of being dominated by conservatism — backing the established investigator, rather than the emerging and less well known investigator, and threatening the growth of innovation … (Australian Technology Network, sub. 34, p. 9)

When funding is limited, the efforts to use it ‘effectively’ multiply. Typically this sees the development of a peer review system dominated by senior experts. Such approaches tend towards decisions favouring high quality but conservative research. The decision processes of the Australian Research Council illustrate this approach well. (Deakin University, sub. 15, pp. 2–3)

[it has been contended that] under the ARC system one has to apply for funding on the basis of research that has already been completed. Only then does one have the publication record and detailed arguments to explain why the research was necessary in the first place and to establish the required track record needed to win a grant. (Professor James Trevelyan, sub. 3, p. 4)

Almost all arguments *against* amalgamation of these two agencies can be readily refuted:

- the two current separate sources of funding — DEST and Health and Ageing — could be easily pooled:
- even if assessment of medical research proposals, or basic vs. applied research, requires different procedures (for example, in regard to ethics issues), there is no convincing reason why this could not be successfully undertaken under the ultimate jurisdiction of the one agency;
- the higher workload of a combined agency is no argument against combination, given the delegated committee-based approaches to assessment used by both agencies currently;
- similarly, there is no clear argument why a combined agency would not be as competent to distribute funds beyond the higher education sector, as the NHMRC is at present;
- the medical educative and other functions of the NHMRC could easily be split off, say to Health and Ageing itself; and

- if there were concern that a combined agency would downplay medical research, the Minister could issue directions (as has been already done in relation to the ARC).

But what, if anything, are the deficiencies with the present arrangements?

- There may be some small saving in administrative overheads if the two agencies are combined.
- Similarly, to the extent that a small number of applicants currently apply for funding from both the ARC and the NHMRC, there might be some transaction and compliance savings from combination.
- Potentially, the most serious deficiency is the inability under present arrangements to trade off the merits of medical and non-medical research projects, at the margin. To the extent that it is not constrained by ministerial direction, the ARC currently has that ability in relation to tradeoffs across the non-medical disciplines. However, any gain in this regard from combination would be limited by the possibility that funding for medical research would be quarantined, even in a combined arrangement.

The Commission has concluded that, in the absence of clear evidence of significant deficiencies in present arrangements, there would be little, if any, gain from combining the ARC and the NHMRC.

APPENDIXES

A Participation

A.1 Discussions and presentations

Both before and after the release of the draft report, Commissioners and staff met informally with and/or made presentations to the following individuals, organisations and interest groups.

Alcatel Australia

Australian Academy of Science

Australian Biotechnology Conference

Australian Centre for International Agricultural Research

Australian Chamber of Commerce and Industry

Australian Graduate School of Management Innovation Policy Panel

Australian Institute for Commercialisation

Australian Institute of Nuclear Science and Engineering

Australian Nuclear Science and Technology Organisation

Australian Research Council

Australian Society for Medical Research

Australian Technology Network of Universities

Australian Vice-Chancellors' Committee

Australian Wine Research Institute

Baker Heart Research Institute

Barlow, Dr Thomas

Brisbane Technology Park

Business Council of Australia

CSL

Commonwealth State and Territory Advisory Council on Innovation

Cooperative Research Centres Association

CSIRO

Dairy Australia

Defence Science and Technology Organisation

Department of Education, Science and Training
Department of Industry, Tourism and Resources
Department of Treasury
Federation of Australian Science and Technology Societies
Foster, Dr Richard N (by phone)
GlaxoSmithKline Australia
Grape and Wine Research and Development Corporation
Group of Eight
Houghton, Professor John and Colin Steele
Howard Partners
Innovative Research Universities Australia
Insight Economics
IP Australia
Melbourne Institute of Applied Economic and Social Research
National Health and Medical Research Council
National Tertiary Education Union
New South Wales Government
New Zealand High Commission
Orica
Pilat, Dirk (OECD)
Rural Research and Development Corporations
South Australian Government
South Australian Research and Development Institute
Uniquest
University of South Australia
Victorian Government

A.2 Roundtable participants

Two roundtable consultations were held to receive feedback on the draft report. Each was chaired by Commissioner Mike Woods, Commissioner Steven Kates and Assistant Commissioner Ralph Lattimore. Attendance was as follows.

Tuesday, 28 November 2006

Association of Australian Medical Research Institutes

Australian Academy of Science

Australian Research Council

Australian Technology Network of Universities

Australian Vice-Chancellors' Committee

Barlow, Dr Thomas

Council of Rural Research and Development Corporations Chairs

CSIRO

Department of Education, Science and Training

Department of Health and Ageing

Federation of Australian Science and Technology Societies

Group of Eight

Innovative Research Universities Australia

Insight Economics

Matthews, Dr Mark

National Health and Medical Research Council

National Tertiary Education Union

Prime Minister's Science, Engineering and Innovation Council

TGR Biosciences

Wednesday, 29 November 2006

AusBiotech

Australian Bureau of Agricultural and Resource Economics

Australian Business Foundation

Australian Industry Group

Australian Institute for Commercialisation

Biota Holdings

Business, Industry, and Higher Education Collaboration Council

CRC Association and Group of CRCs

CSL

Department of Agriculture, Fisheries and Forestry

Department of Communications, Information Technology and the Arts

Department of Education, Science and Training

Department of Industry, Tourism and Resources

Industry Research and Development Board

IP Australia

Uniquest

A.3 List of submissions

DR denotes submission received after finalisation of the draft report.

In addition to the submissions listed below, the Commission received about 90 almost identical short letters, generally marked ‘private and confidential’, expressing concern about the possible changes to the business R&D tax concession arrangements considered in the Commission’s draft report. These letters were similar in form to public submission DR201 from Basell Australia.

Participant	*Submission number*
ARC Centre for Excellence for Creative Industries	20
Association of Australian Medical Research Institutes	41, DR162
AusBiotech	95, DR175
Australasian CRC for Interaction Design	69
Australasian Institute of Mining and Metallurgy	71
Australia Council for the Arts	75
Australian Academy of Science	24, DR113
Australian Academy of Technological Sciences and Engineering	27, DR169
Australian Academy of the Humanities	64, DR192
Australian and New Zealand Association for the Advancement of Science	DR123
Australian and New Zealand Association for the Advancement of Science (NSW Division)	DR189
Australian Biosecurity Cooperative Research Centre for Emerging Infectious Disease	37
Australian Business Foundation	72, DR170
Australian Centre for International Agricultural Research	81
Australian Electrical and Electronic Manufacturers’ Association	51, DR151
Australian Industry and Defence Network	DR152

Participant	*Submission number*
Australian Industry Group	DR121
Australian Institute for Commercialisation	4, 6, 28, DR133, DR136
Australian Institute of Marine Science	61
Australian Mathematical Society	DR125
Australian Marine Sciences Association	35
Australian Petroleum Production and Exploration Association	DR130
Australian Publishers Association	DR141
Australian Research Council	73, DR167
Australian Society for Medical Research	36
Australian Technology Network	34, DR153
Australian Vice-Chancellors' Committee	60, DR148
Baker Heart Research Institute	40
Basell Australia	DR201
Bio21 Australia	DR122
Biomed Central	DR124
Biota Holdings	94, DR187
Bougias, Mr George and Dr Anand Kulkarni	59
Brainwave	DR145
Bushfire CRC	DR166
Business Council of Australia	58, DR204
Business Outlook and Evaluation	90
Business, Industry, and Higher Education Collaboration Council	55
CAMBIA	42
Chief Scientist of Australia	DR200
Chifley Business School	DR120
Cochlear	DR131
Cole, Emeritus Professor Trevor	DR115
Committee for Melbourne	DR137
Commonwealth State and Territory Advisory Council on Innovation	98
Community and Public Sector Union	39
Composite Group	DR118
Cooperative Research Centres Association	11, DR150

Participant	*Submission number*
Corporate Tax Association	DR197
Cotton Catchment Communities CRC	74
Council for the Humanities, Arts and Social Sciences	52, DR171
Council of Australian University Librarians	DR163
Council of Rural Research and Development Corporation Chairs	96, DR172
CRC for Beef Genetic Technologies, CAST CRC, CRC for Innovative Dairy Products, CRC for Forestry, CRC Mining, CRC for the Australian Poultry Industries, the Australian Sheep Industry CRC, Vision CRC	85, DR164
CRC for Spatial Information	32
CSIRO	50, DR184
CSIRO Staff Association	78, DR176
CSL	DR177
Cutler, Dr Terry	43
DA Information Services	DR129
Deakin University	15
Defence Science and Technology Organisation	DR179
Department of Agriculture, Fisheries and Forestry	100, DR190
Department of Agriculture and Food (Western Australia)	44
Department of Communications, Information Technology and the Arts	101, DR180
Department of Economic Development (Tasmania)	97, DR181
Department of Education, Science and Training	87, DR106, DR205
Department of Fisheries (Western Australia)	DR186
Department of Health and Ageing	105
Department of Industry and Resources (Western Australia)	82
Department of Industry, Tourism and Resources	93, DR185
Department of Premier and Cabinet (Tasmania)	103
Department of Primary Industries and Water (Tasmania)	DR193
Department of State and Regional Development (New South Wales)	DR209
Desert Knowledge Cooperative Research Centre	29, DR155
Elsevier Australia	DR157
Engineers Australia	65, 88
Federation of Australian Scientific and Technological Societies	83, DR144

Participant	*Submission number*
Fitzgerald, Prof. Brian	21, DR114
Ford Motor Company	DR188
Gans, Prof. Joshua S	10, DR127
GlaxoSmithKline Australia	38, DR154
Gourley, Mr Colin	1
Graeme Pearman Consulting	86
GrainCorp	DR116
Griffith University	7
Group of Eight	68, 104, DR158
Halton, Charles C	DR178
Harnad, Dr Stevan	DR110
Hine, Dr Damian	DR126
Industry Research and Development Board	77, DR191
Innovation Economy Advisory Board	89
Innovative Research Universities Australia	54
Institute of Public Affairs	30, 76, DR139
Integrated Research	DR208
Invasive Animals CRC	57
Jensen, Dr Paul, Dr Alfons Palankaraya and Dr Elizabeth Webster	9
Lawson, Dr Charles	5, DR112
Livingstone, Ms Catherine	56
Lyons, Prof. Lawrie	8
McAteer, Michael	DR109, DR207
Macquarie University	47
Medical Devices Industry Action Agenda Implementation Group	DR182
Medicines Australia	99
Melbourne Ventures	DR138
Meridian Connections	26, DR143
Michael Johnson & Associates	DR132
Mineral Resources Tasmania	DR107
Minerals Council of Australia	DR210
National Committee for Mathematical Sciences	25

Participant	*Submission number*
National Farmers Federation	DR202
National Health and Medical Research Council	80, DR165
National Tertiary Education Union	62, DR128
New South Wales Board of Vocational Education and Training	67
New South Wales Government	91
Northern Territory Government	DR194
Northern Territory Government, the Northern Territory Research and Innovation Board and Charles Darwin University	23
Novita Tech	DR206
O'Donnell, Dr Carol	DR111
Office of the Privacy Commissioner	63, DR173
Parker, Professor Rachel	DR117
Potts, Dr Jason	18, 19
PricewaterhouseCoopers	DR196
Queensland Government	DR203
Queensland Nanotechnology Alliance	48, DR147
Research Australia	33, 102
Research International	13, DR119
ResMed	DR161
Rice, Michael	DR195
Rio Tinto	46, DR142
Roach Industries	12
Rooney, Dr David and Dr Tom Mandeville	2
Rose, Roy Roderick	DR198
Schibeci, Associate Prof. Renato and Dr Jeffrey Harwood	66
Scholarly Publishing & Academic Resources Coalition	DR149
Science Industry Australia	22
Scott-Kemmis, Don	DR183
Shaw, Dr Roger	DR146
Sinnott, Professor Don	DR168
Society for Knowledge Economics	53
South Australian Government	92, DR212

Participant	*Submission number*
Southern Cross University	DR108
Standards Australia	70, DR156
SVP Industries	DR135
Syngenta Crop Protection	DR134
Taxation Institute of Australia	DR199
TGR BioSciences	16, DR140
Trevelyan, Prof. James	3
University of Canberra	45
University of New England	17
University of Sydney	79
Victorian Government	84, DR211
Volterra Pacific	49
Walter and Eliza Hall Institute of Medical Research	31, DR159
Way, A Shane	DR160
Western Australian Fishing Industry Council	DR174
Winemakers Federation of Australia	14

B Major Australian Government support

B.1 Budget data

Each year the Australian Government publishes detailed data on major support for science/technology related research and development and innovation programs (Australian Government 2006d).[1] These provide the single best assessment of whole-of-government spending (at the Australian Government level) in these areas, though see the Department of Industry Tourism and Resources' criticisms of the validity of the Government's estimates in section B.2.

The estimates given are the cost to taxpayers, which can be different from the amounts of eligible expenditure recorded for specific programs from other data sources. For example, the budget papers record the subsidy equivalent value of the R&D Tax Concession, not the total amount of business spending eligible for the concession. For the 125 per cent component of the Tax Concession, the government contribution equivalent is approximately the additional deduction rate allowed times the corporate tax rate (0.25* 0.30) or only 7.5 per cent of eligible spending. In some instances, such as the R&D Tax Offset, the budget papers do not provide an estimate of the cost to taxpayers.

The Commission has used the data to re-classify the policy measures into four broad categories, and these are shown in the tables below. The classification is necessarily subjective for some programs that have overlapping functions. Only measures that involve some funding after 2003-04 are included (whereas the original tables include many lapsed programs that record successive zero values for these years). The data for 2005-06 are the estimated actual, while those for 2006-07 are budget estimates.

[1] The tables, compiled by the Department of Employment Science and Technology, are available from the website of the responsible Government Minister (the Hon. Julie Bishop MP at http://www.dest.gov.au/ministers/bishop/budget06/scitables.pdf).

Table B.1 **Support for industry performed R&D**

Budget items that are active for some period after 2003-04

Measure	*2004-05*	*2005-06*	*2006-07*
	$m	$m	$m
R&D Tax Concession	580.0	615.0	650.0
Commercial Ready Programme[a]	152.1	152.5	199.0
Food Innovation Grants National Food Industry Strategy	10.8	15.4	13.1
Automotive Competitiveness and Investment Scheme	128.0	194.0	238.0
Shipbuilding Innovation Scheme	2.1	0.0	0.0
Motor Vehicle Producer R&D Scheme	0.0	6.6	9.0
R&D Start Loans Programme	10.4	8.0	0.0
Pharmaceutical Partnerships Programme	4.2	10.2	31.6
Total	**887.6**	**1001.7**	**1140.7**

[a] Commercial Ready provides some finance for commercialisation of already developed ideas, but principally acts as a support mechanism for R&D for commercially promising products in small and medium enterprises.

Source: Australian Government 2006d, *The Australian Government's 2006-07 Science and Innovation Budget Tables*, Canberra.

Table B.2 **Australian Government support of business commercialisation and diffusion**

Budget items that are active for some period after 2003-04[a]

Measures	*2004-05*	*2005-06*	*2006-07*
	$m	$m	$m
New Industries Development Programme	3.5	2.6	2.3
Building Information Technology Strengths (BITS) – Incubators	12.6	10.6	7.5
BITS – Advanced Networks Programme	8.0	7.0	5.0
Renewable Energy Commercialisation Programme	2.7	3.1	0.7
Renewable Energy Equity Fund	3.2	1.5	1.1
Greenhouse Gas Abatement Programme	12.9	15.7	21.6
Low-Emissions Technology and Abatement	2.5	7.0	9.4
Low-Emissions Technology Demonstration Fund	1.7	2.1	52.0
Commercialising Emerging Technologies (COMET)	7.9	8.4	10.3
Innovation Investment Fund	19.6	16.5	18.4
Industry Co-operative Innovation Programme	0.0	2.2	4.7
Innovation Access Programme – Industry (IAccP)	2.3	0.0	0.0
Pooled Development Funds	7.0	7.0	7.0
Pre-Seed Fund	6.7	13.4	12.0
National Measurement Institute	8.0	8.0	8.0
Total	**98.6**	**105.1**	**160.0**

[a] Included are measures used to diffuse technologies, best practice or information to business, as well as financing measures for commercialisation. Some of the judgments made in allocating spending measures to this grouping vary from that of DEST (2005a, table 2.1.27, p. 44), and in particular Commercial Ready has been allocated to table B.1.

Source: Australian Government 2006d, *The Australian Government's 2006-07 Science and Innovation Budget Tables*, Canberra.

Table B.3 **Other support of industry-centred science and innovation not typically undertaken in industry**

2004-05 to 2006-07

Measures	*2004-05*	*2005-06*	*2006-07*
	$m	$m	$m
CSIRO	577.1	593.9	607.2
Australian Animal Health Laboratory	6.8	6.9	7.0
Geoscience Australia	100.9	107.4	113.0
Wool Research	13.7	16.2	16.2
Meat Research	35.6	36.3	36.3
Fishing Industry Research	31.7	32.8	28.0
Grains	35.1	35.1	36.0
Horticulture Research	30.0	32.9	32.9
Land & Water Research	12.5	12.5	12.8
Rural Industries R&D Corporation	17.3	17.1	20.0
Other Rural Research	37.7	37.8	39.2
Centres of Excellence National Food Industry Strategy	3.4	2.4	2.3
Centres of Excellence Biosecurity Risk Analysis & Research	0.4	1.7	1.7
ICT Centre of Excellence	17.2	23.5	24.0
Information Technology Online (ITOL)	1.9	2.3	1.3
Australia Council Synapse Program	0.0	0.3	0.3
Cooperative Research Centres Grants	194.6	208.2	189.4
Advanced Electricity Storage Technologies	0.4	3.8	5.9
Wind Forecasting Capability	1.2	5.2	4.8
Biotechnology Centre of Excellence	5.8	7.1	6.5
Small Scale Mammalian Cell Production Facility	0.0	0.0	2.5
Total	**1123.3**	**1183.4**	**1187.3**

Source: Australian Government 2006d, *The Australian Government's 2006-07 Science and Innovation Budget Tables*, Canberra.

Table B.4 **Non-industry centred science and innovation support**

2004-05 to 2006-07

Measures	*2004-05*	*2005-06*	*2006-07*
	$m	$m	$m
Anti-doping Research Program (ADRP)	0.6	1.1	2.9
Major National Research Facilities	42.3	42.3	0.0
National Collaborative Research Infrastructure Strategy	0.0	13.2	98.2
International Science Linkages	9.3	10.2	9.6
Research Evaluation and Grants for Learned Academies	2.2	2.0	2.0
Capital Works for John Curtin School of Medical Research	0.0	50.0	0.0
Australian Biological Resources Study	3.0	3.0	3.0
Climate Change Science Programme	6.7	6.9	8.6
Emissions Measurement and Analysis	7.4	8.8	8.8
Marine Research	1.8	2.1	1.8
Commonwealth Environment Research Facilities	0.0	4.8	22.1
Bilateral Climate Change Partnerships Programme	0.2	0.1	0.8
NHMRC Research Grants	369.4	403.5	437.6
Capital Works for Medical Institutes	4.1	2.0	0.0
Health Sciences Australian Longitudinal Study on Women's Health	1.1	1.4	1.4
Health & Medical Research Overhead infrastructure Support	10.1	27.0	28.0
Medical Research Infrastructure Projects	0.0	215.0	0.0
Research Support for Counter Terrorism	1.0	2.0	2.1
Payments to Austroads/ARRB Transport Research Ltd.	1.9	2.4	2.4
Australian Research Council	480.9	546.2	570.3
Performance Based Block Funding	1178.0	1234.7	1214.3
Estimate of Other Research and Research Training Support Sourced from the Commonwealth	587.0	447.7	447.7
Defence Science and Technology Organisation	314.4	349.1	340.7
Australian Nuclear Science & Technology Organisation	167.5	138.1	129.7
Australian Institute of Marine Science	22.5	23.1	23.6
Anglo-Australian Telescope	4.1	4.6	4.7
Antarctic Division	86.5	94.6	99.7
Bureau of Meteorology Research Centre (BMRC)	11.0	11.7	12.0
Environmental Research Institute of the Supervising Scientist	7.8	7.5	7.9
Great Barrier Reef Marine Park Authority	6.0	6.1	6.1
National Oceans Office	2.1	0.0	0.0
Total	**3328.9**	**3661.2**	**3486.0**

Source: Australian Government 2006d, *The Australian Government's 2006-07 Science and Innovation Budget Tables*, Canberra.

B.2 Appropriateness of the data

Invariably, data such as those above, involve judgments about classifications of activities that others may not agree with. In particular, DITR (sub. DR185, pp. 41-3) questioned the extent to which the Australian Government's budget tables compiled by DEST (used above and in table 10.1 of this report) represented an adequate statistical picture of innovation spending. This had, in their view, significant consequences for the robustness of the Commission's report, which is why this issue is worth considering in detail. Much of DITR's concern related to the inclusion of one expenditure item in the tables — Geoscience Australia — an area for which it has departmental responsibility.

While the Commission is satisfied that the budget tables should include Geoscience Australia (box B.1), DITR's queries about the Australian Government's science and innovation accounts raise some difficult and legitimate issues about the boundaries defining innovation.

First, tractability in budget reporting means that some expenditures for agencies listed under innovation will relate to non-innovation functions, just as some agencies' spending on innovation will be omitted because that is not a primary function of these agencies.

Second, as emphasised by CHASS (sub. DR171), the Australian Academy of the Humanities (sub. DR192), the Australian Research Council (sub. 73) and many other participants, science and innovation is often narrowly conceived in terms of the natural sciences. This means that R&D and innovation spending by government in the social sciences and other innovation-relevant disciplines is not identified. Much of this is contracted out. In addition, nearly every Australian Government department has an internal social science research function pertinent to their key roles. For instance, DEWR has undertaken sophisticated analyses of the net impacts of the Job Network; DEST oversees an extensive research program into the effectiveness of education programs, DCITA has undertaken significant research into productivity growth and ICT (DCITA 2006); DITR has used ABS data to technically analyse collaboration by innovators (Brunker, D. and Salma 2006) and so on.

Many independent government bodies also devote significant resources to research in the social sciences and the humanities. In the economic field this includes the Reserve Bank, the Australian Bureau of Statistics, the Productivity Commission and ABARE. Various government operated museums, galleries and libraries have significant research functions (for example the National Museum of Australia and the Australian War Memorial).

Box B.1 **In or out? Is the inclusion of Geoscience Australia a litmus test of the validity of the science and innovation budget tables?**

DITR (sub. DR185, pp. 41-43) was concerned that the 'fitness-for purpose' of the Australian Government's budget papers extensively used by the Commission was called into question by the inclusion of Geoscience Australia:

> … we draw to the Commission's attention that whole-of-government data collated by DEST/ABS that the Commission uses to underpin its own analysis of direct government support for innovation and science/R&D includes this program, which is surprising given that Geoscience Australia is [not fully, nor partially, funded through the Australian Government's innovation program, is not formally a publicly funded research agency, and does not undertake research/investigation as a primary objective]. (DITR sub. DR185, pp. 41–2, words in parentheses are a condensed form of DITR's concerns)

As a consequence, DITR considered that Geoscience Australia should be removed from the list of research agencies listed by the Commission in table 10.1 of the report (and if retained, should only have a fragment of its activities counted).

The Commission examined the activities of Geoscience Australia and considers that research does play a primary role in the production of information for users — a view that was widely shared by others.[2] In its 2005–06 annual report, DITR (2006, p. 98) itself indicated that its prime goal (outcome 1) is an 'enhanced potential for the Australian community to obtain economic, social and environmental benefits through the application of first class geoscientific research and information.'[3] The CEO of the organisation classified it as 'Australia's national geoscience research information agency' while its mission statement emphasised its research function.[4] The Australian Government's major report on innovation, *Backing Australia's Ability*, released by the Prime Minister in 2004, listed the body as a 'government research agency'.

On this basis, Geoscience Australia can reasonably be categorised as part of the Australian Government's science and innovation spending and as a government research agency. Is it only a research agency? Probably not, although the boundaries between information collection/management of the sophistication undertaken by Geoscience Australia and research are quite blurred. For this reason, the Commission has not attempted to split its budget into research and non-research activities.

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2 Among participants in this study this included: FASTS sub. DR144, the Australasian Institute of Mining and Metallurgy sub. 71 and the Australian Academy of Technological Sciences and Engineering sub. 27.

3 In its submission DITR also acknowledged that 'the achievement of Geoscience Australia's outcome … frequently involves the application of first-class innovative geoscientific research' (sub. DR185, p. 41).

4 Respectively http://www.ga.gov.au/about/message/ accessed on 1 February 2007. and http://www.ga.gov.au/about/corporate/strategic_direction.jsp accessed 1 February 2007.

Third, as emphasised by DITR (sub. DR185, p. 7), the Australian Business Foundation (sub. DR170), Mr Don Scott-Kemmis (sub. DR183), the Queensland Government (sub. D203, p. 1) and various other submissions, public support for innovation is more than support for research. It could encompass any arrangements that strengthen innovation linkages, increase diffusion of knowledge or that build up complementary capabilities, such as human capital or finance availability. There are obviously resources underpinning these arrangements. Some are reasonably easily enumerated — as in the case of support for venture finance described in table B.2 above. But many of the resources by government used to support the innovation system more generally are often not easily counted in any meaningful way. Should, for example, the salaries of officials trying to reduce regulatory problems that might affect innovative incentives be counted as public support for innovation? (And should the resources committed to those officials that bolster these regulatory problems be counted as a deficit?) In one sense, yes. But where across all the portfolios that address these issues centrally or parenthetically are the boundaries to be drawn, especially where the same expenditure could happily be allocated to multiple spending categories?

The implications are as follows. Governments need accounts that say something useful about where innovation spending is allocated. These have to cover reasonably defined areas for the sake of compliance costs and practicality. Currently, the accounts recording spending by the Australian Government on technologically-oriented R&D and innovation give a reasonably useful indication of the extent of funding of these activities. They do not comprehensively cover the social sciences and the humanities, nor the broader innovating-supporting activities of government. Some indications of the former might be given by adding up the budgets of the separate institutions with these foci. It is not clear that anything other than crude rule-of-thumb measures could be obtained for the latter, and in any case a measure of spending in these areas is probably a poor metric of their efficacy in dealing with faults in the innovation system. As they currently stand, reported spending by governments on innovation will be below the true measure.

Does this matter much? DITR argued that the data on totals ‘underpinned’ the Commission’s findings. Regardless of the different views on Geoscience Australia, there seems little question that the totals recorded on innovation by any department or government, in Australia or overseas, are inexact. So if exact totals were required to underpin conclusions then this would be problematic for innovation analysis and policy worldwide. However, this is not the case. For example, most of the comments and analysis by the Commission relating to government research agencies centred on CSIRO and DSTO because of their size and significance (chapter 10). More general comments were made that would be relevant to the other agencies. Adding or subtracting the admissible agencies does not change the pertinence of this analysis.

What about funding levels? If the adequacy of funding is to be gauged through international comparisons, then the fact that slabs of resources are missing from the accounts would at least be discomforting for that analysis. Moreover, thinking about the types of innovation capabilities associated with these uncounted resources might also weaken the conclusions of such international analyses. Suppose, for example, that a country generously funds R&D, but has made resource allocations that lead to a weak complementary innovation system characterised by inadequate human capital, overly intrusive regulations and poor incentives for competition. Much of the impact of that strong R&D base might be diluted by these weak innovation endowments (whose effects go well beyond whatever government resources elicit them). This is one reason why the Commission regards international comparisons as, at best, only of broad interest (chapter 9).

Ultimately, the Commission's approach is to be cautious in interpreting funding levels. They are one of a set of useful, but individually flawed, indicators of the health of the innovation system, to be interpreted in context and their limitations noted. Processes, institutions, and complementary capabilities are all critical. For example, the Commission considers budget and evaluation processes — which pool the expertise and judgment of many decision-makers — to be a more important basis for considering the 'right' levels and distribution of public funding on innovation than any precise calibration exercise it or any other single body could ever undertake. However, where possible, the Commission draws attention to, and analyses, those particular expenditure areas identified by participants as deficiently funded.

C International comparisons and R&D targets

This appendix provides analysis and data to support the discussion and conclusions set out in chapter 9 in regard to:

- the appropriate role of R&D spending targets for Australia; and
- the appropriate interpretation of differences between Australia's R&D intensities and those of other OECD countries.

The nature and levels of R&D targets adopted for a range of OECD countries as well as their underlying rationales are examined first followed by an assessment of whether they are likely to be achieved. Australia's performance relative to actual, and targeted R&D, levels for other countries is then examined, and country-specific differences are also explored. The key issues of the impact of differences in industry structure on R&D intensity across OECD countries and changes in industry structure over time are considered in some detail. Other factors affecting international comparisons of R&D spending such as firm size, wage rates and public support for BERD are also canvassed.

C.1 OECD R&D targets

Almost all OECD countries have employed targets for science and innovation policy in recent years. Total R&D spending is the indicator generally targeted, as opposed to broader measures of innovation, largely because it is more readily quantifiable as detailed R&D statistics have been available in many OECD countries for over four decades (OECD 2004b). The ratio of gross expenditure on research and development (GERD) to GDP is the most common R&D intensity measure for both domestic targeting and international comparisons. This provides a simple means of comparing R&D spending across different sized countries.[1]

[1] Caution should be exercised in interpreting this ratio, as R&D spending and GDP are not directly comparable measures. The former is a gross expenditure measure while the latter is a measure of value-added. Hence, R&D/GDP does not constitute the proportion of GDP devoted to R&D. R&D intensity can also be calculated as the *net* addition to R&D stock as a percentage of GDP. This measure will differ from GERD/GDP ratios unless the depreciation rate used in the

Although total national R&D intensity is the primary focus for the majority of countries, the targets are generally split into public and private components.

An examination of R&D targets adopted across 30 OECD countries in recent years indicates that around three-quarters of all targets fall within a range of 1.5–3 per cent of GDP (table C.1). On average, OECD countries set targets just under one percentage point higher than their R&D intensities current at the time the targets were announced — which translates into an increase in R&D intensity of 50-100 per cent for most countries. The most common target level chosen is 3 per cent, reflecting the overall European Union R&D intensity target of 3 per cent of GDP by 2010 agreed by the European Council as part of its 'Lisbon strategy' for economic revival and announced in Barcelona in 2002 (European Union 2002).

In setting the target, the European Council acknowledged that different levels of spending on science and innovation were appropriate for member countries and rejected a 'one size fits all' approach. Instead, each member country was expected to determine how best to contribute to the overall target. Latest individual member country targets reported at the Brussels European Council in March 2006 indicate that:

- Austria, Belgium, Denmark, Germany, France, Luxembourg, Norway and the Netherlands are each aiming to meet the 3 per cent target;
- Sweden and Finland, which are already above the 3 per cent level — and were at the time the Barcelona target was announced — are aiming for 4 per cent by 2010;
- Greece, Portugal, Spain, Italy, Ireland and the United Kingdom have clearly aimed lower than the Barcelona target, aiming for targets in the range of 1.5–2.5 per cent; and
- a number of the new member states[2] have set even lower percentage targets (0.75–1.5 per cent), although in terms of total increase, their targets often required doubling or trebling their current investments (table C.1).

Among the non-EU OECD countries, Canada has specified an ordinal, or ranking-based, target rather than a precise figure. Canada is aiming to achieve an R&D intensity level within the top five in the OECD by 2010. Based on current levels this would amount to around 2.9 per cent of GDP. However, the precise level Canada

perpetual inventory method (PIM) calculations underlying the R&D stock is zero. As this method is generally not used for target setting or for international comparisons it is not employed here.

2 On 1st May 2004 ten additional states joined the EU — Cyprus, the Czech Republic, Hungary, Poland, Slovenia, Slovak Republic, Estonia, Lithuania, Latvia, and Malta.

will need to achieve to meet this target is unclear as it depends on changes in R&D intensities in other countries.

Table C.1 **R&D targets and expenditures, selected OECD countries**[a]

GERD/GDP, per cent

Country/region	*R&D intensity in 2005*	*Target*	*Target date and characteristics*
Austria	2.36	3.00	2010
Belgium	1.82	3.00	2010
Canada	1.98	Top 5 OECD	2010
Cyprus	0.40	1.00	2010
Czech Republic	1.42	2.06	Target of 1% public R&D with estimated 1.06% of private expenditure in 2010
Denmark	2.44	3.00	Target of 1% public R&D in 2010
Estonia	0.94	1.90	2010
Finland	3.48	4.00	2010
France	2.13	3.00	2010
Germany	2.51	3.00	2010
Greece	0.61	1.50	2010
Hungary	0.94	1.80	Increased participation of private sector by 2010
Ireland	1.25	2.50	2013
Italy	1.10	2.50	2010
Korea	2.99	Double spending	2007
Latvia	0.57	1.50	2010
Lithuania	0.76	2.00	2010
Luxembourg	1.56	3.00	2010
Malta	0.61	0.75	2010
Netherlands	1.78	3.00	2010
New Zealand	1.14	..	Target of OECD average (0.68%) for public R&D — no year specified
Norway	1.51	3.00	Target of 1% public and 2% private R&D by 2010
Poland	0.57	1.65	2008
Portugal	0.81	1.80	Target of 1% public R&D and tripling of private R&D by 2010
Slovenia	1.22	3.00	2010
Slovakia	0.51	1.80	2010
Spain	1.12	2.00	2010
Sweden	3.86	4.00	Target of 1% public R&D and unchanged private R&D by 2010
Turkey	0.66	2.00	Target of 1% public R&D and 1% private R&D by 2010
United Kingdom	1.79	2.50	2014

a Values for Italy, United Kingdom and the Netherlands are for 2004, New Zealand are for 2003, and Turkey are for 2002.

Data sources: Council of the European Union 2006, Eurostat Science and Technology Database 2007, http://epp.eurostat.ec.europa.eu, (accessed February 2007)), OECD 2004c, 2006c New Zealand Ministry of Research, Science & Technology Budget Speech (May 2006).

While New Zealand has not targeted total R&D intensity, the New Zealand Minister for Research, Science and Technology announced in 2006 the Government's aim of achieving OECD average public R&D spending levels (0.68 per cent of GDP), although he also stated that additional public spending is contingent on further policy consideration and overall budgetary constraints (New Zealand Ministry of Research Science and Technology (MORST) 2006). This represents a softening of its previous public spending target of 0.8 per cent of GDP identified in its 2000-01 budget (Hodgson 2000).

It is interesting to note that apart from Australia, the only other OECD countries that do not employ empirical R&D targets are the two largest R&D performers, the United States and Japan.[3] Despite ongoing domestic debates about the appropriate level of government commitment to science and innovation in the United States, spending targets do not appear to have played an important part of its national science and innovation policies.[4]

Rationales and choice of targets

Stated rationales for choosing to target R&D were fairly consistent across countries. Invariably, the adoption of R&D targets begins with a recognition of the importance of innovation for productivity growth and economic prosperity. A strong link is then drawn between R&D spending and innovation and productivity growth.[5] The EU, for example justified the overall desirability of increasing R&D intensity on the basis of the positive link between R&D spending and multifactor productivity growth (EU 2002). A key study cited in the EU Barcelona announcement based on panel data for 16 OECD countries over the period 1980–1998 found that a 1 per cent increase in business and public R&D generates 0.13 per cent and 0.17 per cent rises in national productivity respectively (Guellec and Van Pottelsberghe 2001). Guellec and Van Pottelsberghe, however, urged caution in drawing policy conclusions, noting that their work was undertaken at a very aggregated level and that any policy lessons should be confirmed by more detailed country level studies. This study was also cited in support of the Canadian and United Kingdom target announcements (HM Treasury 2004, Government of Canada 2001).

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[3] Although the Japanese *Basic Law on Science and Technology* (1995) mandates that the government prepare a science and technology plan every five years which outlines planned public R&D investments over the medium term (JETRO 2005).

[4] For a discussion of science and innovation policy in the United States see National Science Foundation (2006).

[5] See for example, EU (2002); HM Treasury (2004); Government of Canada (2001).

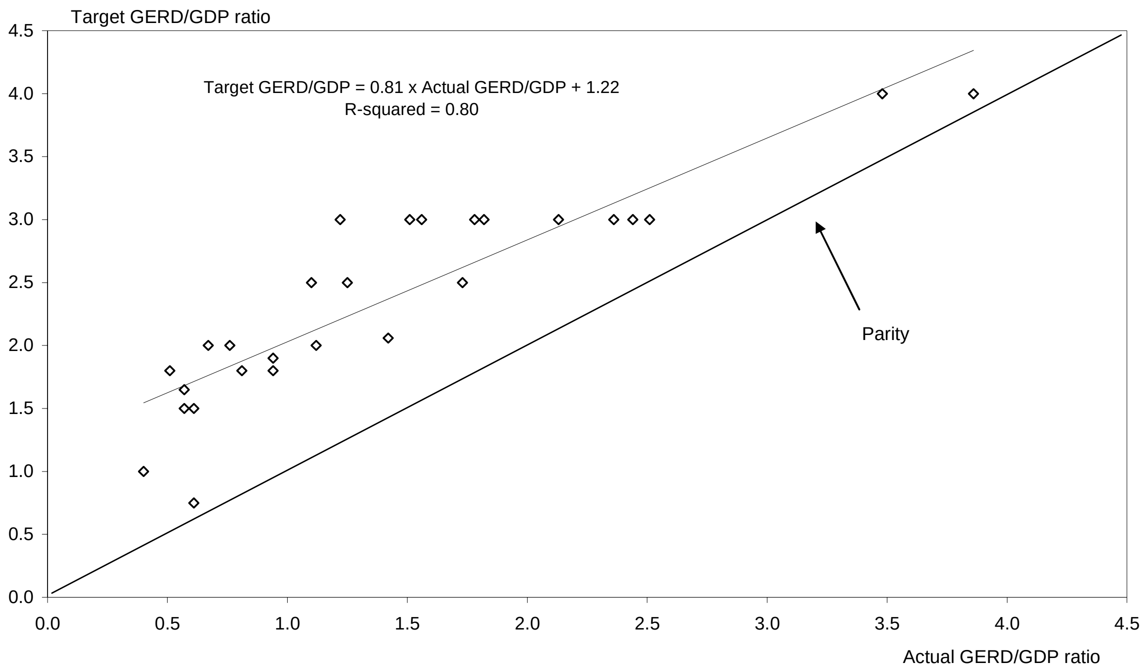
Another factor frequently cited in support of R&D targeting is the need to 'keep up' with 'leading' R&D performing countries or at least to match OECD averages (which are largely driven by the performance of a few key players in any case). Indeed, the desire to maintain or improve relative rankings, rather than empirical analysis, appears to be a key factor in setting the actual level of the target. For example, in announcing the Barcelona target, the European Council noted (EU 2002, p. 5):

> At present, less than 2 per cent of Europe's wealth (GDP) is devoted to research, which compares badly with 2.5 per cent in the USA and more than 3 per cent in Japan … The European Council therefore agrees that overall spending on R&D and innovation in the Union should be increased with the aim of approaching 3 per cent of GDP by 2010.

Clearly, the choice of the target at 3 per cent, as opposed to say, 2.9 per cent or 3.1 per cent, was not empirically based. This was the case across the OECD, with most countries selecting round number targets between 0.5 and 1.5 percentage points higher than their actual R&D spending levels (figure C.1).[6]

Figure C.1 **OECD targets compared with actual R&D intensities**

Per cent, 2005 or nearest available year



Data source: Table C.1.

[6] The average difference between actual and targeted R&D intensity across the OECD was 0.93 percentage points. However, the percentage point difference between actual and targeted R&D intensity declines slightly with increases in actual R&D intensity (ie the slope of the line of best fit was less than one).

The way the EU target was articulated, ‘approaching 3 per cent’, reflects the fact that the precise level of R&D intensity is not the focus. What is important is raising R&D. For example, when the EU target was announced, both Finland and Sweden were already spending substantially more than 3 per cent of GDP on R&D. However, the target was clearly never intended to suggest they put in place policies to limit their national R&D spending to 3 per cent of GDP. In this sense, the targets are asymmetric in character, reflecting a view that higher national R&D is always a positive sign.

The European Commissioner for Science and Research, Janez Potocnik, recently emphasised the dual role of R&D intensity as both a policy goal as well as an indicator of national success (2006, p. 2):

> When we talk about the 3 per cent goal, we have to be aware it is not just a goal, it is also an indicator of whether we are doing things in the right way. … Increasing investment in R&D will not in itself guarantee success — it is also a question of how we invest. But if we don’t invest, we are guaranteed to fail.

Hence, R&D targets employed across OECD countries are more appropriately viewed as fundamentally aspirational policy instruments, rather than empirically based economic assessments of the optimal level of resources each country should be devoting to R&D.

Are the targets likely to be achieved?

The relatively recent commitment to targets by most countries coupled with the lack of up-to-date R&D statistics means that care must be taken in assessing whether specific countries are on track to achieve their targets. Nevertheless, it is possible to gain a sense of whether existing R&D targets taken as a group are likely to be achieved.

In most cases, business was accorded the lion’s share of the task of achieving the R&D targets. Hence, several commentators have examined these questions by examining factors such as industry structure, firm size and investment intentions and the availability of skilled personnel.

The European Commission announced that two-thirds of the additional growth required to achieve the Barcelona target should come from the private sector. Given the starting shares, this represents a 1 per cent public R&D spending target and a 2 per cent BERD spending target. In response, the European Round Table of Industrialists, an association of leaders from 42 companies that represent around 13 per cent of total European R&D spending, expressed doubts about whether the target was realistic. It also noted that an internal survey of its member companies revealed that few had expectations of substantially increasing their R&D investments in the coming years and concluded that 'unless there is a dramatic reappraisal of Europe's approach to R&D and its framework conditions for business, the gap between the Barcelona target and the real world will not be bridged by 2010' (ERT 2002).

Other commentators have also expressed doubts about the feasibility of the EU as a whole achieving its 3 per cent target as well as whether a number of individual EU countries are likely to achieve their targets. Sheehan and Wyckoff (2003), for example, examined the economic and policy implications of the Barcelona target. They found that given the labour intensive nature of most R&D, a key constraint would be the supply of suitably skilled researchers, estimating that meeting the target would require the addition of 500 000 to 600 000 workers by 2010. They also highlighted the substantial social and economic challenges associated with achieving the target.

Arundel and Hollanders (2005) studied detailed industry structure data for a selection of 13 EU countries which combined account for around 95 per cent of EU R&D. They concluded that the 2 per cent BERD intensity goal is unrealistic and unachievable by 2010, or indeed, by 2015, noting that meeting the target would require 'massive and economically painful' changes in the structural distribution of sectors within Europe.

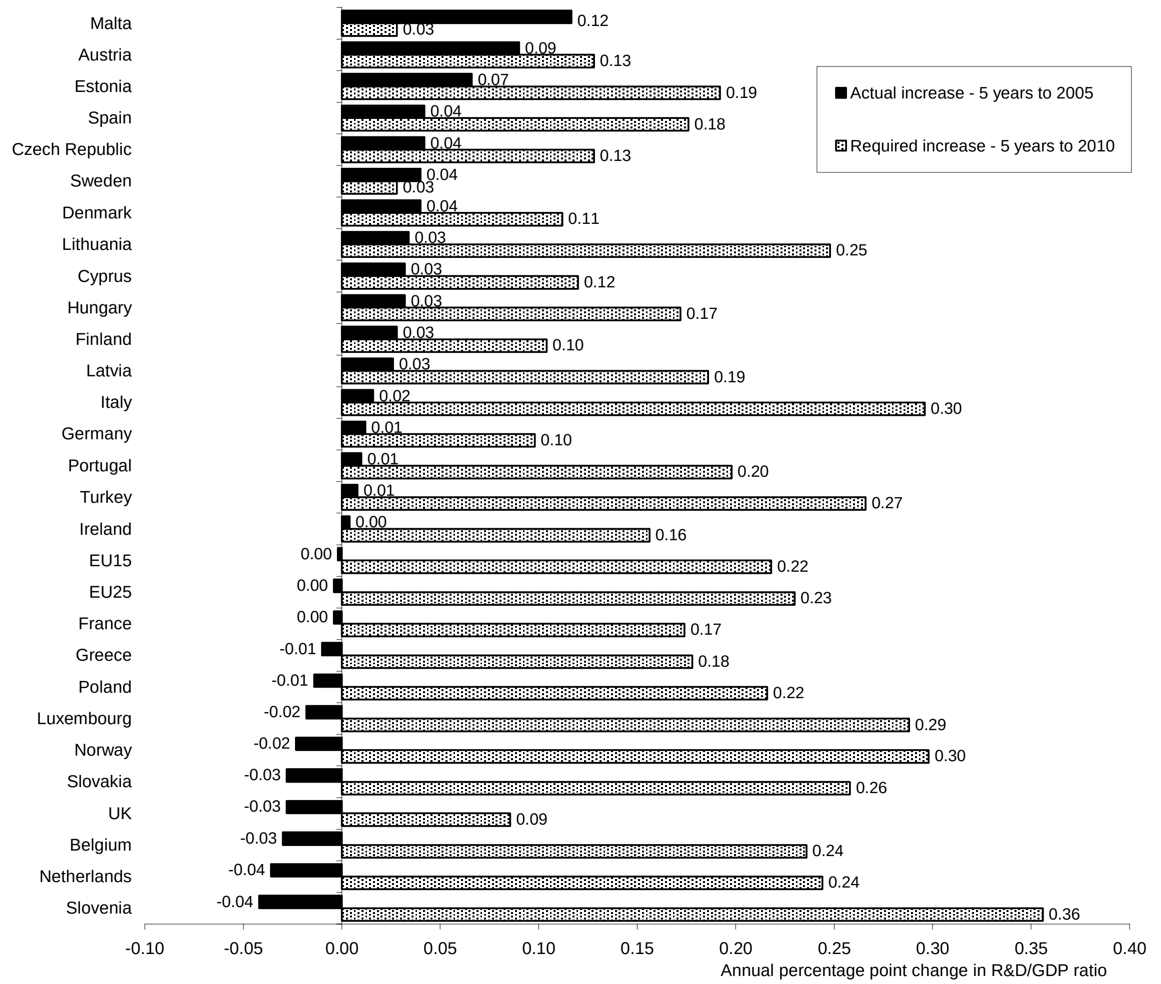
Indeed, latest Eurostat R&D data suggest that the EU as a whole is *not* on track to meet the target. In fact, the overall EU25 R&D intensity has actually declined since the Barcelona target was announced, falling from 1.89% of GDP in 2002 to 1.85% in 2005 (provisional). Even when the 10 EU member countries that joined in 2004 are excluded, R&D spending for the original EU15 is not on track to reach 3 per cent by 2010. EU15 R&D declined from 1.95 per cent of GDP in 2002 to 1.91 per cent of GDP in 2005.[7]

An examination of changes required to meet individual country R&D intensity targets across the OECD between 2005 (latest available data) and 2010 compared with the actual changes achieved in the previous five years illustrates how ambitious most countries' targets are (figure C.2). While explicit R&D targets for each country had not been articulated at the start of the period (2000), the importance of R&D has been widely recognised across OECD countries for many years. For most countries, the required boost in R&D intensity in the five years to 2010 is substantially larger than the increases achieved over the past five years.

[7] These data are close but not identical to the OECD R&D data employed elsewhere in this appendix and are used as they contain a more complete set of estimates for 2005.

Overall, only two countries, Sweden and Malta, achieved growth in R&D intensities commensurate with the increases required to meet their 2010 targets.

Figure C.2 **Actual and required annual changes to R&D intensities across OECD countries, 2000 to 2010[a]**



[a] Required increases for countries with targets other than 2010 (United Kingdom and Ireland) are on a pro-rata basis.

Data source: Eurostat Science and Technology Database 2006, http://epp.eurostat.ec.europa.eu, (accessed February 2007).

C.2 How does Australia compare?

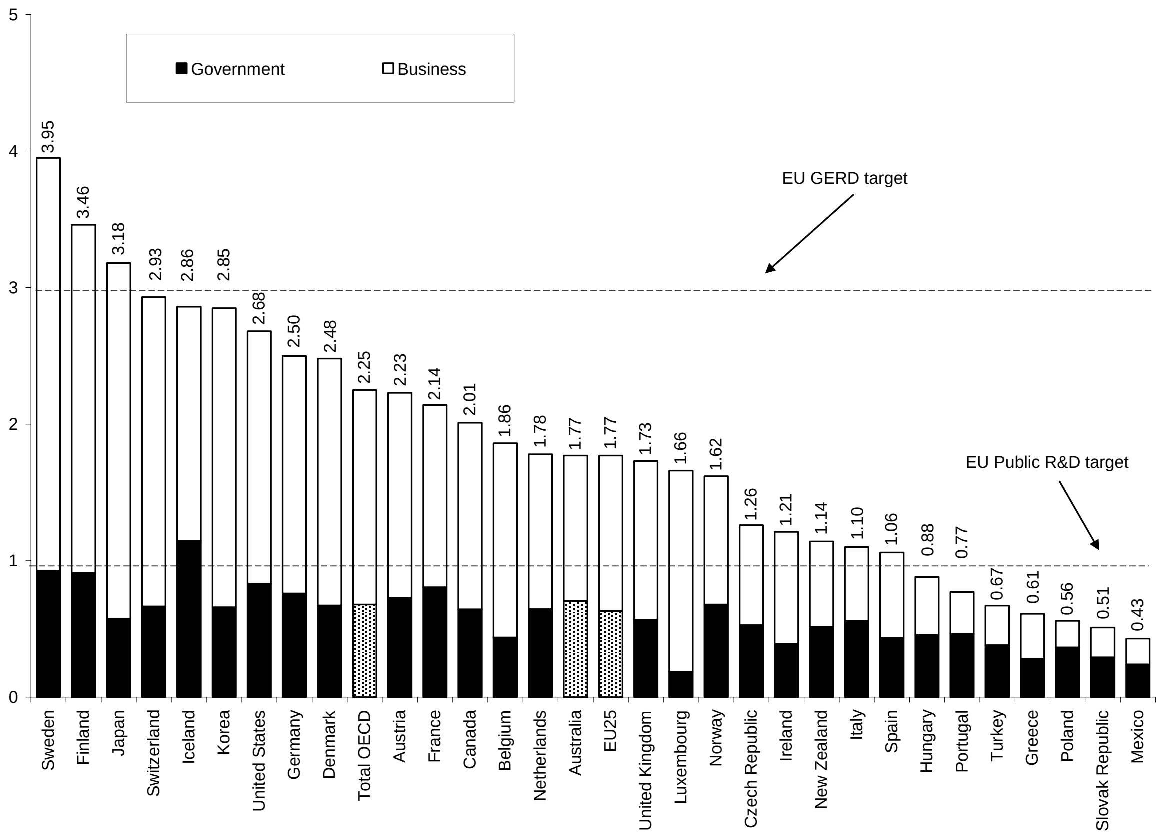
A number of participants to this study noted that Australia R&D intensity was low by international standards (see for example, subs. 31, 41, 51, 54, 59, 87 and 89). Despite strong real increases in R&D spending over the past two decades (discussed in chapter 1), Australia's R&D intensity, at 1.77 per cent in 2004, remains well below the OECD average. Overall, on this measure Australia ranked 15th out of 30

OECD countries — 0.5 percentage points below the OECD average of 2.25 per cent and just over half the Barcelona target (figure C.3).

Australia's performance against this measure reflects much lower business-financed R&D intensity, which, at just under 1 per cent (relative to GDP) was 0.6 percentage points below the OECD average and less than half the EU business R&D target. This was counteracted to a small extent by Australia's above average government-financed R&D spending which was 0.7 compared with an OECD average of 0.68 per cent.

Figure C.3 **Government and business-financed[a] GERD to GDP ratios across the OECD, 2004**

Per cent



[a] Also includes other non-government sources of R&D funding. Data for Iceland, Mexico, New Zealand and Sweden are for 2003.

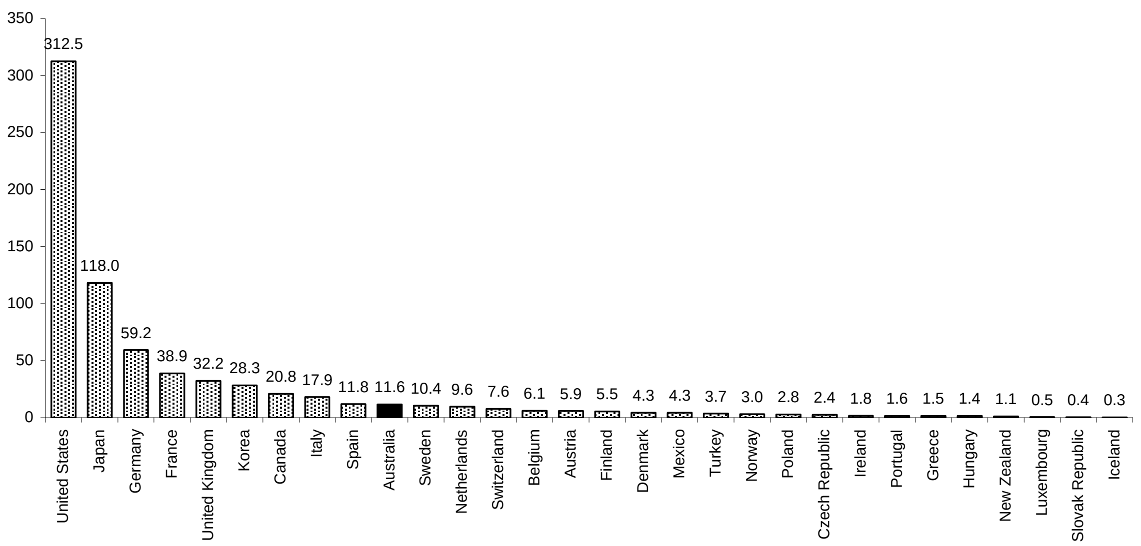
Data source: OECD Research and Development Statistics Database (accessed February 2007).

A fair degree of diversity is evident in R&D intensities across the OECD. For example, Sweden (4.0 per cent), the highest ranking country, achieved an R&D intensity ten times greater than Mexico (0.4 per cent), the lowest ranking country (figure C.3). This variation reflects substantial differences in both private and public investment levels across countries.[8] However, business R&D intensities registered almost twice as much variability as public R&D intensities.[9] This, coupled with their larger size, has meant that variations in business R&D spending across countries are the major driver of differences in national R&D intensities.

One interpretation of these international data is that Australia is underperforming in terms of total R&D spending, and in particular, business R&D expenditure. However caution needs to be exercised in interpreting these results. The OECD averages are heavily skewed by a few key players, with the two largest performers, the United States and Japan, accounting for almost 60 per cent of OECD R&D in 2004 (figure C.4). The sheer size of their spending combined with their high R&D intensities drives up the OECD averages considerably. For example, when these two countries are excluded, the average OECD R&D intensity for the remaining 28 OECD countries drops sharply — from 2.25 per cent to 1.75 per cent, just below Australia's R&D intensity in 2004.

Figure C.4 **Gross expenditure on R&D across OECD countries, 2004**

$US billion PPP



Data source: OECD Main Science and Technology Indicators Database (accessed 26 February 2007).

8 It is interesting to note that there is also substantial variation in R&D intensities *within* countries. For example, in the US, the six states with the highest levels of R&D expenditures — California, Michigan, New York, New Jersey, Massachusetts, and Illinois — accounted for one-half of the entire national effort in 2000 (National Science Foundation 2002).

9 Business and public R&D intensity levels across OECD countries registered coefficients of variation of 0.66 and 0.38 respectively.

Setting aside absolute differences in economy size, differences *within* countries, particularly in areas such as industry and firm structure, can affect national R&D spending (and intensities). These are examined below.

C.3 The role of industry structure

Normalised indicators, such as R&D/GDP ratios, are useful for international comparisons because they both account for size differences between countries and obviate the need for exchange rates. However, even normalised indicators are not always directly comparable from one country to another. Simple R&D intensities only control for GDP differences, not for structural differences between countries or other factors that can explain R&D variation (National Science Foundation 2006).

It has been observed that countries with higher concentrations of particular manufacturing industries (including computers, communications equipment, pharmaceuticals and transportation equipment), generally have higher R&D intensities than countries whose industrial structures are weighted more heavily toward industries such as mining, agriculture and services (Sheehan and Wyckoff 2003). Analysis by Davis and Tunny (2005) of R&D intensities of Australia's industries relative to those in key R&D performing countries such as the United States and Japan, for example, found that industry structure was an important contributing factor to Australia's low BERD intensity.[10]

This issue was raised in a number of submissions (see for example, subs. 22, 23, 56 and 60). However, there was some disagreement about the magnitude of the impact of structural factors and, hence, their importance relative to other drivers of R&D intensity. Citing analysis from OECD (2006b), the Australian Institute for Commercialisation, for example, claimed that the 'structural differences' explanation of intercountry differences in R&D intensity 'has recently been disproved' (sub. 28, p. 5).

This is an important question and warrants further examination. As noted above, differences in BERD are the major driver of intercountry differences in total R&D/GDP ratios. Hence the following discussion focuses on *business* R&D expenditure in OECD countries.

[10] BERD intensity is generally measured as the ratio of BERD to business value added rather than GDP — which also includes non-business value added (OECD 2006a).

Adjusting for structure

National R&D intensity is a function of the intensity with which R&D in undertaken in each industry; and the share of national value added contributed by each industry:

$$\mathrm{R}_{\mathrm{A}} = \sum_{\mathrm{j=1}}^{31} S_{jA} R_{jA} \qquad \{1\}$$

where R_A is the BERD/VA ratio for Australia; j represents each industry in the business sector (there are 31 industries in total see box C.1 and table C.2); S_j is the share of industry j in total business sector value added; and R_j is the R&D intensity for industry j in Australia.

One means of examining the role played by intercountry differences in industry structure is to apply a uniform OECD average industry structure to all countries and recalculate the overall business sector R&D intensity for each country:

$$\mathrm{R}_{\mathrm{A1}} = \sum_{\mathrm{j=1}}^{31} S_{jO} R_{jA} \qquad \{2\}$$

where R_{A1} is the BERD/VA ratio that would occur if Australia were given the OECD average industry structure and S_{jO} is the OECD average share of industry j in total OECD business sector value added.

The results from this approach indicate that industry structure plays an important role in BERD intensity for Australia. Overall, Australia's BERD increased from 1.2 to 1.9 per cent of value added in 2002 when the OECD structure was employed (figure C.5).

This increase reflected a mix of effects at the industry level. Australia's large mining industry contribution to BERD falls by three-quarters under the OECD structure. However, this was outweighed by strong increases in BERD across a range of manufacturing industries (including electronics, communication equipment, transportation, chemicals and pharmaceuticals and transport equipment).

Not only does Australia's manufacturing sector contribute a smaller share of value added than most OECD countries, but more importantly, the specific manufacturing industries that Australia specialises in generally exhibit low R&D/value added ratios. Overall, Australia's manufacturing industry has half the share of high technology activities as the OECD average (sub. 67, p. 6).

Box C.1 **About the data**

The analysis undertaken above was based on two key datasets. Value added data for OECD countries were obtained from the *Groningen Growth and Development Centre, 60-Industry Database* (http://www.ggdc.net/ October 2005) updated from O'Mahony and van Ark (2003). This is a comprehensive dataset based on the *OECD STAN Industrial Database* and supplemented with data published by individual countries' statistical agencies. Although some discrepancies in data were evident between the two datasets, overall they appeared to concord quite closely for the overwhelming majority of industries/countries. BERD estimates are drawn from the *OECD Analytical Business Enterprise Research and Development (ANBERD) Database* (accessed July 2006).

The level of analysis undertaken was governed by the availability of data across all countries, industries and years. In some instances BERD data were not available for each industry in all countries and years. To resolve this it was necessary to aggregate the number of industries (from 60 to 33) — which resolved the overwhelming majority of data issues (table C.2).

Data on two industry groups, Agriculture, forestry and fishing and Public administration, community and personal services were not used in the shift-share analysis — in the case of the former, because BERD data are not collected for agriculture, and for the latter because it is not part of the business sector. In Australia's case, the omission of Agriculture, forestry and fishing slightly understates the structural component of differences between Australia's BERD intensity and the OECD average. This is because Australia's agricultural sector accounts for, on average, twice the share of GDP of other OECD countries.

If data were missing for particular years within a given country, interpolation was used by applying the R&D intensity of adjoining years to the value added figures for the required year. If there were no data upon which to base an interpolation for a particular industry in a given country, then average R&D intensities for the remaining countries were applied to the value-added data to impute an R&D value. This technique was, for the most part, employed for smaller industries that did not impact greatly on R&D totals. The adjustments undertaken to BERD data to complete the dataset typically resulted in changes of 1–2 per cent in total BERD in any given year for countries for which this was required. The resulting estimates of aggregate BERD/VA ratios for the individual countries examined were close, but not identical, to those published in the OECD Main Science and Technology Indicators database (www.sourceoecd.org).

Unless otherwise specified, analysis for all countries was based on the years 1987 to 2002. All estimates are based on current price data converted into United States dollars using GDP USPPPs — the measure used by the OECD for all currency conversions of R&D expenditure data (OECD 2006c).

Adjusting for industry structure also results in strong increases in intensities for Norway and the Netherlands. Moreover, those countries with particularly high aggregate R&D intensities tend to gravitate more towards the OECD mean if adjustment is made for their idiosyncratic industry structure. Sweden, Finland and

Korea recorded falls in their BERD intensity of around 30–40 per cent when their structure was adjusted to the OECD average. In contrast, the two largest economies, the United States and Japan, did not record large changes (the former decreased by less than 0.1 percentage point while the latter increased by 0.4 percentage points) — an unsurprising result given that the industry structure of these two countries has a major impact on the industry structure for the OECD as a whole.

Table C.2 **Industry breakdown (and ISIC Revision 3 concordance)**

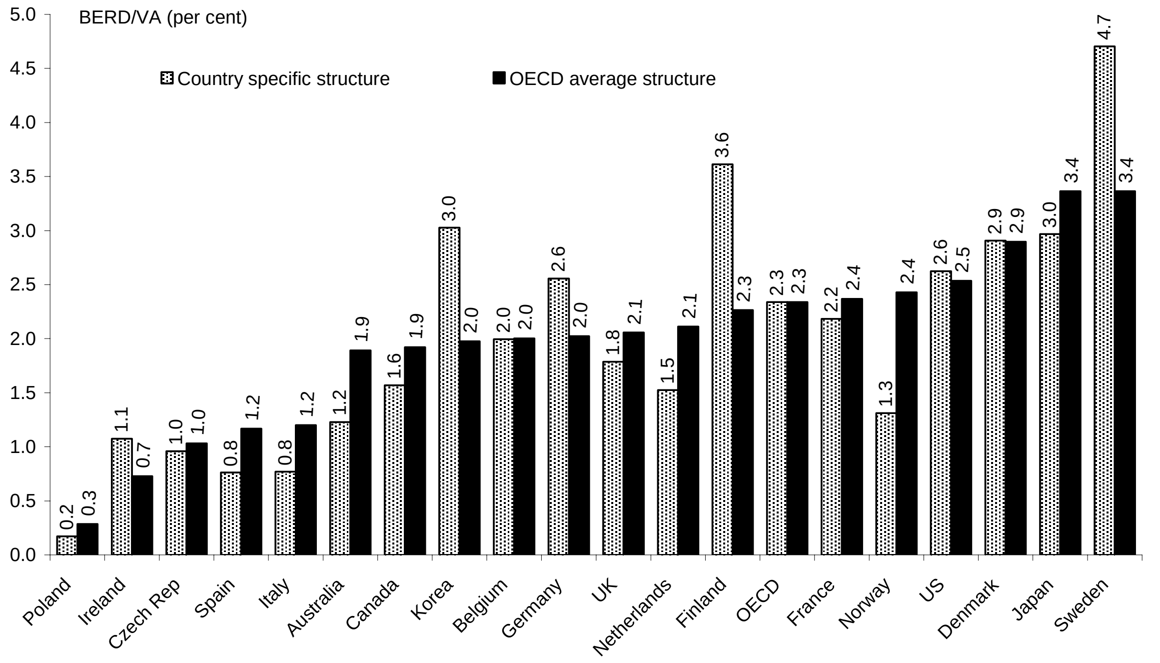
1	Mining and quarrying (10–14)	18	Other transport equipment (351)
2	Food, drink & tobacco (15–16)	19	Aircraft and spacecraft (353)
3	Textiles, textile prod, leather & footwear (17–19)	20	Railroad equip and transport equip nec (352+359)
4	Wood, wood and cork prods (20)	21	Furniture, misc manufacturing/recycling (36–37)
5	Pulp, paper, printing/publishing (21–22)	22	Electricity, gas and water supply (40–41)
6	Coke, refined petroleum prod & nuclear fuel (23)	23	Construction (45)
7	Chemicals and chemical prods (24)	24	Wholesale and retail trade; repairs (50–52)
8	Rubber and plastic prod (25)	25	Hotels and restaurants (55)
9	Non-metallic mineral products (26)	26	Transport and storage (60–63)
10	Basic metals (27)	27	Post and telecommunications (64)
11	Fabricated metal products (28)	28	Financial intermediation (65–67)
12	Mechanical engineering (29)	29	Computer and related activities (72)
13	Office, accounting and computing equip (30)	30	Research and development (73)
14	Electrical machinery & apparatus, nec (31)	31	Real estate and other business (70, 74)
15	Electronics and communication equip (32)	32	Agriculture, forestry and fishing (1, 2, 5)
16	Medical, precision/optical instruments (33)	33	Public admin, community/personal serv (75–99)
17	Motor vehicles, trailer/semi trailers (34)		

Data source: See box C.1.

Despite the importance of industry structure for some countries, the overall evidence suggests that industry structure is an incomplete explanation for international variations in BERD intensities. Even with standardised industry structures, considerable variations in BERD intensities are evident across countries. And the rankings of the 19 countries examined do not change substantially when structure is adjusted for. Overall, industry structure alone accounted for around one-third of the variation in BERD intensity between countries.[11]

[11] The following relationship was found: $R_i = -0.47 + 1.21R_{ia}$; where R_i is unadjusted BERD intensity of country i; and R_{ia} is structure-adjusted BERD intensity (which removes industry structure as a factor); R-squared = 0.69, n = 18, correlation coefficient = 0.84. Ireland was omitted from the regression as its shift-share estimates are affected by aggregation errors due to the absence of detailed industry data on the chemicals and pharmaceuticals industry.

Figure C.5 **BERD intensities across OECD countries adjusted for variations in industry structure[a], 2002**



a All countries are assumed to have the same industry structure. Estimates are calculated on the basis of R&D intensity per industry with the weights of each industry corresponding to their share of total business-sector value added on average across the 19 OECD countries listed (which combined accounted for over 90 per cent of OECD GDP and business value-added in 2002).

Data source: See box C.1.

The impact of industry aggregation

The observed importance of industry structure for some countries, including Australia, is highly sensitive to the level of industry aggregation employed. Analysis by the OECD (2006b) referred to above, for example, found that Australia's BERD intensity only increases by 0.2 percentage points when adjusted for structural differences. The OECD analysis examined the impact of BERD/VA ratios by the imposition of the G7 structure on each country. Although the G7 structure is not identical to the OECD average structure employed here, the high concentration of OECD R&D in these countries means that differences are not large.

Discussions with the authors of the OECD report prior to, and following, the release of the Commission's draft report have confirmed that the major source of the difference between their results and those reported here lies in the level of industry aggregation employed. The OECD analysis was based on an eight industry breakdown of BERD.[12] While this level of analysis is sufficient to demonstrate their main point — that structural differences were not the major driver of differences in BERD intensities across the OECD as a whole — it also meant that a large degree of industry diversity was masked in some countries, including Australia.

To illustrate this, equation {2} was recalculated based on only 5 broad industries — mining, manufacturing, electricity, gas and water, construction and services. The resulting estimates found that a much smaller structural effect was evident for most countries. In the case of Australia, the imposition of the OECD's broad structure only resulted in an increase in BERD intensity of 0.2 percentage points. This was one quarter of the structural effect observed with the more detailed analysis and around the same result found in the OECD analysis.

Problems occur for shift-share analysis when industries with markedly different BERD intensities are grouped together. The more aggregated the data the greater is the extent to which differences are masked. For example, it is well known that Australia's manufacturing sector is highly oriented to industries that add value to agricultural and mineral products. And these industries have lower R&D intensities than other areas of manufacturing. Although Australia also has some higher BERD intensity manufacturing industries, the relative proportion of low and high BERD industries are very different to the OECD average.

The forgoing discussion highlights the sensitivity of the forgoing analysis to the level of aggregation employed for Australia — with the observance of larger structural effects when a more detailed industry breakdown is employed.

Adjusting for intensity

As noted above, structural factors were not the sole drivers of variations in BERD/VA ratios across OECD countries. Differences in R&D intensities *within* industries across countries also play a role. In the communications sector, for example, R&D as a share of value added in OECD countries ranges from a low of 4 per cent in Poland to a high of 65 per cent in Sweden. In the transportation sector, corresponding values range from a low of 2.5 per cent in Norway to 24 per cent in Sweden. In the service sector, overall levels of R&D as a share of value added were

12 The analysis presented here was based on a 31 industry breakdown. Other sources of discrepancy include a different raw dataset (see box C.1) as well as a different choice of years — the OECD used period averages for 1999 to 2002 which would be expected to lessen the impact of year-to-year volatility.

much lower, ranging from 0.1 per cent in Poland to 0.9 in the United States (Sheehan and Wyckoff 2003).

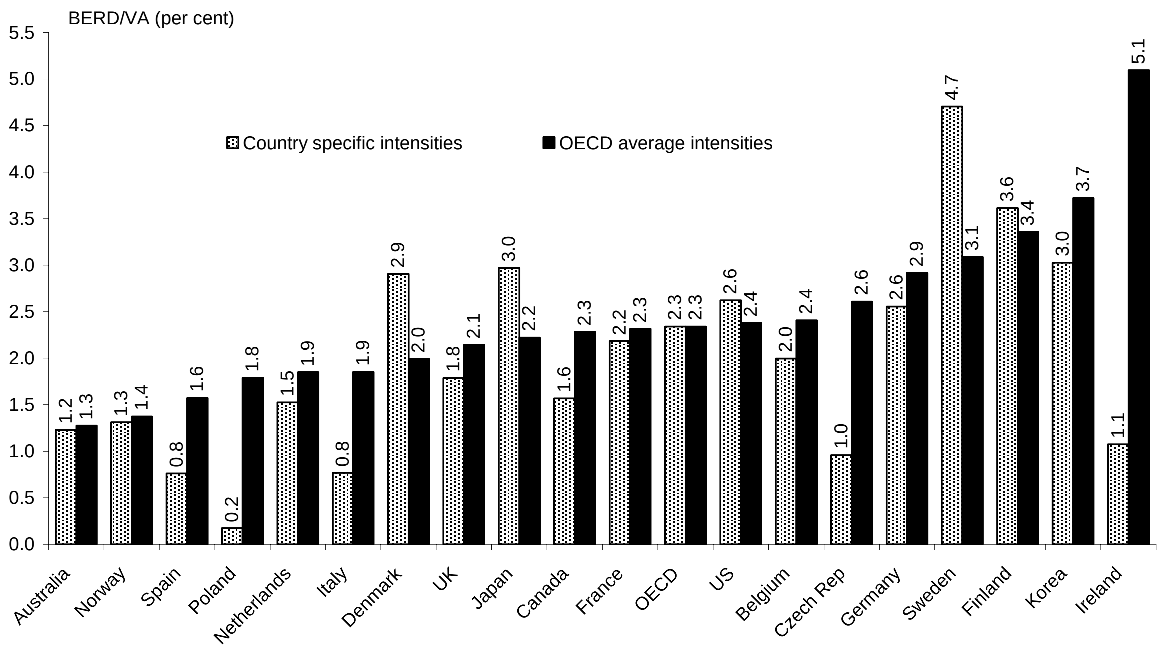
One means of examining the role played by intercountry differences in industry R&D intensities is to apply uniform OECD average BERD/VA ratios for each industry to all countries and recalculate the overall business sector R&D intensity for each country:

$$R_{A2} = \sum_{j=1}^{31} S_{jA} R_{jO} \qquad \{3\}$$

R_{A2} is the BERD/VA ratio that would occur if Australia were given the OECD average industry BERD intensities and R_{jO} is the OECD average BERD intensity for industry j.

As expected, an examination of the resulting 'intensity-adjusted' BERD/VA ratios reveals a convergence across OECD countries, with increases in most below average countries (including Australia, Norway, Spain, Poland, Netherlands, the United Kingdom, Czech Republic and Ireland) and decreases in leading R&D countries such as Sweden, Finland, Japan and Denmark, figure C.6).

Figure C.6 **BERD intensities across OECD countries if all countries adopted OECD average industry intensity levels, 2002**



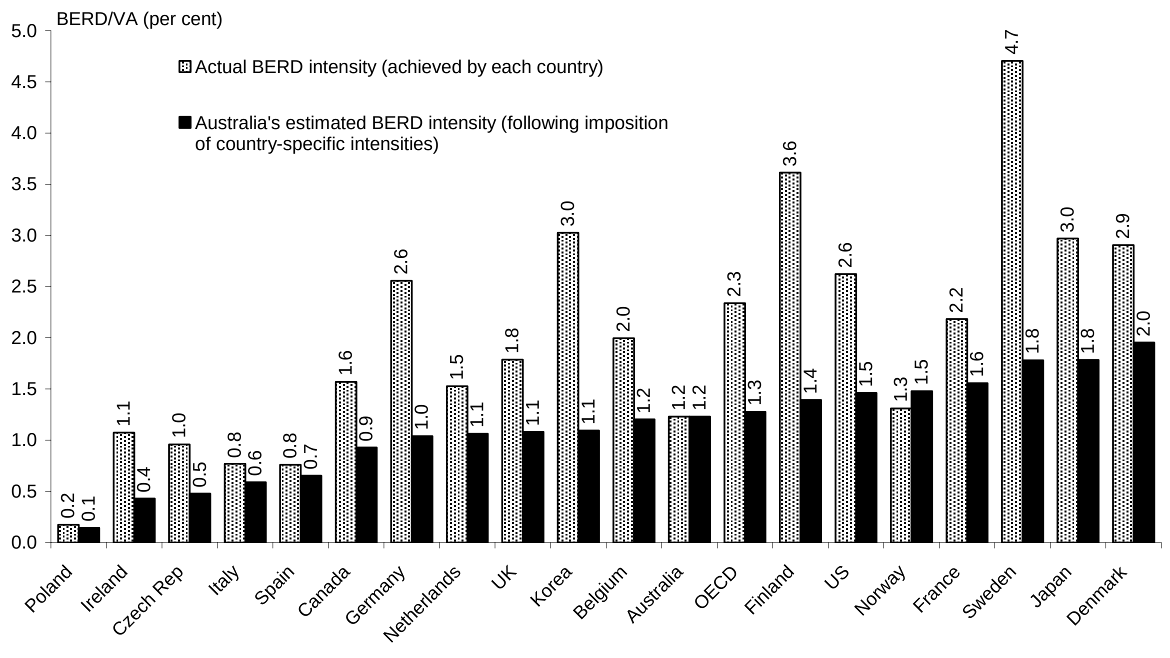
a All countries are assumed to have OECD average intensities. Estimates were calculated for each country by multiplying each industry's observed value added by OECD average BERD intensities.

Data source: See box C.1.

In Australia's case, applying OECD average intensities to Australia results in a minor increase in BERD intensity — of 0.05 percentage points. The fact that Australia's 'intensity-adjusted' BERD ratio (1.3 per cent) was the lowest observed of all countries reinforces the importance of structural differences for Australia highlighted above.

Clearly, it is possible to achieve larger increases for Australia by selectively applying R&D intensities from a subset of countries. For example, applying intensities for countries such as the United States, Japan and Denmark results in more substantial increases in Australia's BERD intensity of 0.3, 0.6 and 0.8 percentage points respectively (figure C.7 — actual country BERD intensities are included for purposes of comparison). While this moves Australia closer to the OECD average, the fundamental point remains that Australia would need to achieve above average 'within industry' R&D intensities to achieve an overall BERD intensity approaching, but still below, the OECD average. Or, put another way, Australia is highly unlikely to achieve the OECD average BERD intensity with its existing industry structure.

Figure C.7 **Australia's BERD intensities if it adopted the industry R&D intensities of each OECD country[a], 2002**



a These results can also be interpreted as the BERD intensities that OECD countries would achieve if they were given Australia's industry structure, while maintaining their own industry intensities. In other words, if the OECD overall were to be given Australia's industry structure, its BERD intensity would drop from 2.3 per cent to 1.3 per cent.

Data source: See box C.1.

This approach was adopted by Davis and Tunny (2005) in assessing the impact of industry structure on Australia's BERD intensity. Although the coverage and aggregation differed for their study, the authors reached similar conclusions to those reported here.

Decomposition

A drawback of the preceding partial analysis in {2} and {3} is that the sum of the total impacts does not equal the total differences between each country's BERD intensity and the OECD average intensity. For example, in Australia's case, adjusting for structure (+0.66 percentage points) and intensity (+0.05 percentage points) only accounts for 0.71 percentage points of the 1.1 percentage point difference between Australia's BERD intensity and the OECD average. The remaining 0.39 percentage points is a 'mix effect' which represents the interaction of structure and intensity effects.

However, it is possible to allocate this mix effect among the structure and intensity effects to allow a full decomposition of the difference between each country's BERD/VA ratios and the OECD average.

The difference in intensity between Australia and the OECD (ΔI_{AO}) is:

$$\Delta I_{\mathrm{AO}} = \sum_{\mathrm{j=1}}^{31} (S_{jA} R_{jA} - S_{jO} R_{jO}) \qquad \{4\}$$

where S_{jA} is the share of industry j in Australia's value added; R_{jA} is the intensity of BERD in industry j in Australia; S_{jO} is the share of industry j in OECD value added; R_{jO} is the intensity of BERD in industry j in the OECD.

There are two (symmetric) representations of ΔI_{AO}:

$$\Delta I_{\mathrm{AO}} = \sum_{\mathrm{j=1}}^{31} (S_{jA} R_{jA} - S_{jO} R_{jO}) = \sum_{\mathrm{j=1}}^{31} (S_{jA} R_{jA} - S_{jO} R_{jO} + (S_{jA} R_{jO} - S_{jA} R_{jO})) = \sum_{\mathrm{j=1}}^{31} (S_{jA} \Delta R_j + R_{jO} \Delta S_j) \qquad \{5\}$$

and that also

$$\Delta I_{\mathrm{AO}} = \sum_{\mathrm{j=1}}^{31} (S_{jA} R_{jA} - S_{jO} R_{jO}) = \sum_{\mathrm{j=1}}^{31} (S_{jA} R_{jA} - S_{jO} R_{jO} + (S_{jO} R_{jA} - S_{jO} R_{jA})) = \sum_{\mathrm{j=1}}^{31} (S_{jO} \Delta R_j + R_{jA} \Delta S_j) \qquad \{6\}$$

where $\Delta R_j = R_{jA} - R_{jO}$ and $\Delta S_j = S_{jA} - S_{jO}$;

which on averaging gives:

$$\Delta I_{AO} = \sum_{j=1}^{31} (\Delta R_j \times \overline{S}_j) + \sum_{j=1}^{31} (\Delta S_j \times \overline{R}_j) \qquad \{7\}$$

where; $\overline{S}_j = (S_{jA} + S_{jO})/2$,

and $\overline{R}_j = (R_{jA} + R_{jO})/2$; and

$$\sum_{j=1}^{31} (\Delta R_j \times \overline{S}_j) = \text{difference due to intensities} \qquad \{8\}$$

$$\sum_{j=1}^{31} (\Delta S_j \times \overline{R}_j) = \text{difference due to structure} \qquad \{9\}$$

Applying this approach[13] we see that the gap of 1.1 percentage points between Australia's BERD intensity and the OECD's BERD intensity reflects 0.9 percentage points (or 77 per cent) due to structural differences and 0.2 (or 23 per cent) due to differences in intensities within industries (figure C.8).

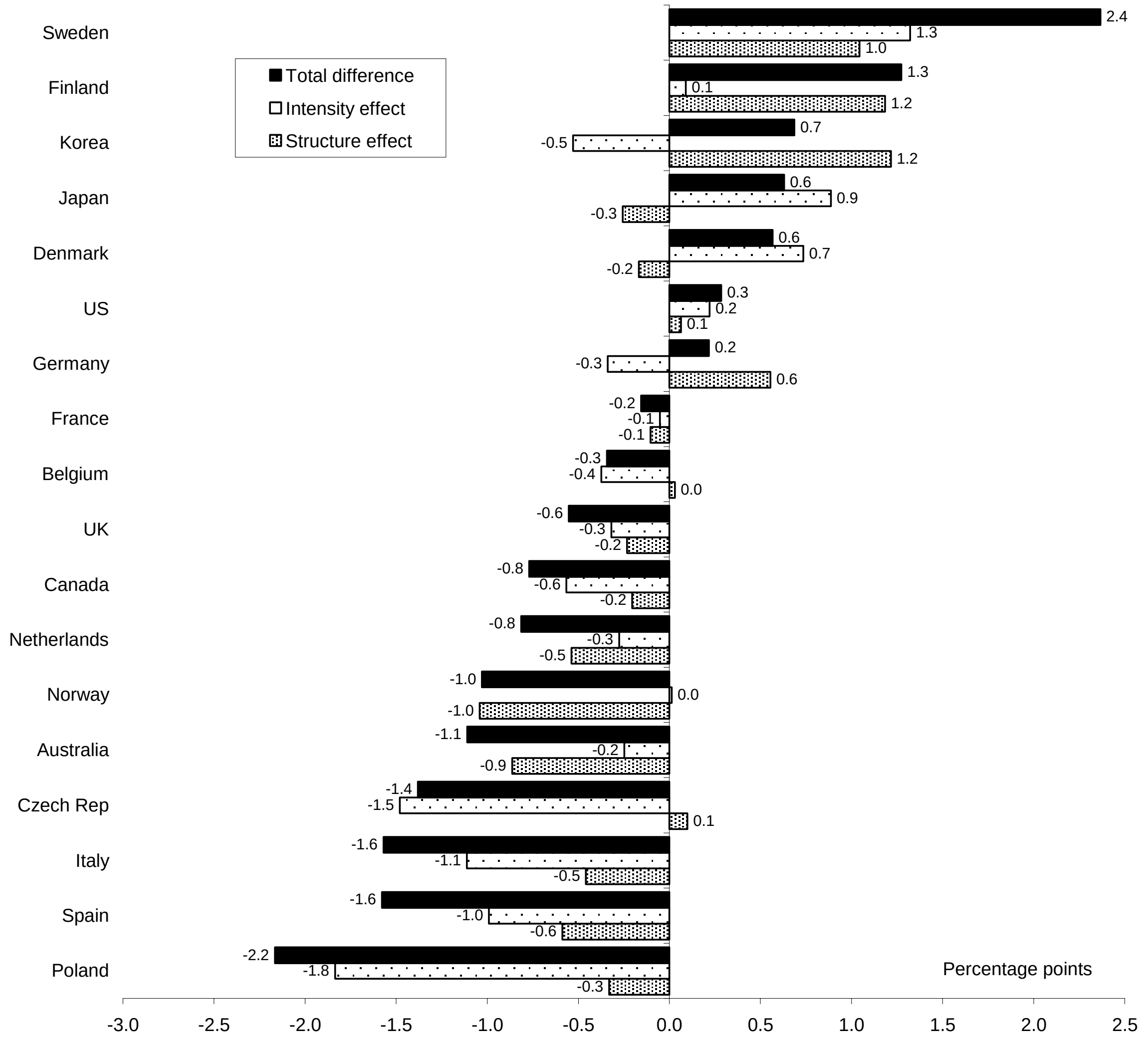
As noted earlier, this is not the norm for OECD countries, with structural effects outweighing intensity effects in only seven countries — whereas intensity effects were the major contributor to divergence in overall BERD/VA ratios from the OECD average for the remaining eleven countries.

However, for Australia, the decomposition results re-emphasise the importance of industry structure as the key driver of differences between the Australia's BERD intensity and the OECD average. In terms of intercountry rankings, when structure is adjusted for, including the structural component of the mix effect, Australia's BERD intensity ranking increases from 14th to 8th of the 18 countries for which comparable data are available.[14] Overall, Australia was one of a large group of countries with structure-adjusted BERD intensities of around 2 per cent (figure C.9).

13 For a more detailed explanation of the 'linear interpolation' method — which provides the underlying analytical motivation for deriving the partial effects as the average of the multiple representations of ΔI_{AO} — see PC 2005b (Technical Paper 6).

14 This represents a greater improvement in Australia's ranking relative to the partial adjustment for structure made earlier (figure C.5). It reflects the much smaller role of intensity effects in Australia relative to other countries identified in the partial analysis (figure C.6) and the impact this has on the apportioning of the mix effect. However, Australia's precise ranking, whether following partial or total structural adjustment, is less important than the substantial convergence to the OECD average evident in both cases.

Figure C.8 **Decomposition of differences in country[a] BERD/value-added ratios from OECD average, 2002**

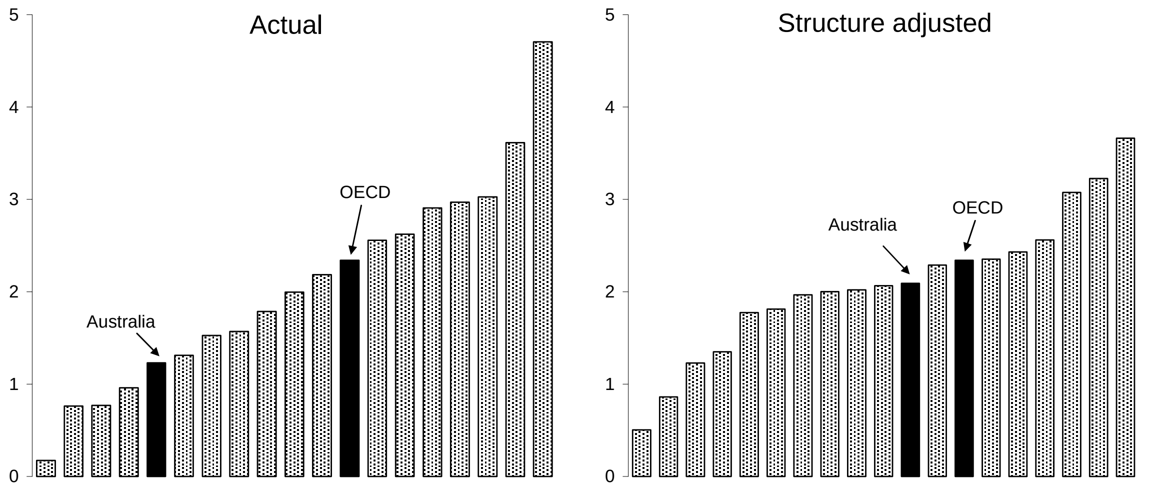


a Data for Ireland are omitted due to aggregation problems stemming from the absence of detailed industry data on the chemicals and pharmaceuticals industry.

Data source: See box C.1.

Figure C.9 **Comparison of actual and structure adjusted BERD intensities across OECD countries**

BERD/value-added ratio (per cent), 2002



Data source: Figure C.8.

Structural change

In addition to providing useful information about existing BERD intensities within countries, industry structure provides an insight into the capacity for a country to increase its overall BERD intensity. Sheehan and Wyckoff (2003, pp. 22–3), for example, consider that:

> High-technology sectors offer considerably more opportunity than other industry sectors for improving R&D as a share of value added, and high levels of overall R&D intensity are unlikely to be achieved without them.

Industry structures are not fixed — the industrial composition of countries is constantly changing (PC 1998 and 2003b). In turn, this could be expected to influence R&D intensities over time.[15]

A number of participants noted the importance of structural change in the context of BERD intensity. The AVCC, for example, contended that:

> Australia cannot and should not rely on our current industry structure to maintain future living standards … [The] interaction between sectoral BERD intensity and sectoral strength is a 'chicken and egg' issue. (sub. 60, p. 3)

[15] Some evidence on the related question of the impact of public support for R&D in Australia over the past decade and a half on firm and industry transformation is examined in appendix T.

A standard approach for measuring rates of structural change (PC 2003b) is to derive structural change indexes to facilitate comparisons, both between countries, and over time. Structural change (SC) is defined as:

$$SC_t = 100 \times \sum_{j=1}^{31} \frac{1}{2} \left| S_{jt} - S_{jt-1} \right| \qquad \{10\}$$

where S_{it} is the value added share of industry j at time t. The resulting index is bounded between zero and one hundred, with a higher number representing more structural change.

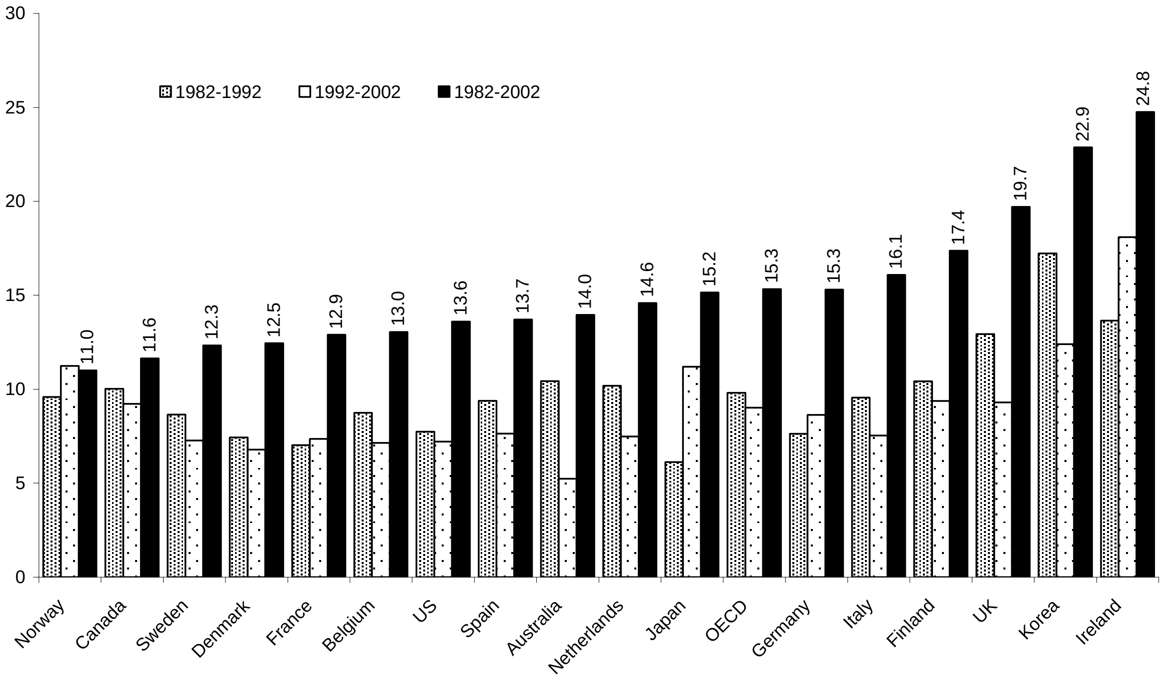
Estimates of structural change for the past two decades indicate that there have been considerable variations in the degree of change across countries and over time — ranging from a low of 11 per cent in Norway to a high of 25 per cent in Ireland (figure C.10).

Between 1982 and 2002, Australia registered an SCI value of 14 per cent, or 0.7 per cent a year. This means that in 2002, 14 per cent of total Australian non-farm business value added would have to be moved into different industries in order to re-establish the industry value added shares prevailing in 1982. Australia's rate of structural change was just under the average for the OECD countries studied (15.4 per cent) over the period, however its rate of change from 1992 to 2002 was the slowest of the OECD countries examined. Rates of structural change were generally slightly higher in the 1980s relative to the 1990s for most countries, although there were some exceptions, including Japan, Ireland and Germany. Australia, along with the United Kingdom, Korea and the Netherlands, registered considerably stronger rates of structural change in the 1980s relative to the rates recorded in the 1990s.

Although SCIs indicate that ongoing structural change is the norm in all OECD countries over the past decades, including Australia, they do not reveal the *direction* of structural change and how it impacts on aggregate BERD intensity.

Figure C.10 **Indexes of structural change, 1982 to 2002**[a]

Value added, current price shares, per cent



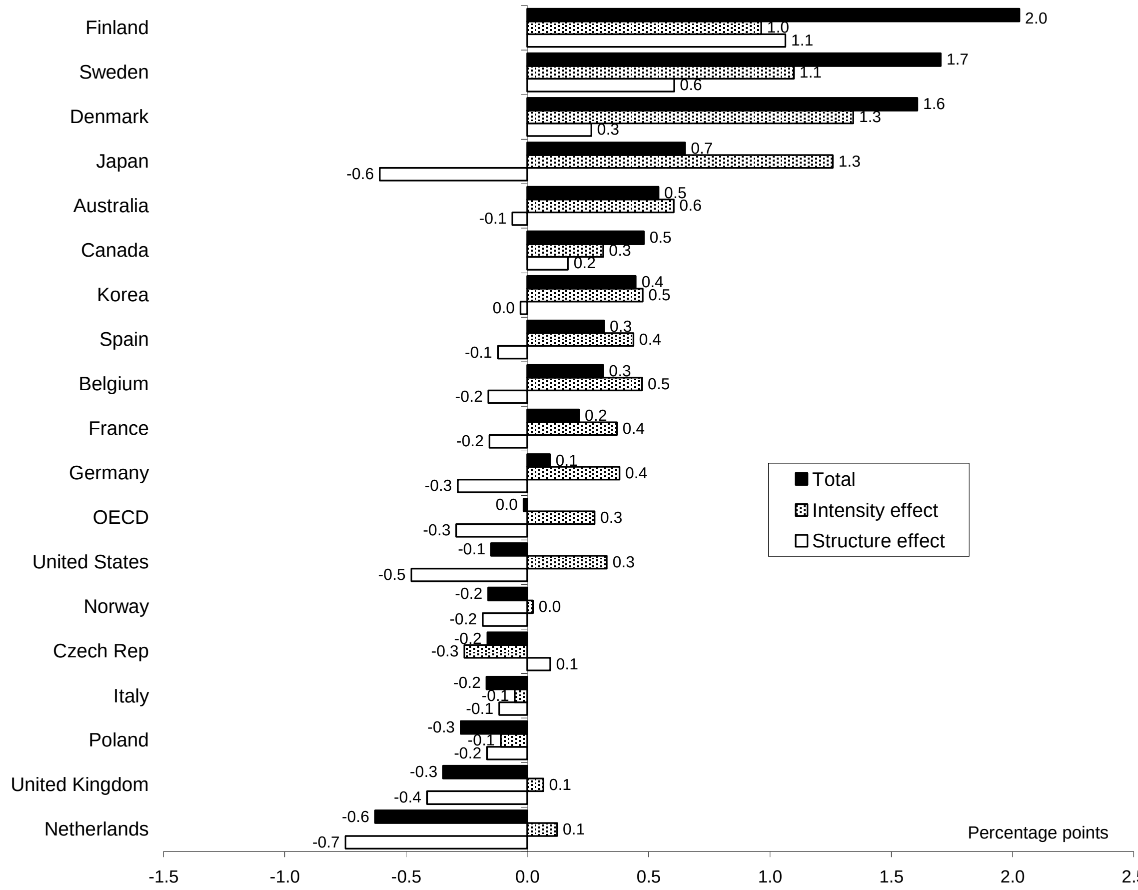
a Subtotals for each decade do not sum to the total for the period due to changes, including reversals, in the direction of structural change across decades. SCIs are highly sensitive to the level of industry aggregation employed, with a lower level of aggregation resulting in the observance of more structural change (PC 2003b).

Data source: See box C.1.

To determine whether the structural change has contributed to increases in BERD/VA ratios it is possible to employ the same methodology outlined in {4} – {9} to decompose the change in BERD intensity over time within each country into a structure effect and an intensity effect (figure C.11).

The results for Australia indicate that, overall, structural factors have had a minor impact on BERD intensity in Australia over the past decade and a half. In fact, the direction of structural change has been slightly away from high R&D industries — with declines in the value added shares of high R&D industries exerting a drag of around 0.1 percentage points on the total increase in observed BERD intensity between 1987 and 2002. Put another way, in the absence of structural change Australia's BERD intensity would have increased by 0.6 percentage points (compared with an actual increase of 0.5 percentage points).

Figure C.11 **Decomposition of differences in BERD/value-added ratios between 1987 and 2002**[a]



a Data for Germany, Italy and the OECD (total) cover the period 1991 to 2002. US data cover the period 1989 to 2002. As the results for Korea cover the period from 1995, Czech Republic from 1993 and Poland from 1994, these countries were omitted from the OECD total BERD/VA ratio — which remained flat over the period. This contrasts with the OECD MSTI Database 2006 estimates for the OECD overall of a slight (0.08 percentage points) increase in the BERD/VA ratio between 1991 and 2002. This difference largely reflects the smaller range of countries employed in the analysis presented here. Individual country estimates of total changes in BERD/VA ratios are close, but not identical, to OECD MSTI estimates. Data for Ireland are omitted due to aggregation problems.

Data source: See box C.1.

Most other OECD countries experienced a similar 'structural drag', although, on average, the structural shifts away from high R&D industries were larger than those experienced in Australia (-0.3 percentage points on average across the OECD). Overall, structural effects reduced BERD intensities in 13 of the 18 countries examined. Although structural effects also made positive contributions to the growth in BERD intensity in five countries, the only country in which structural effects outweighed intensity effects as the driver of *increases* in BERD intensity was Finland.

In contrast, intensity effects exerted a positive effect on BERD intensities in most countries, with an overall impact of an increase of 0.3 percentage points. The only exceptions were the Czech Republic, Poland and Italy. The generally weak or negative contribution of changes in industry structure to BERD intensity observed here are not surprising. Service industries have historically recorded low R&D intensities on average, in part due to the way R&D data are reported. And structural shifts away from manufacturing industries towards services industries have been observed across most high income countries (PC 2003b).

Hence, these results indicate that over the past decade and a half increases in BERD/VA ratios, and hence R&D/GDP ratios, have generally been driven by increases in individual industry BERD intensities rather than through structural change.

C.4 Firm size

Australia's industrial structure is also characterised by a preponderance of small firms and relatively few multinational corporations headquartered here. The Department of Industry, Tourism and Resources (sub. 93) noted, for example, that Australia is home to only two of the top 1000 global corporate R&D spenders.[16]

While both small and large firms play an important role in innovative performance, their relative importance for business R&D varies. For example, in their submission, Jense et al. stated:

> [T]he relationship between firm size and innovation is well-researched in the economics literature. Schumpeter (1934), for example, argued that large firms are more innovative since they have the retained earnings with which to re-invest in risky innovative activities. There may also be an advantage to being large if there are economies of scale in R&D production and the innovative process more broadly. (sub. 9, p. 12)

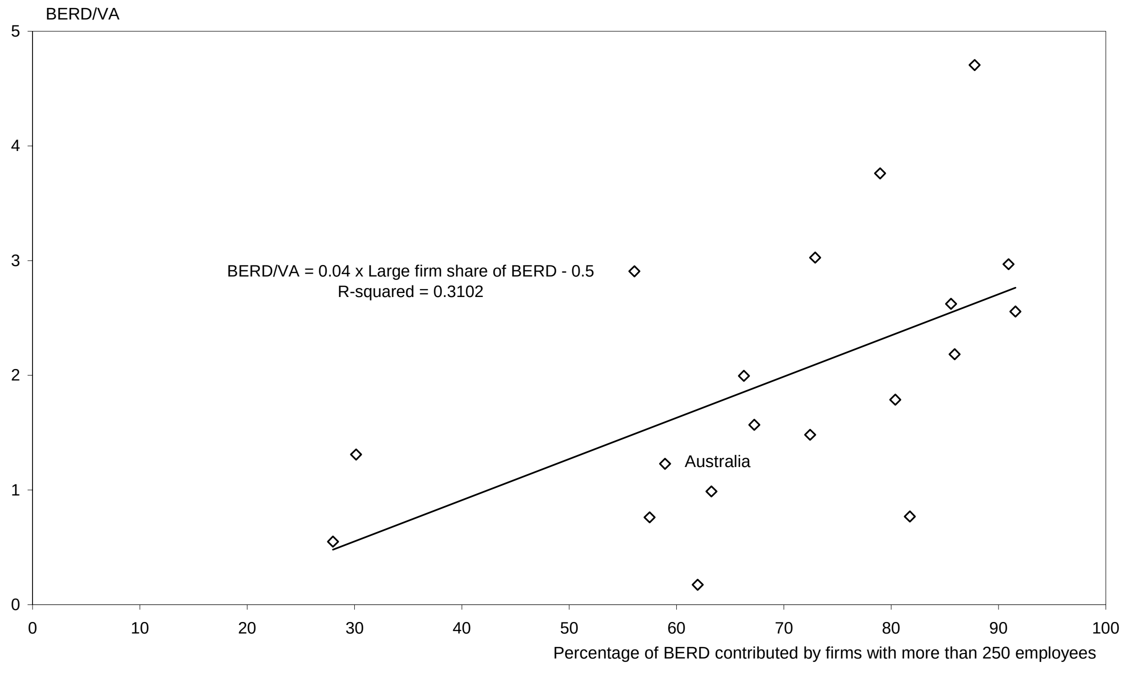
In OECD countries, the share of R&D performed by small and medium-sized enterprises (SMEs) (defined here as firms with fewer than 250 employees) is generally greater in smaller economies than in larger ones.

Firms with fewer than 250 employees account for a large share of business R&D in New Zealand (72 per cent), Norway (70 per cent), Ireland and Greece (49 per cent), the Slovak Republic (46 per cent) and Australia (42 per cent). In the larger EU

[16] While Australia's industry structure is one of the major reasons for this, Australia's geographic isolation is also likely to play a role. This issue is not examined here. However, an overview of recent studies that examine R&D and the role of foreign exposure and trade intensity is included in Tunny (2006).

countries, their share is less than one-fifth, and in the United States it is less than 15 per cent. Japan has one of the lowest shares among OECD countries, with only 9 per cent. Moreover, firms with fewer than 50 employees account for a significant share of business R&D (over one-fifth) in Norway, New Zealand, Ireland, Denmark and Australia. When these data are compared with BERD intensities a positive relationship is evident (figure C.12).

Figure C.12 **Share of BERD performed by firms with over 250 employees compared with BERD/VA ratios across OECD countries, 2002**



Data source: See box C.1.

Although there are insufficient data to incorporate firm size into the decompositions presented earlier, it is clear that these factors are both important (and interrelated) influences on national BERD intensity. Combined, firm size and industry structure accounted for almost 60 per cent of the variation in BERD intensities across OECD countries.[17]

[17] The following relationship was found $R_i = -1.08 + 1.24R_{ia} + 0.53L_{ia}$; where R_i is BERD intensity of country i; R_{ia} is adjusted BERD intensity; L_{ia} is the large business share of BERD; R-squared = 0.58, n = 17, F-stat = 9.8. Industry structure and firm size were found to be positively correlated (correlation coefficient = 0.33), an unsurprising result given the generally higher incidence of small firms in the service sector.

C.5 Researcher wages

The conventional image of R&D involves expensive scientific equipment such as supercomputers, linear accelerators, satellites or wind tunnels. However, the biggest part of R&D expenditures is actually wages paid to researchers. As labour costs comprise around half of R&D costs in OECD countries on average, differences in wage rates across countries can have an impact on measured R&D spending and R&D intensities.

Dougherty et al. (2003), for example, found substantial differences (up to one-third) were evident in labour costs for scientists, researchers and support staff for a selection of the major R&D performing OECD countries. They note these differences are not specifically taken into account in official OECD R&D statistics. When these differences were accounted for, a convergence in R&D spending levels (and R&D intensities) across countries was evident, with most countries making ground on the United States due to its relatively higher wage rates for researchers.[18]

Although the study did not include Australia, an examination of Australia's labour costs for scientists suggests that Australia's R&D spending may be understated relative to the United States at least — which, as noted earlier, accounted for around 42 per cent of OECD R&D in 2002. For example, broad estimates from the Association of Professional Engineers, Scientists and Managers, Australia (APESMA) on salaries for graduate and experienced engineers, professionals and scientists for 2005 suggest a wage gap of between 30–60 per cent for Australian graduates and 10–25 per cent for experienced professionals relative to their United States counterparts (figure C.13).

However, although Australia's lower wages differences will affect dollar value comparisons of R&D between countries, this does not necessarily mean that R&D intensities will be affected. The key factor here is the wages of scientists and research staff in Australia relative to the average wage in Australia. If this ratio differs between countries then R&D intensities will not provide an accurate indication of each country's relative commitment to R&D.[19] Difficulties in obtaining consistent detailed data on this measure across countries, have meant that this issue is not examined here.

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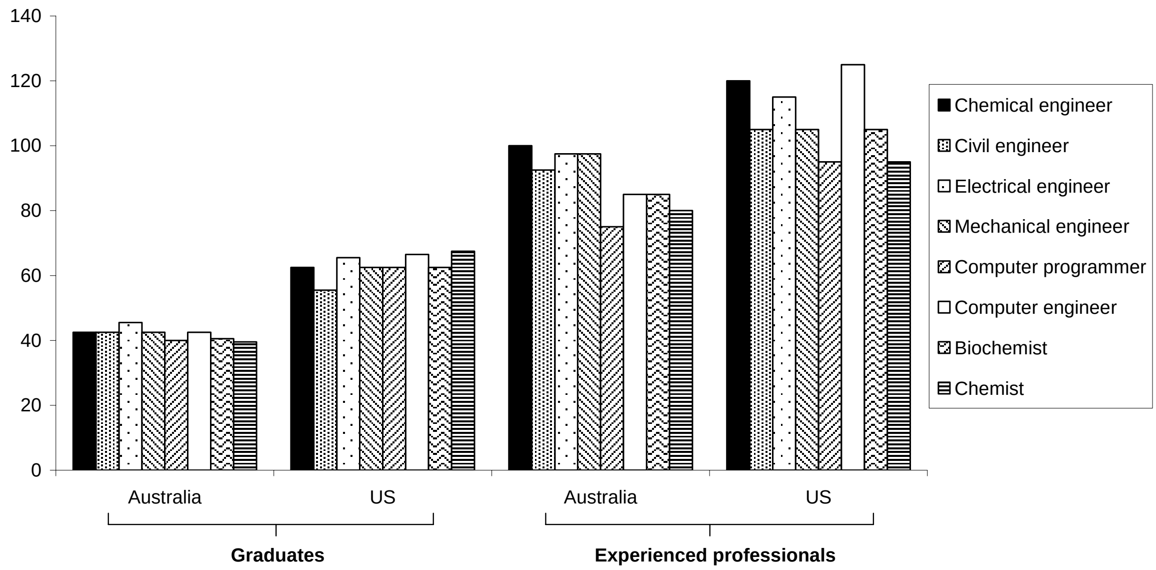
[18] Dougherty et al. (2003) for example, found that average R&D labour price levels per unit of R&D labour relative to the United States for manufacturing industries were lower in France (86 per cent); Germany (93 per cent); Japan (97 per cent), Netherlands (79 per cent) and the UK (63 per cent) in 1997.

[19] PPPs used by the OECD to convert all R&D spending to a common currency will pick up differences in economy-wide average wages across countries, but do not capture R&D-specific costs (including researcher wages).

Another indicator of a country's commitment to R&D is full-time-equivalent researchers per thousand workers (figure C.14). Australia's figure, of 7.8 in 2002, was above the OECD average (6.9) and eighth in the OECD overall — a jump of nine places relative to Australia's R&D intensity ranking based on expenditure in the same year.[20] Australia registered the equal second largest jump in ranking after New Zealand (16 places) — Norway also increased nine places. The largest falls in ranking were registered by Switzerland and Korea (down 11 and 8 places respectively). These differences notwithstanding, there was generally a strong positive correlation between rankings based on R&D intensity and researcher intensity across the OECD.[21]

Figure C.13 **Comparison of median Australian and United States salaries for research professionals, 2005**

$A 000 current prices



Data source: APESMA 2005, http://www.apesma.asn.au/newsviews/professional_network/2005/dec_jan_05_06/salaries_here_there.asp (accessed June 2006).

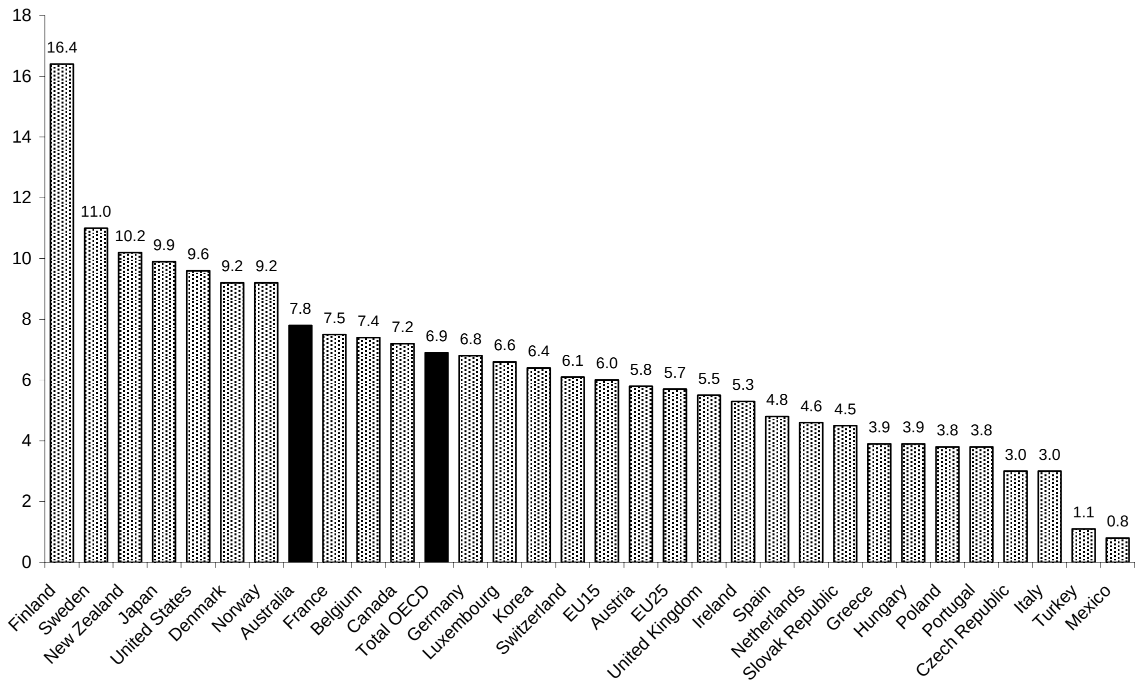
Australia's changed position in terms of researcher intensity may reflect, at least it part, lower wages relative to the OECD average. However, the labour-intensive character of much of the R&D undertaken in Australia relative to larger countries is likely to be the major factor. Given Australia's higher concentration in research fields such as health and the environment it would be expected that researchers in

[20] All comparisons relate to 2002 as consistent data on researchers are not available for later years for a full set of OECD countries.

[21] R&D intensities and full-time equivalent researchers per thousand workers registered a correlation coefficient of 0.77 for the 29 OECD countries for which consistent data were available. Iceland is excluded due to lack of data on researchers.

Australia would not, on average, require as much capital expenditure as countries with, for example, strong aerospace, defence or nuclear research programs. Barlow (2006) notes that Australia is one of the few countries with substantial weighting in its research output towards the life sciences. Of all Australian scientific publications between 1996 and 2000, 30 per cent were in the medical and health sciences, 20 per cent were in biological sciences, and 10 per cent were in agricultural, veterinary and environmental sciences.

Figure C.14 **Total researchers per thousand workers across OECD countries, 2002**



Data source: OECD Main Science and Technology Indicators Database (accessed February 2007).

C.6 Public support

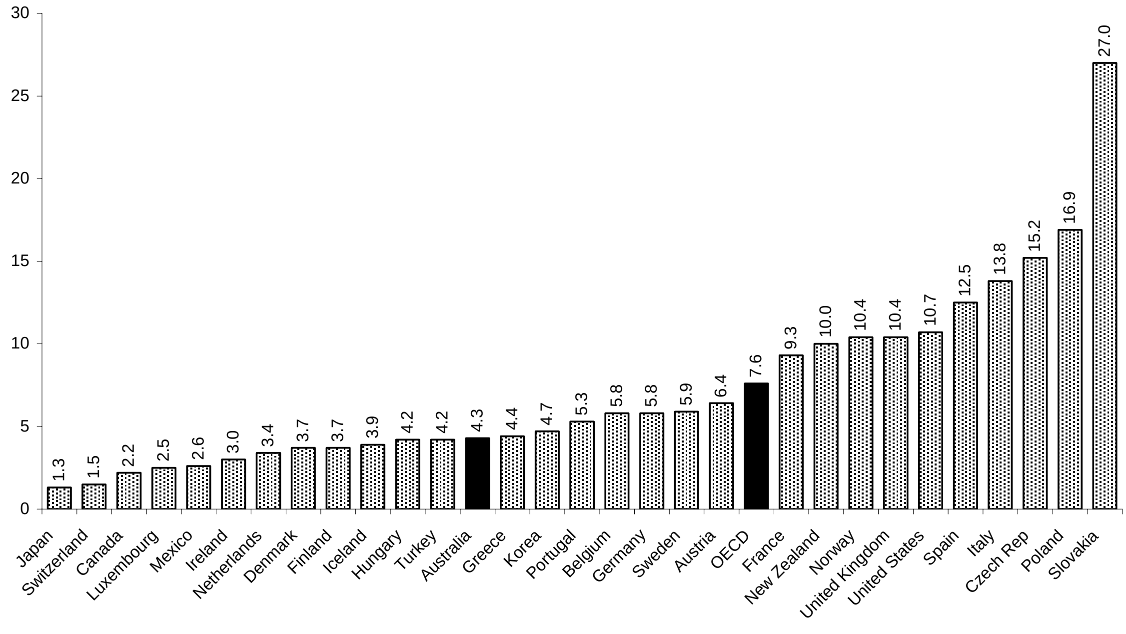
Participants have also noted that a direct comparison of the proportion of Government funded BERD indicates that Australia is also below the OECD average. For example, the AVCC claimed that under-funding of BERD by government has contributed to the structural differences in Australia that contribute to low R&D intensity:

> Many of Australia's industry sectors are small because of Australia's historic lack of support for innovation. (sub 60, p. 3)

Latest OECD data indicate that public financed BERD, in Australia was 4.3 per cent of total BERD in 2004. This was well below the OECD average of 7.6 per cent (figure C.15), which largely reflected higher public spending on BERD by the United States, the United Kingdom and France. Although the data do not provide a precise breakdown, some of this spending is likely to reflect higher defence spending in these countries. Defence budget R&D as a percentage of total government budget appropriations or outlays for R&D (GBAORD) in 2004 for the United States (55.7 per cent), the United Kingdom (31.0 per cent) and France (22.2 per cent) were considerably higher than Australia (5.6 per cent).[22]

Figure C.15 **Percentage of BERD financed by government**

2004 (or latest available year)



Data source: OECD MSTI Database 2007.

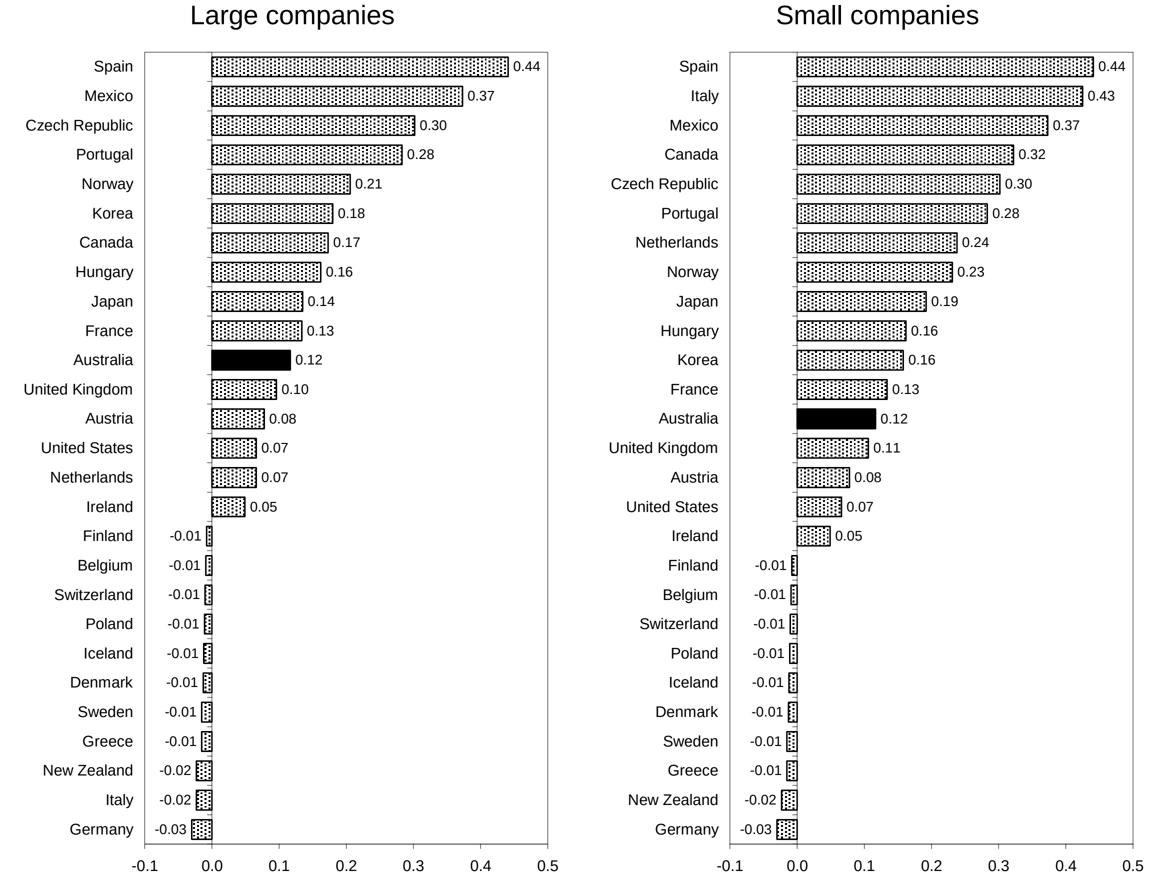
That said, regardless of the type of BERD expenditure funded by government, this indicator does not provide a complete picture of intercountry differences in support for BERD as it excludes assistance via tax concessions. For example, in the five years to 2003-04, Australia provided more than twice as much assistance to BERD via the R&D tax concession than in direct assistance (as measured by the OECD).

22 The National Science Foundation (2006) notes that although defence-related R&D does result in spillovers that produce social benefits, non-defence R&D is more directly oriented toward national scientific progress, standard-of-living improvements, economic competitiveness, and commercialisation of research results.

It is difficult to pinpoint exactly how Australia measures up with other countries in terms of the level of support for BERD via tax measures. The OECD notes that such comparisons are difficult as detailed data on tax expenditures from public budgetary accounts are available for only a few countries (OECD 2006b).[23]

Warda (2006) employs B-indexes to compare the relative net subsidy equivalent effects across countries (box C.2). According to this measure, Australia's ranks around the mid-point for the OECD (figure C.16).

Figure C.16 **R&D tax subsidies across OECD countries based on B-indexes**[a]
2003 (or latest available year)



a Data presented here are the amount of tax subsidy, which is equal to 1 minus the B-index — with a larger number representing a greater inducement effect.

Data source: Warda 2006.

23 For a discussion of the difficulties in finding reliable comparisons of fiscal incentives for R&D across countries see HM Treasury (2005).

Box C.2 **B-indexes — an explanation**

The amount of tax subsidy to R&D is calculated as 1 minus the B-index. The B-index is defined as the present value of before-tax income necessary to cover the initial cost of R&D investment and to pay corporate income tax, so that it becomes profitable to perform research activities. This means that the calculation includes the consideration of depreciation allowances, tax credits and other allowances on R&D assets.

Algebraically, the B-index is equal to the after-tax cost of an expenditure of $1 on R&D divided by one minus the corporate income tax rate. The after-tax cost is the net cost of investing in R&D, taking into account all the available tax incentives.

$$\text{B-Index} = \frac{(1 - A)}{(1 - \tau)}$$

where A = the net present discounted value of depreciation allowances, tax credits and special allowances on R&D assets; and τ = the statutory corporate income tax rate (CITR). In a country with full write-off of current R&D expenditure and no R&D tax incentive scheme, A = τ , and consequently B = 1. The more favourable a country's tax treatment of R&D, the lower its B-index.

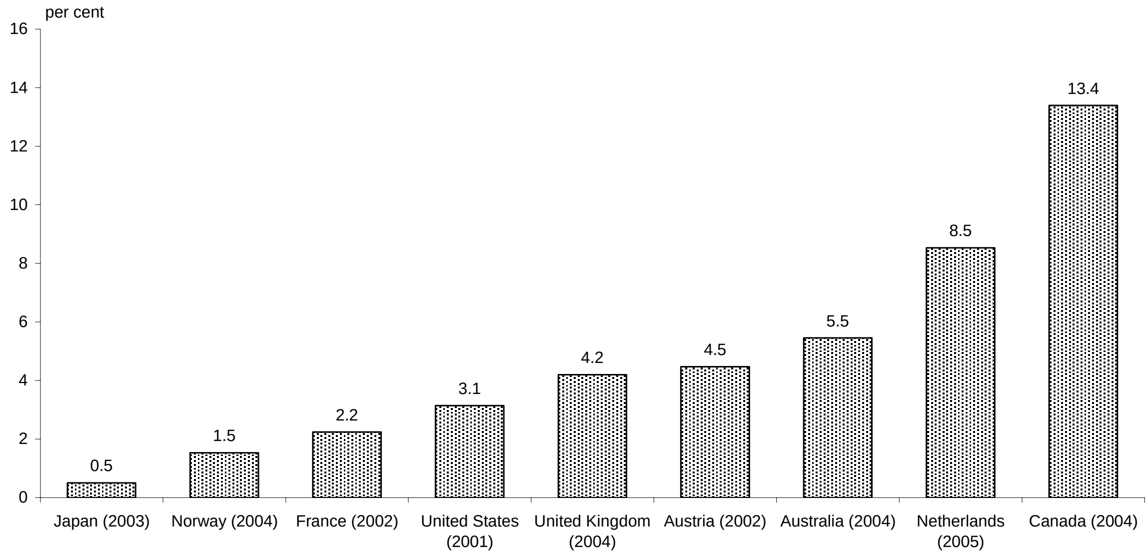
B-indexes are calculated under the assumption that the 'representative firm' is taxable, so that it may enjoy the full benefit of the tax allowance or credit. For incremental tax credits, calculation of the B-index implicitly assumes that R&D investment is fully eligible for the credit and does not exceed the ceiling if there is one. Some detailed features of R&D tax schemes (for example, refunding, carryback and carryforward of unused tax credit or flowthrough mechanisms) are therefore not taken into account.

The effective impact of the R&D tax allowance or credit on the after-tax cost of R&D is influenced by the level of the CITR. An increase in the CITR reduces the B-index only in those countries with the most generous R&D tax treatment. If tax credits are taxable (as in Canada and the United States), the effect of the CITR on the B-index depends only on the level of the depreciation allowance. If the latter is over 100 per cent for the total R&D expenditure, an increase in the CITR will reduce the B-index. For countries with less generous R&D tax treatment, the B-index is positively related to the CITR.

Sources: OECD 2004b; Shanks and Zheng 2006.

Recent OECD (2006g) data for a selection of countries suggest that Australia is above average in terms of tax revenue foregone as a proportion of BERD (figure C.17). Overall, of the nine countries for which data were available, Australia's tax revenue forgone as a share of BERD was 5.5 per cent, the third highest of the group, behind Canada (13.4 per cent) and the Netherlands (8.5 per cent).

Figure C.17 **Tax incentives for R&D as a share of BERD[a] — selected OECD countries, 2004[b]**



a When these data are taken as a share of GDP the country ranking changes substantially due to differences in BERD intensities discussed earlier in this appendix. **b** Or nearest available year.

Data source: OECD 2006g and OECD 2006c.

However, it is difficult to know exactly where Australia ranks across the OECD. The choice of countries is highly selective, as data for 18 of the 27 countries in the Warda analysis are not included. Moreover, of the nine countries for which data were available, only one country (Netherlands) was in the bottom half of the Warda rankings in terms of tax subsidies provided to large companies. Similarly, only two of the nine countries (Austria and the United States) were in the bottom half of the Warda rankings in terms of tax subsidies provided to small companies (figure C.16).

C.7 Other measures of innovativeness

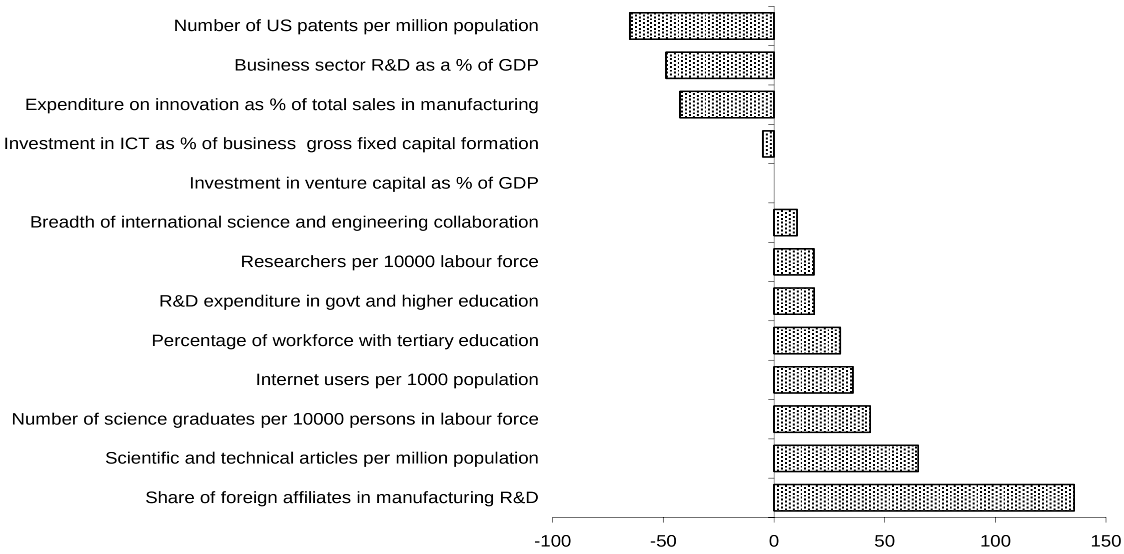
One limitation of focusing on R&D intensity measures is that R&D expenditure is an input to the innovation process rather than an output or outcome. It says nothing about the effectiveness and efficiency with which R&D funds are being, or might be, used. As the OECD noted recently (OECD 2006b, p. 59):

> [L]ooking at the amount of resources devoted to R&D is not sufficient to assess a country's innovation outcome. The main reason is that, as for all types of investment, it is not only how much that is spent that matters but also how efficiently resources are used.

Australia's performance relative to OECD averages for a broader range of innovation-related indicators based on the Australian Innovation Scorecard (DEST 2004a) does not suggest that Australia is performing poorly (figure C.18).

Figure C.18 **Australia's innovation performance compared with the OECD average, 2004[a]**

Per cent difference



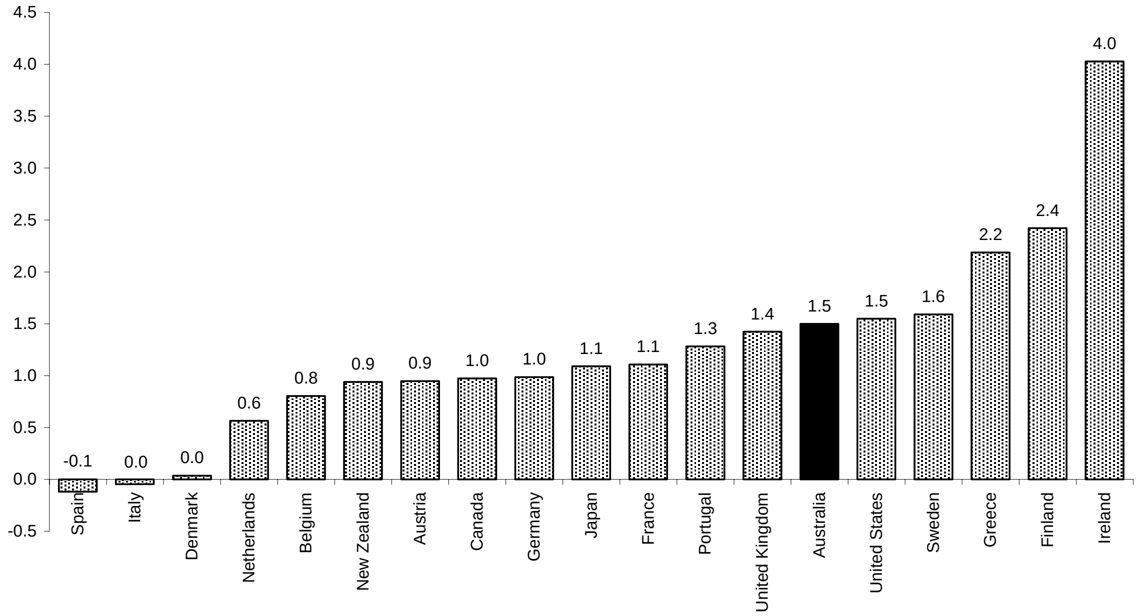
[a] Or nearest available year.

Data source: DEST 2004a.

While Australia was below average on some indicators such as business R&D, United States patents and innovation/sales ratios, it registered above average performances across a range of other indicators including scientific and technical articles, science graduates in the labour force, internet usage, tertiary education and public R&D.

Estimates of multifactor productivity (MFP) growth also provide some insight into a country's relative 'innovativeness'. However, caution should be exercised in making detailed inferences about relative country performances based on comparisons of MFP growth rates without a consideration of differences in business cycles across countries. Relative country rankings can change markedly depending on the time period chosen. That said, period average MFP growth rates can provide at the very least a broad indication of a country's relative position. On this basis, latest OECD estimates indicate that of the 19 countries for which data are available, Australia recorded the sixth highest annual average rate of MFP growth over the past decade (figure C.19).

Figure C.19 **Annual average MFP growth across OECD countries, 1995 to 2005[a]**



a Or latest available year. Data for Australia, Japan and Spain are to 2004; Austria, Denmark, Finland, Greece, Ireland, Italy, Netherlands, Portugal, Sweden and United Kingdom are to 2003; and New Zealand is to 2002. The OECD notes that these estimates are based on harmonised price indices for ICT capital goods to improve international comparability. Data are not adjusted for cyclical factors.

Data source: OECD Productivity Database October 2006 (http://www.oecd.org/statsportal, accessed 26 February 2007).

C.8 Conclusion

On the basis of the evidence presented above, Australia's business R&D performance is broadly in line with that of other OECD countries when differences in country size, industry structure, firm size and wage rates are taken into account. Similarly, in terms of public R&D spending, international evidence does not suggest that Australian governments are underinvesting in R&D. Moreover, based on the way targets are used internationally, it is clear that they are fundamentally aspirational in character rather than prescriptive, and best viewed as policy tools to assist in generating political will to achieve an already identified goal. Some of these issues are examined further in chapter 9.

D Absorption costs

In many instances, firms or individuals must make some investments in 'absorptive capacity' to gain the benefits of others' knowledge creation. As elaborated below, the nature of absorption strategies and the context in which they take place affect whether spillovers justify public support (with the alternative cases illustrated in figure D.1).

Case 1: Absorption of external knowledge is based on R&D that produces its own spillovers

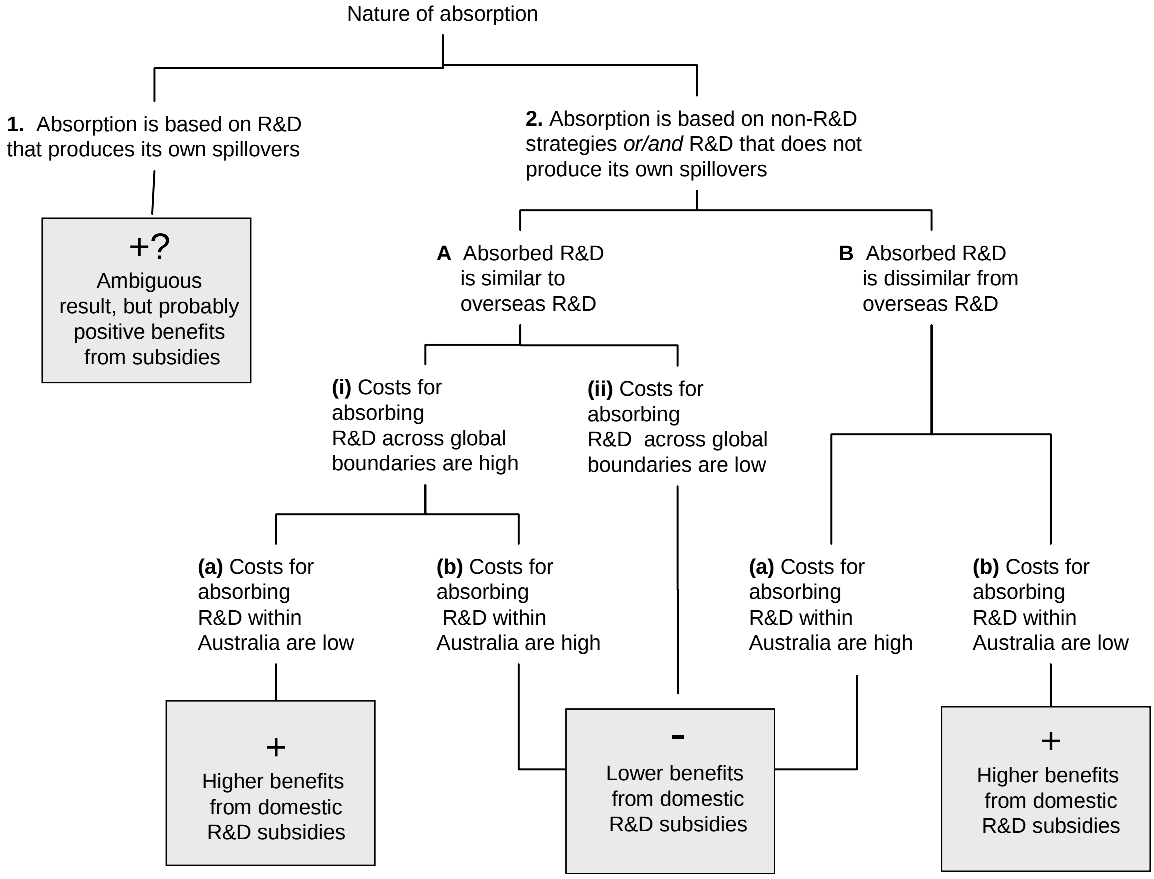
The dominant view of absorption accentuates investments in R&D as the strategy for learning from external knowledge. It is now commonly argued that a firm or agency may need to be close to the research frontier to understand and use spillovers:

> A nation needs the capability to understand the knowledge produced by others and that understanding can only be developed through performing research (Salter and Martin 2001).

There is a wide literature that confirms the importance of such capabilities within firms, such as Cohen and Levinthal (1989), Blomström and Kokko (1998), Wakelin (1998) and Girma (2005) for firms; Griffith, Redding and Van Reenen (2004) in a 13 country macro-panel data study; and Henderson (1998) in a case study of the pharmaceutical industry. Leahy and Neary (2006) provide a useful summary of the literature.[1]

[1] While most of the discussion of R&D as an absorptive strategy is centred on firms, it also applies to universities and public sector agencies. The R&D activities of universities and public research agencies are often the *quid pro quo* for privileged access to international research infrastructure and linkages with the elite academic and research programs.

Figure D.1 **When are subsidies to elicit spillovers from domestic firms warranted?**



This suggests that countries that contribute little to the global stock of frontier knowledge, like Australia, cannot free-ride on the world science and innovation system. Consequently, the possession of a domestic capability in science and innovation is important.

However, the need for absorption also affects firms' R&D investment incentives in a way that makes it ambiguous whether public support is required to develop that capability in a business setting. When R&D has an absorptive benefit, it is undertaken for its own sake *and* to increase the capacity for learning from the relevant pool of global knowledge. This has the effect of increasing the incentives for undertaking R&D. The incentive to undertake innovation may also be stimulated if it takes time for rivals to imitate and then improve an originator's innovation.[2]

When firms are engaged in competitive rivalry, each will undertake R&D to absorb each other's ideas, develop new innovations and gain a temporary edge — thus

[2] The simple spillover models assume instantaneous costless diffusion.

pushing the innovative frontier further out in a virtuous cycle. Consequently, while spillovers are still present, the benefits from, and delays associated with, absorption can increase R&D investment instead of depressing it. Geroski (1996) then poses the question of whether public support to counteract the adverse impacts of incomplete appropriability of returns is then warranted.

However, the policy-relevant issue is whether subsidies to R&D might even further increase R&D and social welfare, not the fact that R&D may increase with spillovers when the need for absorptive R&D is taken into account. In circumstances *where rivals' absorptive R&D adds to the useful stock of knowledge and generates further spillovers* (case 1 in figure D.1), Graevenitz (2004) shows that social welfare is still enhanced when R&D subsidies are provided because it stimulates even further the virtuous cycle of innovation. However, this result depends on the nature of the competitive games played between firms and the characteristics of technologies and costs — hence the question mark about the value of subsidies noted under case 1 in figure D.1.[3]

Case 2: Absorption of external knowledge is based on R&D that does not produce its own global spillovers or on non-R&D strategies

Firms absorb external knowledge in many ways — such as seeking external advice; investing in physical and intangible capital (including software, R&D, hiring and training); and tapping business networks. The choices among strategies depend on nature of the knowledge that is being absorbed, and the capabilities and technological objectives of the recipient firm. Case 1 is only a subset of these strategies, providing a reasonable description of the processes of rivalrous R&D in many innovation-intensive oligopolistic industries (Baumol 2002).

Case 2 captures a broader range of strategies:

- R&D may not add to the global pool of knowledge, but be aimed at imitation (for example, generic drugs and, more generally, copies of brand products), or technology catch-up (such as learning how to apply new foreign process technologies to a domestic firm's production line).
- There are many other non-R&D strategies. In a global innovation system, efficient absorbers of others' innovation have incentives to package that knowledge in digestible components as a source of their own advantage, and to market this globally to less capable absorbers (box D.1).

[3] For example, Grünfeld (2003), who characterises absorption differently, gets different results.

Box D.1 Institutions have adapted to diffuse knowledge among firms and other agents without them having to undertake their own R&D

There are a myriad of national and global scientific consulting companies in the physical, engineering and social sciences, whose purpose is to provide frontier specialist technical advice to clients who lack that capacity.

Professional conferences, fairs and exhibitions are commercially organised mechanisms for knowledge exchange. Around one half of innovative Australian firms say that these mechanisms acted as a source of the idea or information used to generate their innovations (ABS 2006a).

Software can incorporate complex knowledge that is invisible to the user, yet enables users to gain the benefits of that complex knowledge. This is typical, for example, with most modern menu-driven econometric and scientific statistical and mathematical packages.

Review articles, textbooks, and other synthesising methods are widely available that aim to explain, interpret and select the most important of recent developments in any scientific field — their *purpose* is spillover maximisation.

Much of human capital accumulation is premised on efficiently distilling past learning and maximising spillovers from the relevant world stock of knowledge. Higher educational institutions are agencies whose specialised task is to organise, rank and efficiently diffuse this knowledge to students. The spillovers are not free, but they are cheap relative to the costs of generating whole bodies of knowledge, such that the huge efforts in physics or mathematics by thousands of people in the last 1000 years are distilled adequately into four years of training. A particularly important economy of this transmission of knowledge is a filtering mechanism that can avoid imparting failed or redundant theories and methods. For example, Ptolemy developed highly complex calculations that gave (often quite useful) astronomical predictions, but were premised on the earth being the centre of the solar system. None of this large body of knowledge now needs to be transmitted to students. There are many instances in the science and innovation system where failures are cheaply and generally absorbed.

The reason why MNCs exist at all is that they have developed efficient methods for transmitting and absorbing useful knowledge across borders (Kogut and Zander, 1993), through ICT and paper-based systems, and routinised person-specific linkages, such as inter-unit visits, international staff mobility, international committees, cross-country teams and training (Piscitello and Rabbiosi 2006). The density of their inter-unit linkages enable multinational companies to locate R&D facilities in countries quite different from ones in which they establish management, design, marketing, production or maintenance functions.

More broadly, international scientific spillovers are diffused more widely and in unexpected ways than would be implied by the usual absorption models. Australia may benefit from spillovers that are embodied in imported goods and services and that are not internalised by the prices of those services. For example, scientific research in the United States may generate knowledge spillovers that lead to new material technologies that are widely diffused among US firms and then exported globally. No individual firm can re-capture the spillover as a rent because they compete with each other. In this case, Australian firms (and consumers) benefit from the new technology — as an embodied spillover — without having to pay for it.

Australia’s experiences with the use of information and communication technologies (ICT) provides a good illustration of the capacity for a country to absorb and exploit technologies, without needing to have a significant global presence in the R&D underpinning the technologies. Australian firms have proven to be excellent and innovative *users* of ICT and this has been a major contributor to Australia’s recent high multifactor productivity growth (Parham et al. 2001; DCITA 2005; Diewert and Lawrence 2005).

Whether there is a rationale for subsidies to support R&D in these broad circumstances is contingent on several factors, which are illustrated in figure D.1 above. This is a simplified classification. Obviously absorption costs are on a continuum and the features that make up the competitive environment are very much more complex than figure D.1 suggests. Nevertheless, the possible cases may provide some policy guidance.

Foreign knowledge stocks are expensively acquired — Case 2A(i)

This case applies when the costs of absorbing R&D across national boundaries is high (case 2Ai). This might occur when external knowledge is highly complex, less readily observed, dependent on tapping into local customer-supplier networks, or relies on movements of employees carrying tacit knowledge.

Leading domestic firms are then effectively forced to undertake more costly larger-scale R&D to absorb and partly re-create foreign stocks of knowledge. But if other domestic firms can cheaply absorb the knowledge created by these leaders (case 2Aia), then the leaders may have weak incentives to undertake R&D and subsidies are potentially justified. This is the orthodox spillover case in textbooks.

Alternatively, if the costs of absorbing R&D from the leaders are high (case 2Aib), then leaders retain incentives to undertake R&D and the case for subsidies are weak.

Cheap if not free-riding — Case 2A(ii)

This case applies when the R&D in the domestic originator firm is similar to R&D undertaken overseas *and* the costs of absorbing the equivalent foreign R&D is low. In this instance, 'cheap'-riding on foreign knowledge stocks economises on domestic resources and is, in a unilateral sense, the optimal strategy.[4] A small country, like Australia, can *potentially* benefit from science and innovation conducted overseas, without reducing its use in the countries that produced them.[5] There may be a global need for public support of this type of R&D, but not necessarily a country-specific rationale.

There is question about the likelihood of realistically encountering case 2Aii in applications by Australian firms for R&D subsidies, which is the policy issue under scrutiny. Why would such firms apply for R&D subsidies at all if it is cheap to acquire external knowledge from abroad?

In many cases, firms use small-scale R&D efforts as they routinely adapt their businesses to keep up with continually shifting technological frontiers. Using ABS data, chapter 1 showed that most Australian business R&D is not new to the world. In other words, as emphasised in the broader discussion of case 2 above, R&D *itself* can be a relatively cheap form of acquiring and applying foreign knowledge pools. In this case, firms could be expected to apply for R&D subsidies were they available. But the subsidies would have few social benefits because the R&D would most likely have occurred anyway or would be likely to displace non-R&D methods of absorption. Box D.2 provides an illustration.

R&D is Australia-specific (Case 2B)

The situation when the R&D absorbed from a domestic firm is different from R&D undertaken overseas (case 2B) is more simple, because the question of absorption

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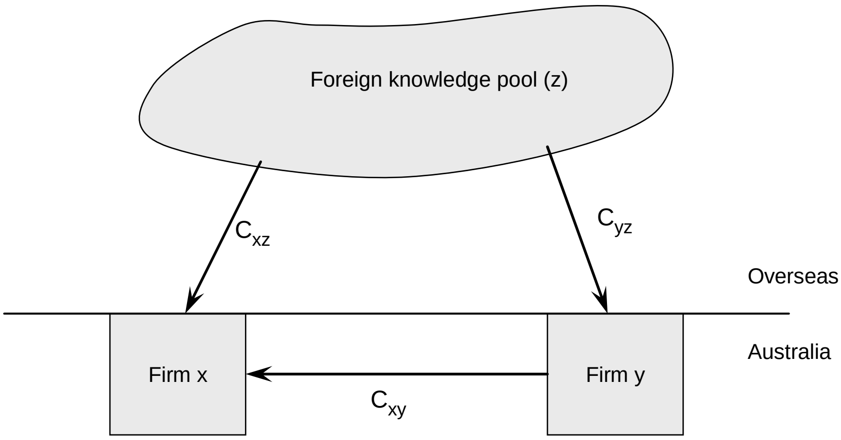
4 For example, it is sometimes possible to free-ride on the science underpinning foreign regulatory decisions if the regulators can be trusted. A dozen Eastern European countries recognise rulings by the European drug-approval agency, economising on the high costs of approval (*The Economist* 2001, 'How Countries Go High-Tech').

5 Australian expenditure on innovation and science is dwarfed in absolute terms by the expenditure in many other OECD countries, but even single multinational companies spend about the same on R&D as the whole of Australia. For instance, three US corporations, Microsoft, The Ford Motor Company and Pfizer *each* spent about the equivalent of around A$10 billion on research and development in 2003, which was just a little less than Australian GERD and roughly double the Australian Government budget for public support of science and innovation (National Science Board 2006, p. 4.20). In fact, all of the top 20 global R&D spending corporations spend about the same as, or more than, the Australian Government on R&D.

from abroad does not arise. In this case, there is a symmetry with cases 2Aia and 2Aib, with subsidies again being rationalised on conventional grounds if the costs of absorption are low (case 2Bb)

Box D.2 **An illustration of 'cheap'-riding**

The figure below summarises a simple situation as an illustration of the issues that arise in these circumstances. There is a foreign stock of knowledge (z), which is valuable and can be acquired relatively cheaply by either conducting small-scale R&D (or by using similarly cheap non-R&D methods of absorption). Firm y undertakes R&D to absorb the foreign stock with cost Cyz. Firm x has two choices. It can undertake R&D to absorb from the foreign stock with cost Cxz or from firm y with cost Cxy. All absorption costs — Cyz, Cxz and Cxy — are small under the assumption of cheap absorption costs.



To the extent that R&D subsidies are available, firm y will apply for a subsidy, even though the subsidy is unlikely to have made any difference to its decision to absorb by using R&D. A subsidy to firm y to undertake its R&D cannot produce significant domestic spillovers since, by definition, the beneficiary of those spillovers, firm x, still faces some absorption costs and Cxz-Cxy must be *very* small.

The availability of the subsidy also means that firm x will apply for the subsidy, since this tilts its absorption decision from any other cheaper method of absorption to R&D as the mechanism. So an R&D subsidy will not make a difference to firm x's actual capacity for absorption, just the means chosen to do so.

Consequently, case 2Aii can be expected to elicit applications for R&D subsidies even though those subsidies have nearly zero social welfare benefits.

The insights provided by absorption costs

The argument that Australia could free-ride on global research is not convincing in its extreme form, but neither is the argument that R&D needs to be publicly supported to absorb foreign knowledge flows. So what are the policy implications of this complex story?

The need for strategies to absorb external knowledge complicates assessment of the need for public subsidies of domestic business R&D. There is a stronger rationale for public support of more radical business innovations. These are more likely to elicit virtuous cycles of improvements by rivals (case 1). Such innovations are probably also more likely to be new to the world, yet cheaply disclose to rivals what is possible, if not exactly how to do it (case 2Bb). On the other hand, R&D aimed at imitation, while commercially useful, is more likely to fit into case 2A(ii), without a clear rationale for R&D subsidies.

The significance of absorption further challenges the usefulness of simple international comparisons of R&D intensities. Pure free-riding is not possible, but undoubtedly there are large knowledge transfers across borders and a multitude of strategies to raise these flows. It is more appropriate to identify the capacity of the innovation system to facilitate information flows from abroad and between the parts of the domestic system, than to consider a single measure that represents a given way of achieving this end. Public policy strategies have a role in widening the types of investments that can be successfully used to promote absorption.

E Multifactor productivity

Chapter 4 provides estimates of the returns to multifactor productivity (MFP) of investments in R&D. It is important in that context to understand how MFP is defined, its role in economic growth and the possible connections it has to R&D.

Under certain assumptions, economic growth can be broken down into various components:[1]

$$\Delta \log(\frac{MY}{POP})_t = \Delta \log(MFP)_t + (1-\alpha)\Delta \log(\frac{MK}{MHours})_t + \Delta \log(\frac{MHours}{POP})_t$$

where Y is GDP, MY is market sector value added, MFP is market sector multifactor productivity, α is the labour share of total factor income, MK is market sector capital stock, Mhours is annual hours worked in the market sector and POP is the total population.

The three components of growth in market sector output per capita are:

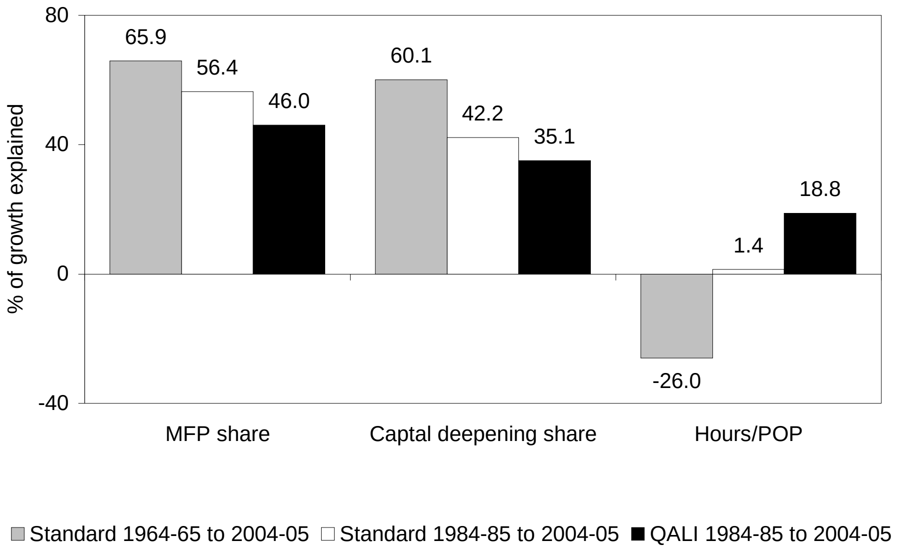
- the annual percentage growth of market sector MFP;
- $(1-\alpha)$ times the annual percentage growth in market sector capital intensity; and
- the annual percentage growth market sector hours per capita.

The ABS only provides MFP estimates for the market sector where output measures are market-based (figure E.1). Actual GDP growth is lower than market sector growth, but this reflects the assumption by the ABS that output growth in some parts of the economy (for example, education services) is equal to the growth of inputs in those sectors (a zero productivity assumption).

This is unlikely to hold in practice. In this case, market sector output growth per capita is probably an adequate proxy for (correctly measured) GDP per capita. Accordingly, the contribution of MFP to market sector growth is probably a good measure of the real underlying contribution of productivity to overall economic growth per capita.

[1] *Source:* IC (1997a) and ABS (2005a,b).

Figure E.1 **Contribution of multifactor productivity to long run prosperity**
Australia, 1964-65 to 2004-05[a]



[a] Growth is measured as market sector output per capita, indexed to 100 in 1964-65. The standard MFP estimates are based on just two inputs: labour and a consolidated measure of capital inputs (calculated by the ABS from weighted average of different types of capital inputs). The QALI measure takes account of quality improvements in labour stemming from improved education of the labour force (QALI=quality adjusted labour index). Because it takes account of another input (education), this reduces MFP. The QALI-adjusted MFP estimates are only available from 1984-85, hence the different time frame for the decomposition. The standard measure of MFP is also calculated for this timeframe as a comparison.

Data source: ABS, *National Accounts, Australia*, Cat. No. 5204.0.

MFP is a catch-all for everything else that affects market output apart from labour and capital. It includes:[2]

- the short-run effects of the business cycle on utilisation of labour and capital. These inputs are often idle during recessions, so measured productivity and output falls during those times;
- the improved quality of labour that results from investments in human capital. The ABS has produced experimental measures of the effects of education on the quality of labour. When these are taken into account when measuring MFP, the effect (over a shorter time frame) is reduced, but is still highly significant at around 45 per cent;
- changes in publicly-provided infrastructure, like roads, that affect the costs of bringing inputs together;

[2] Economic growth is measured in value-added terms, netting out material inputs that are used to produce goods and services. Accordingly, material inputs are not included again as an input into economic growth.

- changes in the mix of capital that might be important for productivity. A series of quantitative studies by DCITA of Australian productivity, backed by rich case study evidence (sub. 101), have indicated an important role of information and communication technologies as a driver of productivity in the 1990s;
- changing rules and regulatory arrangements, which reduce or increase the transactions costs of business (for example, changing trade barriers); and most importantly for the present study; and
- innovation within firms or other entities that produce market goods and services.

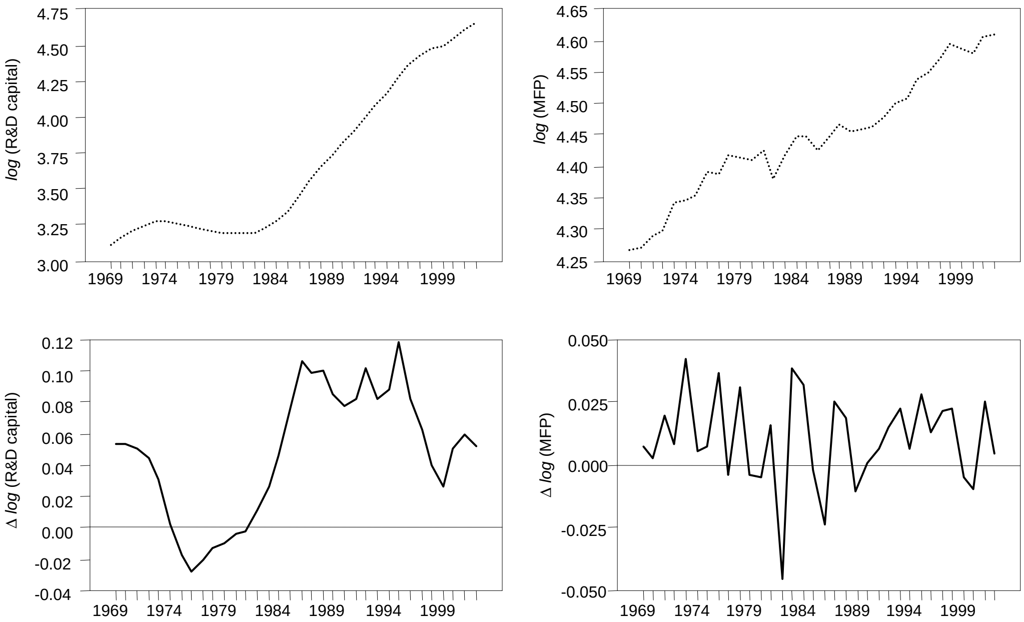
F Static models of multifactor productivity

This appendix sets out some simple static models of MFP that illustrate some of the pitfalls from the spurious regression problem in estimating rates of return. The regressions are based on Australian time series data.

A major issue in econometric estimation of trending series is spurious regression. Many economic variables — including multifactor productivity (MFP) indexes and R&D stocks — exhibit certain forms of growth trends. When the log values of these variables are differenced (amounting to computing the annual growth rates), they typically no longer show such trends. They are like white noise around a flat line (or ‘stationary’). Graphs of log(MFP) and log(domestic capital stocks) are shown in figure A.1 in both their raw form and in this differenced form. The graphs suggest that MFP is difference stationary, but this is less clear for R&D, which might require double differencing — an I(2) variable. When a series can be made stationary through single differencing, they are known as I(1) in their raw form (or integrated of order one)and as I(0) in their differenced form.

When any two I(1) variables are regressed on each other — or an I(1) on an I(2) variable — it is very likely that the relationship will be highly statistically significant and display a high R^2, *even if no relationship exists between the variables* (Granger and Newbold 1974; and Yule 1926). If they are both trending upwards, the sign on the coefficient will be positive. It is apparent that log(MFP) and log(R&D capital) show strong upward trends. Tests suggest that log(MFP) and log(R&D capital) are both at least I(1), with R&D capital possibly I(2) during the period under consideration.

Figure F.1 **Time series behaviour of R&D and multifactor productivity**
Australia 1969-70 to 2002-03



a R&D is business R&D with a depreciation rate of 15 per cent.

Data source: Provided by Shanks and Zheng (2006).

So it can be strongly predicted that a regression of one on the other will show a positive, statistically significant relationship, even if there is no underlying relationship. A regression of these two variables confirms the strong positive relationship:

$$\log(M\hat{F}P)_t = 3.83 + 0.171 \log(R\,\&\,D\text{ capital})_{t-1} \qquad \{1\}$$

$$(77.3) \quad (12.6)$$

R^2=0.833, Period = 1968-69 to 2002-03 (or N=34)

The figures in parentheses are the t statistics, and the log R&D capital stock is based on business sector R&D estimated with a depreciation rate of 15 per cent. The R&D stock is lagged one period to deal with the possible confounding effect produced by a contemporaneous positive link between the demand for R&D and improvements in national income (an endogeneity bias).[1] Similar positive, highly significant relationships are found between single variable regressions between MFP and the (once lagged) capital stocks based on GOVERD, HERD and foreign R&D expenditures.

1 Positive shifts in MFP will increase national income.

These estimates imply very large rates of return to R&D. For example, with an elasticity of 0.173, the implied spillover rate of return for business R&D is around 500 per cent.

When two variables are non-stationary, the crux of the test of whether they are really linked to each other is the behaviour of the residuals $\varepsilon_t = \log(\hat{MFP})_t - \log(\mathrm{MFP})_t$. If they are really linked, then ε will be I(0), even though log(MFP) and log(capital) are non-stationary — this is 'cointegration'. Two cointegrated series can be thought of as linked by elastic. This reflects the fact that in non-stationary processes, shocks to one variable are permanent. So if they are linked, then the permanent shocks in the R&D will affect MFP and the series will remain linked in the long run. But if they are not linked, the cumulative values of permanent shocks to domestic R&D capital will tend to pull the series apart. In this instance then ε will still be non-stationary and as $t \rightarrow \infty$ the variance, $\sigma_\varepsilon^2 \rightarrow \infty$.

One symptom of the absence of cointegration is that successive values of ε_t will be highly correlated with each other ('serial correlation'). A routine test for this is the Durbin Watson (DW), which has a value of 2 when there is no first-order serial correlation and less than 2 when consecutive values of ε_t are positively correlated. In the case of {1} above the DW=0.24. A rule of thumb is that when the DW<R^2, spurious regression may be present, which certainly suggests that equation {1} is spurious. Further tests of the residuals suggests that they are indeed I(1) and that at least the simple formulation above lacks credibility as an estimate of the spillover rate of return to R&D. It is possible that more complex formulations involving other variables on the right-hand side, or in further transformations of the domestic R&D capital stock, might reveal a cointegrated relationship.

To demonstrate that it is easy to get false correlations of the kind represented by {1}, we ran simulations of regressions of artificially generated log(MFP) on the observed Australian domestic capital stock. In this case, the right-hand side variable is the same as in {1}, but MFP is simulated as a random walk with drift:

$$\log(MFP)_t = 0.01 + \log(MFP)_{t-1} + \varepsilon_t \text{ with } \log(MFP)_0 = \log(100.0) \qquad \{2\}$$

The variance $\sigma_\varepsilon^2 \sim N(0,1)$ is re-scaled so as to give a variance for $\Delta\log(\mathrm{MFP})_t$ that is close to the observed $\Delta\log(\mathrm{MFP})_t$.

By design, $\log(\mathrm{MFP})_t$ is not causally linked with $\log(R\&D\ capital)_{t-1}$, so MFP and R&D are not cointegrated. 10,000 simulations were run of regressions of log(MFP) against the lagged domestic R&D capital stock. In 98.6 per cent of the simulations, $\log(\mathrm{R\&D\ capital})_{t-1}$ had a positive and statistically significant coefficient. The average estimated elasticity was 0.174 with the 90 per cent confidence interval of such elasticities lying between 0.062 and 0.286. All of these translate to apparently large rates of spillover returns (between around 190 and 860 per cent), though they are entirely fictitious. The DW consistently showed signs of the misspecification, averaging 0.29 with a median value 0.22 and being lower than the R^2 in more than 94 per cent of cases (a rule-of-thumb indicator of spurious regression). The lesson of this simulation is that any I(1) variable with characteristics roughly depicted by {2} is nearly guaranteed to give high apparent spillover returns, even when the variables are not linked. The extent of returns can be changed by altering the value of the drift factor in {2}. If it is bigger than 0.01, bigger elasticities will be generated. And changes to the depreciation rate for the calculation of the domestic capital stock can also be used to affect the measured elasticities in a predictable way: Higher depreciation rates give lower measured elasticities.[2]

By the same logic, it can be shown that any non-stationary variable on the RHS will also show high correlations with actual observed MFP in Australia.

There are many regressions involving more complex sets of R&D and other variables in Shanks and Zheng (2006) where the authors observe that the hypothesis that residuals are I(1) cannot be rejected (for example, p. 106). Shanks and Zheng accordingly do not accept such models as adequate. The point to emphasise is that regressions with this property do not count *at all* as evidence about the size of spillover effects. It would be inappropriate, for example, to include such estimates in a meta study of rates of return.

This is why Shanks and Zheng conducted careful tests of their models for stationarity and why the Commission also applies those standards to the extensions used in this study.

2 Rates of return will not be much affected because rates of return are equal to $Y/K^{*}\eta$, where η is the elasticity. K falls as depreciation rates rises. So Y/K is rising as η is falling.

G Semi-parametric estimates of the impact of R&D

G.1 Method

This appendix sets out a semi-parametric method for calculating the impacts of R&D. Its advantage is that it imposes some common-sense priors about the effects of variables other than R&D on multifactor productivity (MFP), which may aid in isolating the possible impacts from R&D. The cumulative impacts of alternative factors cannot exceed MFP growth and any bigger role played by one factor must come at the expense of a smaller role played by another factor. This approach avoids some of the risks entailed by standard econometric analysis, which can result in the unconvincingly high responsiveness of MFP to R&D or other factors.[1]

In natural log form, market sector output can be formulated as:

$$\ln Y_t = \ln A + \varphi \ln L_t + (1-\varphi)\ln K_t + \gamma \ln RO_t + \eta \ln RS_t + \sum_{i=1}^{j} \theta_i \ln M_{it} \qquad \{1\}$$

Y is market sector GDP. L is labour hours worked, adjusted for labour quality changes over time. K is the physical capital stock. RO is the stock of R&D that would occur in the absence of public support and RS is the stock of R&D that requires public support for the underlying investments to be made. M_i to M_j capture all other factors that affect output growth (for example, foreign R&D, non-technological innovation, any excess returns from ICT investments and business cycle effects).

Not all of the R&D undertaken in higher education or public sector research agencies aims to increase market sector GDP, simply because their value relies on more intangible benefits that are not reflected in market transactions. These benefits need not be any less or more than those realised in the market sector, but in theory

[1] An example is the very large responsiveness of MFP to stocks of standards found by the CIE (for Standards Australia in the attachment to sub. 70). The CIE and Standards Australia make a convincing case that standards can play a useful role in the diffusion of knowledge and productivity growth. But the actual elasticities found in the econometric analysis are too high to be plausible.

the stocks that produce these gains should be removed from an analysis of market sector gains. Otherwise, the *market* rate of return estimated for such stocks will be underestimated. Accordingly, R&D capital stocks exclude any R&D that is not directly relevant to the market sector.

{1} can be re-arranged so that it is in terms of labour quality-adjusted multifactor productivity (MFPQ):

$$\ln Y_t - \varphi \ln L_t - (1-\varphi)\ln K_t = \ln MFPQ_t = \ln A + \sum_{i=1}^{j} \theta_i \ln M_{it} + \gamma \ln RO_t + \eta \ln RS_t \qquad \{2\}$$

Differencing yields:

$$\Delta \ln MFPQ_t = \sum_{i=1}^{j} \theta_i \Delta \ln M_{it} + \gamma \Delta \ln RO_t + \eta \Delta \ln RS_t \qquad \{3\}$$

Let us express $\sum_{i=1}^{j} \theta_i \Delta \ln M_{it} = \xi . CYCLE_t + \lambda_t$ {4}

which represents a decomposition of these other factors into cyclical and long-term components. This means:

$$\Delta \ln MFPQ_t = \xi . CYCLE_t + \lambda_t + \gamma \Delta \ln RO_t + \eta \Delta \ln RS_t \qquad \{5\}$$

Suppose that on average $\lambda_t = \Omega \, \Delta \ln MFPQ_t + \varepsilon_t$ where Ω must be bounded between 0 and 1 and ε_t is the yearly deviation from this, assumed to have an average value of zero.

λ is likely to be a significant source of MFP gains

It is likely that λ_t accounts for a significant share of the long-run change in MFP so that estimates associated with $\Omega<0.8$ are regarded as less plausible. Why? Figure 4.1 in chapter 4 provides the underpinning logic, but it is worth re-iterating the principal mechanisms given the pivotal role of assumptions about Ω.

First, many of the benefits of R&D are private (and therefore already incorporated in output).

Second, non-R&D forms of innovation are likely to be a critical source of gains. As noted by Smith and West (2005):

> Research and Development (R&D) is often not a source of innovation, but an effect of innovation decisions … Innovation and growth impulses are pervasive across the economic system, which would explain why so many so-called ‘low-tech’ sectors and low-tech companies have been growing rapidly … Growing sectors innovate in different ways, with a great deal of variety in their methods, approaches and results.

A major driver of such non-R&D innovation is competition between firms, which provides an impulse for continual improvement by managers and employees. Changes in trade barriers through reduced tariffs and quotas, and emerging competition from developing economies has probably intensified competitive forces in the last few decades, as has microeconomic reform generally. Shanks and Zheng (2006) found empirical evidence of a link between R&D investment and increased openness. It seems likely that there is a similar link between more intangible forms of innovation and openness/competition.

The importance of such non-R&D innovation has probably intensified with the ascendancy of services and the *relative* decline of manufacturing and agriculture, though non-technological innovation still remains significant in the latter sectors.

Third, foreign knowledge flows — both technological and non-technological — are very important for a small open economy like Australia, and their diffusion and adoption is likely to be a major source of MFP gains. As discussed in Shanks and Zheng (2006), an international literature has confirmed the importance of foreign R&D stocks (which is a more easily observable component of foreign knowledge stocks more generally). It should be noted that Australia's domestically-generated technological knowledge stock is less than 5 per cent of the global stock. Of course, domestic R&D can assist in absorbing such foreign technological knowledge flows. But as discussed in chapter 3, domestic R&D is by no means the only mechanism for effective transfer of foreign knowledge (and even less so in the case of non-technological knowledge).

While we prefer an assumption of Ω=0.8, it could be higher or lower than this, and the consequences for elasticities and rates of return are investigated later.

Calculating elasticities and rates of returns

The gross rate of return (ρ) on the stocks of R&D capital is the multiple of the relevant elasticity and the GDP to R&D stock ratio (Shanks and Zheng 2006):

$$\rho O_t = \gamma\,(Y_t/RO_t) \text{ and } \rho S_t = \eta\,(Y_t/RS_t) \qquad \{6\}$$

It is customary when calculating summary rates of return to use average output to R&D ratios, so that:

$$\overline{\rho O} = \gamma \frac{1}{n}\sum_{t=1}^{n}(Y_t/RO_t) \text{ and } \overline{\rho S} = \eta \frac{1}{n}\sum_{t=1}^{n}(Y_t/RS_t) \qquad \{7\}$$

In the absence of any other guidance, a tractable assumption is that the average gross rates of return on these market-sector relevant R&D stocks are about the same over the long run (the net returns will be the same if the depreciation rates are also the same); ie $\overline{\rho O} = \overline{\rho S}$.

{7} can be manipulated so that:

$$\gamma = \overline{\rho O} \times n / \sum_{t=1}^{n} (Y_t/RO_t) \qquad \{8\}$$

In that case:

$$\gamma = \overline{\rho O} \times n/\sum_{t=1}^{n} (Y_t/RO_t) = \eta \frac{1}{n} \sum_{t=1}^{n} (Y_t/RS_t) \times n/\sum_{t=1}^{n} (Y_t/RO_t)$$
$$= \eta \frac{\sum_{t=1}^{n} (Y_t/RS_t)}{\sum_{t=1}^{n} (Y_t/RO_t)} = \eta S \text{ since } \frac{\sum_{t=1}^{n} (Y_t/RS_t)}{\sum_{t=1}^{n} (Y_t/RO_t)} \text{ is a fixed number} \qquad \{9\}$$

Accordingly, given observations on the stocks of R&D and market sector GDP, an estimate of γ can be made from η. Substituting these conditions into {5} and taking note of the definition of λ_t, yields:

$$(1 - \Omega) \Delta \ln MFPQ_t = \xi.CYCLE_t + \eta\{S \times \Delta \ln RO_t + \Delta \ln RS_t\} + \varepsilon_t$$
$$= \xi.CYCLE_t + \eta R_t^* + \varepsilon_t \qquad \{10\}$$

Where R* is the composite R&D measure $(S\,\Delta \ln RO_t + \Delta \ln RS_t)$.

As discussed below, it is possible to estimate {10}. However, a first step is construction of the data.

G.2 Construction of observable R&D stocks

Data on stocks of total business, higher education and public sector agency R&D stocks are available from Shanks and Zheng (2006) (with assumed depreciation rates of 15 per cent). Some assumptions must be made about the shares of these relevant for RO and RS. Reasonable judgments are made about the parameters concerned, but because of the uncertainty, a later section of the appendix uses simulation methods to explore the consequences of different assumptions.

Information compiled by the ABS on the socio-economic objectives of R&D by the performing sector provides some information (table G.1).

Table G.1 **R&D by socio-economic objective**

By R&D performing sector, 2002-03[a]

Objective	*Business*	*Public Sector*	*Higher Education*
	%	%	%
Non-market			
Defence	2.5	11.4	0.3
Health	5.2	9.2	28.3
Education and Training	0.2	0.5	4.7
Social Development and Community Services	0.4	2.4	10.0
Environmental Policy Frameworks & Other Aspects	0.3	1.4	1.0
Environmental Management	0.6	19.1	5.4
Non-oriented Research	0.1	2.0	21.3
Total 'non-market'	9.3	46.0	71.1
Market-oriented	90.7	54.0	28.9

[a] Market-oriented R&D is defined as the sum of data defined by socio-economic codes 620000 to 720000 (such as plant production; energy resources; manufacturing; construction and so on). On unadjusted figures, just over 90 per cent of R&D activity in the business sector fell into this category. It seems reasonable to suppose that all of the activity of businesses relates to market-oriented activities, so that in the business sector, the apparently non-market research actually has market value. The same will apply to non-business sectors. This is clear for health, for example. It is also notable that basic research by universities into general areas of research — non-oriented research — may well produce long-term economic value that shows up in market measured output. Accordingly, actual market-oriented shares are likely to be higher than those shown here — and this is reflected in the subsequent modelling.

Source: Derived by PC from ABS, *Research and Experimental Development All Sector Summary, 2002-03*, Cat no. 8112.0.

It is assumed that around 60 per cent of public sector R&D stocks are relevant to the market sector measure of GDP, reflecting the fact that significant amounts of R&D in these agencies are directed at public good issues, such as defence, environmental or social issues. The choice of 60 per cent rather than the 54 per cent shown in table G.1 is based on the judgment that some notionally non-market research is ultimately realised in gains for the market economy. Of the R&D that is relevant, it is judged that around 10 per cent would have happened without public support. This reflects the fact that businesses and farms contract with some of the agencies to undertake R&D on their behalf and could be expected to undertake at least a component of such research through other avenues (probably within the business sector) even if the public sector research agencies did not exist.

Higher education research has a greater orientation to basic research that expands the global research frontier and less to research aimed at Australia-specific issues than public sector research agencies. This sector also has an orientation to applied research in the social and environmental sciences (chapter 2). There is a less direct orientation to commercially-relevant research, although that has increased in recent years. However, it should be noted that basic research can have longer term impacts in the market sector, so that short-run and long-run effects should be distinguished.

Here, a long-term view is taken so that overall, it is judged that around 40 per cent (compared with the 30 per cent from table G.1) of higher education research shows up as benefits to market sector outputs (and the rest to global knowledge accumulation and intangible benefits). It is judged that around 10 per cent of higher education research would be undertaken in the absence of public support for research in the higher education sector.

Finally, all business R&D aims to increase market sector output. As a whole, this sector receives relatively little public assistance. The revenue costs of R&D benefits provided to the business sector by the Australian Government amount to just over 10 per cent of total business R&D (chapter 2). Supposing that the 'bang for a buck' is around 80 cents (chapter 4), this implies that the share of observed business R&D that can be ascribed to business support (μ) is 0.10×*0.8 = 0.08 (or 8 per cent), as shown in table G.2.

These various sub-components can be added to give estimates of RS and RO.

Table G.2 **Parameters used in constructing relevant R&D stocks**

	Market relevant share	*What share of observed R&D can be ascribed to public support?*	*Contribution to RS*	*Contribution to RO*
	(s)	(μ)	$(s \times \mu \times R)$	$(s \times (1-\mu) \times R)$
Public sector R&D stocks (R_{pub})	0.60	0.9	0.54 R_{pub}	0.06 R_{pub}
Higher education R&D stocks (R_H)	0.40	0.9	0.36 R_H	0.04 R_H
Business R&D (R_B)	1.00	0.08	0.08 R_B	0.92 R_B
Totals			0.54 R_{pub}+ 0.36 R_H+0.08 R_B	0.06 R_{pub}+ 0.04 R_H+0.92 R_B

G.3 Estimation and results

For an assumed value of ρ and given the relationships observed above, an appropriate estimable model is:

$$(1-\Omega)\Delta \ln MFPQ_t = \hat{\xi}.CYCLE_t + \hat{\eta}R_t^* + \varepsilon_t \qquad \{11\}$$

$\Delta \ln MFPQ_t$ is the growth in MFP adjusted for changes in human capital and the CYCLE variable is measured as Δ(Y/HPY-1), where Y is market sector GDP and HPY is the Hodrick Prescott filtered value of Y.

An alternative model can be estimated by using a variant ($\Delta \ln AMFP_t$) of $\Delta \ln MFPQ_t$. This variant is derived by making simple corrections to the conventional measure of the growth in MFP (which is *unadjusted* for changing labour quality). This approach has the benefit of allowing models to be estimated over the longer period from 1969-70 to 2002-04 because labour quality-adjusted data are only available from 1984-85. Using this alternative involves major assumptions, as discussed in box G.1, and accordingly results using this variant should be regarded with greater caution. The model estimated was:

$$(1-\Omega)\,\Delta \ln AMFP_t = \hat{\xi}.CYCLE_t + \hat{\eta} R_t^* + \varepsilon_t \qquad \{12\}$$

where the derivation of AMFP is described in box G.1.

Box G.1 **Using MFP unadjusted for labour quality changes**

$\Delta ln\, MFPQ_t$ is conventional MFP growth ($\Delta ln\, MFP_t$) corrected for changes in the quality of labour. In the absence of an official ABS measure of $\Delta ln\, MFPQ_t$ prior to 1984-85, an alternative is to develop a proxy adjustment for human capital changes and subtract it from $\Delta ln\, MFP_t$. A simple, indicative approach is adopted. A regression was estimated of $\Delta ln\, MFP_t$ against the growth in R&D stocks, a measure of growth in educational attainment ($\Delta ln(education)$) as a proxy for improving labour quality, a constant (to pick up trends in MFP ascribable to foreign R&D stocks and other knowledge flows) and a business cycle variable. Then a new indicator of MFP growth adjusted for changes in labour quality was calculated as $\Delta ln\, AMFP_t = \Delta ln\, MFP_t - \hat{\psi}\Delta ln(education)_t$ where $\hat{\psi}$ is from the auxiliary regression.

This approach makes it legitimate to use the same Ω factor as for $\Delta ln\, MFPQ_t$, but is subject to the limitations of the derivation of $\Delta ln\, AMFP_t$.

It should be emphasised that the goal of the estimation procedure is to find the value for $\hat{\eta}$ *given the restrictions suggested by {11} or {12}*, not the conventional aspiration of deriving the best model for MFP from an initially general specification. This, for example, is why the model is estimated with no constant and why R* enters in its composite form, rather than in its parts.

Given the greater quality of the more recent data, the significant shifts in the nature of Australia's economic landscape between the 1970s and later decades, and the more rigorous basis on which labour quality adjustment is made, model {11} is probably the more reliable. The Commission also estimated the specification {12} over the full sample from 1969-70 to 2002-03 (shown in the table as $\{12\}^*$). If these full sample results were regarded as better, they nevertheless provide estimates that are very close to that of model {11}.

Various statistics of the significance of the included variables are included in table G.3, but these should be interpreted with care for the R&D variable. This is because a constant must be excluded from the regression for the method to make sense. Since CYCLE has a mean of roughly zero and both the R&D variable and (1–Ω) Δlog MFP have non-zero means, the R&D variable can be expected to be significant. This is not necessarily true for the CYCLE variable, though it is, in fact, highly significant. The value of the key coefficient on R&D — an elasticity of around 0.02 — is associated with a rate of return of around 65 per cent. The result is consistent with the preferred conventional econometric model of MFP productivity estimated and discussed in chapter 4.

Table G.3 **Regression results (Ω=0.8)**[a]

	$(1-\Omega)\Delta\ln MFPQ_t$	$(1-\Omega)\,\Delta\ln AMFP_t$	
Variable	*{11}*	*{12}*	*{12}**
CYCLE	0.120	0.116	0.129
	(5.0)	(4.9)	(9.6)
R^* or $\{S\times\Delta\ln RO+\Delta\ln RS\}$	0.0180	0.0213	0.0213
	(4.6)	(5.8)	(6.3)
100SE	0.202	0.187	0.210
DW	1.50	1.51	1.20
Obs	19	19	34
Start	1984-85	1984-85	1969-70
End	2002-03	2002-03	2002-03

a t statistics in parentheses (robust errors).

Source: PC estimates.

Estimates of η from OLS regressions for alternative values of Ω are shown in table G.4, as are the implied rates of return to R&D.

Table G.4 Estimates of the impact on market sector productivity of R&D elicited by public support

Ω	*{11} 1984-85 to 2002-03*	*{12} 1984-85 to 2002-03*	*{12*} 1969-70 to 2002-03*
	Impacts ($\hat{\eta}$)*100		
0.50	4.50	5.32	5.33
0.60	3.60	4.26	4.26
0.70	2.70	3.19	3.20
0.80	1.80	2.13	2.13
0.85	1.35	1.60	1.60
0.90	0.90	1.07	1.07
	Rates of return (%) ($\hat{\eta} \times Y / R_S$)		
0.50	160.8	190.1	190.3
0.60	128.7	152.1	152.3
0.70	96.5	114.0	114.2
0.80	64.3	76.0	76.1
0.85	48.2	57.0	57.1
0.9	32.2	38.0	38.1

[a] The labour quality adjusted estimates of MFP are only available from 1984-85, which is why {11} is estimated over this period. Model {12} has been estimated over the shorter sample for comparisons to {11}, but is also estimated over the full period (model {12*}).

G.4 Implications

The results imply relatively high gross spillover rates of return to publicly supported R&D of around 65 per cent, plus or minus around 20 points.

What does this imply about the contribution of (truly additional) supported R&D to total conventional MFP growth? Conventional MFP growth is:

$$\Delta \ln MFP_t = \Delta \ln MFPQ_t + \kappa \, \Delta \ln QALI_t \qquad \{13\}$$

where $\kappa \Delta \ln QALI_t$ is the effect of changes in labour quality on market-sector GDP. Using the definition of $\Delta \ln MFPQ_t$ from {5} then:

$$\Delta \ln MFP_t = \Omega \, \Delta \ln MFPQ_t + \kappa \, \Delta \ln QALI_t + \xi . CYCLE_t + \eta \, S \times \Delta \ln RO_t + \eta \, \Delta \ln RS_t + \varepsilon_t \qquad \{14\}$$

Accordingly, in period 1, ln MFP can be expressed as:

$$\begin{aligned} \ln MFP_1 = \ln MFP_0 + \Omega \, \Delta \ln MFPQ_1 + \kappa \, \Delta \ln QALI_1 + \xi . CYCLE_1 + \\ \eta \, S \times \Delta \ln RO_1 + \eta \, \Delta \ln RS_1 + \varepsilon_1 \end{aligned} \qquad \{15\}$$

and in period 2 by recursion as:

$$\ln MFP_2 = \ln MFP_0 + \Omega(\Delta \ln MFPQ_1 + \Delta \ln MFPQ_2) + \kappa(\Delta \ln QALI_1 + \Delta \ln QALI_2) + \xi.(CYCLE_1 + CYCLE_2) + \eta S \times (\Delta \ln RO_1 + \Delta \ln RO_2) + \eta(\Delta RS_1 + \Delta \ln RS_2) + \varepsilon_1 + \varepsilon_2 \quad \{16\}$$

Accordingly, by period T, the long run growth in MFP between period 0 and period T can be expressed as the sum of the changes of each of the parts:

$$\ln MFP_T - \ln MFP_0 = \Omega \sum_{i=1}^{T} \Delta \ln MFPQ_i + \kappa \sum_{i=1}^{T} \Delta \ln QALI_i + \xi \sum_{i=1}^{T} CYCLE_i + \eta S \sum_{i=1}^{T} \Delta \ln RO_i + \eta \sum_{i=1}^{T} \Delta \ln RS_i + \sum_{i=1}^{T} \varepsilon_i \quad \{17\}$$

Consequently, each of these sums can be expressed as a share of $\ln MFP_T - \ln MFP_0$ and will add to one. For example, the total percentage contribution to MFP change of R&D stimulated by public support from 1983-84 to 2002-03 is:

$$\text{Contribution from supported R \& D} = 100 \times \frac{\eta \sum_{i=1984-85}^{2002-03} \Delta \ln RS_i}{(\ln MFP_{2002-03} - \ln MFP_{1983-84})} \quad \{18\}$$

At the assumed default value of Ω=0.8, around 5 per cent of conventional MFP change in the market sector from 1983-84 to 2002-03 can be attributed to R&D stimulated by public support, around 10 per cent to other market sector-relevant R&D and the remaining 85 per cent to other factors (table G.5). Were Ω to be as low as 0.5, then the contribution of R&D stimulated by public support is still only 13 per cent, and at the other extreme of Ω=0.9, just 2.5 per cent. Consequently, even though the social rates of return to publicly supported R&D may be high, it should be noted that the actual implications for long-run productivity growth are relatively modest compared with other factors.

Table G.5 **Contribution of different factors to growth in multifactor productivity**

1983-84 to 2002-03

	Ω					
Factors	0.5	0.6	0.7	0.8	0.85	0.9
	%	%	%	%	%	%
Share due to additional publicly supported R&D (RS)	**12.6**	**10.1**	**7.6**	**5.0**	**3.8**	**2.5**
Share due to other R&D (RO)	24.0	19.2	14.4	9.6	7.2	4.8
Share due to business cycle (CYCLE)	1.7	1.4	1.0	0.7	0.5	0.3
Share due to other short-term influences (ε)	3.0	2.4	1.8	1.2	0.9	0.6
Share due to increased quality of human capital (QALI)	17.4	17.4	17.4	17.4	17.4	17.4
Share due to other long-run factors (Ω Δlog MFPQ)	41.3	49.5	57.8	66.1	70.2	74.3
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: PC calculations.

That said, the implications in terms of *absolute* market-sector GDP are still significant. This is calculated by setting Δln RS to zero in equation {14} so that the counterfactual MFP growth rates from 1983-84 to 2002-03 are:

$$\Delta ln \widetilde{MFP}_t = \Omega \Delta ln MFPQ_t + \kappa \Delta ln QALI_t + \xi . CYCLE_t + \eta S \times \Delta ln RO_t + \varepsilon_t \qquad \{19\}$$

Then counterfactual growth in per capita market sector GDP is:

$$\widetilde{g}_t = \Delta ln \widetilde{MFP}_t + \Delta Capital\ deepening_t + \Delta labour\ hours_t \qquad \{20\}$$

so that counterfactual per capita GDP in any time period is:

$$Y\widetilde{CA}P_t = Y\widetilde{CA}P_{t-1} \times e^{\widetilde{g}_t} \text{ where in period 0} : \text{YC}\widetilde{\text{A}}\text{P}_0 = \text{YCAP}_0 \qquad \{21\}$$

and counterfactual market sector GDP is $\widetilde{Y}_t = Y\widetilde{CA}P_t \times POP_t$. Then the market sector GDP gain from R&D stimulated by public support over the period from 1983-84 to 2002-03 is $\text{Cumulative gain} = \sum_{1983-84}^{2002-03} (Y_t - \widetilde{Y}_t)$, while the gain in just the last year is $\text{Gain (2002 - 03)} = (Y_{2002-03} - \widetilde{Y}_{2002-03})$.

If Ω is 0.8, then the accumulated gross gains to market-sector GDP over the roughly two decades from 1983-84 to 2002-03 is around $54 billion in 2003-04 prices (table G.6). In 2004-05, the gains from R&D stimulated by public support were around $6.5 billion (noting that this, in part, reflects the growth benefits of past supported R&D). It might not be thought that this benefit is substantial given that governments invest around $6 billion annually in R&D. However, it should be recalled that a significant share of R&D stimulated by government is not allocated to activities that affect market-sector GDP. They still make contributions, however, to unpriced, but valuable goods and services (such as the environment or improved health) and these gains are not reflected in table G.6.

General equilibrium models provide a different approach to measuring aggregate GDP (and consumption) gains from publicly funded R&D. Econtech (2006) have undertaken an analysis using this approach and find more substantial consumption and GDP effects (box G.2). But the model involves more assumptions than those used above.

Table G.6 **Impacts on market sector GDP of R&D stimulated by public support**

Ω	*Cumulative gain 1983-84 to 2002-03*	*Gain in 2002-03*
	$ million 2003-04 prices	$ million 2003-04 prices
0.5	133 082	16 073
0.6	106 712	12 899
0.7	80 219	9 704
0.8	53 603	6 490
0.85	40 249	4 875
0.9	26 863	3 255

Source: PC calculations.

Box G.2 **Comparison with aggregate results from a general equilibrium model**

An alternative approach that can usefully show how and where the returns from publicly funded R&D may arise uses large general equilibrium models. Where these models are based on survey evidence from firms and others about the returns from particular projects (such as those making up the CRC program) they are reviewed in section 4.5 below. One study by Econtech (2006) takes a broader perspective and considers the magnitude and nature of the gains from *Backing Australia's Ability* (BAA) and total public R&D spending. The model suggests that the gains from all public support of R&D — roughly 0.6 per cent of GDP annually — generates a 2.3 per cent increase in aggregate consumer living standards annually (the best measure of the welfare effects of a policy in such models) and a one per cent increase in GDP annually. The comparable figures for BAA were 0.31 and 0.12 per cent respectively. However, while the model provides a useful basis for considering the possible disaggregated industry effects of spillover returns and their ultimate consumption effects, it is based on *assumptions* of spillover rates of return from public R&D, rather than empirical estimates.

Simulation analysis

Since there is considerable uncertainty about the values of Ω, s and μ, another approach is to presume some distribution of these and to sample their distributions, re-estimate the above model and then form the distribution of the resulting values of η and rates of return.

The approach taken was to use the beta distribution, which is bounded between one and zero. The shape of the beta distribution is determined by two parameters, α and β. If $\alpha=\beta$ and they are greater than one, then the distribution is symmetric and takes an inverted-u shape. In all cases in the simulation, $\alpha=\beta$. In any given simulation run, the sample taken from distribution was calculated as follows:

$$\text{if } \bar{x} >= 0.5, x_i = \bar{x} + (1.-\bar{x}) * 2. * (\text{ranbeta}(\alpha,\beta) - 0.5)$$
$$\text{else if } \bar{x} >= 0.5 \text{ then } x_i = \bar{x} + \bar{x} * 2 * (\text{ranbeta}(\alpha,\beta) - 0.5))$$

where ranbeta(α,β) provides a random draw from the beta distribution, x_i is the value of the ith random draw of the random variable x and $\bar{x}$ is the mean value of the variable. For example, in the case of values of Ω, $x_i = \Omega_i$, and $\bar{x} = \overline{\Omega} = 0.8$, and $\alpha=\beta=5$. Table G.7 discloses the assumptions about α and β for each relevant parameter in the simulations. Based on 10 000 random draws, the table also shows the characteristics of the distributions of the underlying parameters, the impact elasticity and the rates of return. A graph of the distributions of the returns and elasticities of R&D stimulated by public support from this simulation is shown in figure G.1.

Table G.7 **Characteristics of distributions of parameters and outcomes**

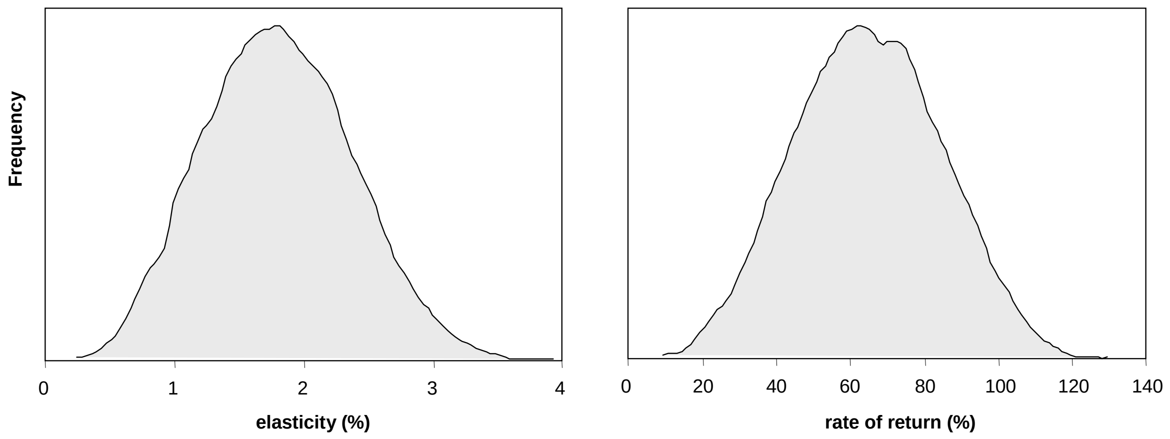
10 000 draws

	Theoretical mean	*5 per cent tail*	*95 per cent tail*	*Mean of draws*	*Median of draws*	*$\alpha=\beta$*
μ_{pub}	0.900	0.851	0.949	0.900	0.900	5
μ_H	0.900	0.874	0.926	0.900	0.900	20
μ_B	0.080	0.051	0.109	0.080	0.080	10
s_{pub}	0.600	0.399	0.793	0.598	0.598	5
s_H	0.400	0.259	0.546	0.400	0.398	10
Ω	0.800	0.700	0.899	0.799	0.799	5
Elasticity*100	1.80	0.87	2.77	1.80	1.78	..
Rate of return (%)	64.3	32.5	97.3	64.7	64.6	..

a s is the share of R&D conducted in various parts of the system that is relevant to the market sector output; μ is the measure of additional R&D relevant to the market sector from support, and pub, H and B are the public sector research agencies, higher education research institutions and business sector agencies respectively.

Source: PC calculations.

Figure G.1 **The distribution of the impact of publicly supported R&D**



[a] Density estimation using an Epanechnikov kernel based on a 10 000 simulation.

Data source: PC calculations based on the simulation methods described in the text.

Another important issue is which factors are decisive in influencing the rate of return in the simulations. It is apparent from the formulation of the estimation equation, {1}, that Ω must play a significant role, and this is also clearly apparent when a response surface is estimated on the basis of the simulated results. The response surface shows how the estimated rate of return is affected by any parameter, holding other factors constant. Only a simple linear model is estimated below (t statistics are in parentheses), when it is clear from {1} that the actual underlying relationships are non-linear. However, the goal was to see if a very simple formulation provided any useful insights. The simple model explains much of the variation in the outcomes for the rate of return and tests of some non-linear alternatives suggest better models do not qualitatively change the results. The results suggest that, for example, an increase in Ω of 0.1 decreases the rate of return by around 30 percentage points and that other parameters have relatively second-order impacts on rates of return.

$$RateR*100 = \underset{(451)}{310} - \underset{(239)}{20\, s_{pub}} - \underset{(202)}{24\, s_H} + \underset{(69)}{24\, \mu_{pub}} + \underset{(22)}{14\, \mu_H} - \underset{(8)}{5\, \mu_B} - \underset{(1889)}{322\, \Omega}$$

$R^2 = 0.997$; N = 10 000, t statistics in parentheses

G.5 Some cautions

The Commission’s method is semi-parametric rather than just based on assumption, though assumptions still play an important role. The assumptions used in any aggregate analysis of this kind generally have a large bearing on the outcomes of the analysis. Assumptions should be explicit, the sensitivity of the outcomes to changes in them should be tested, and their credibility gauged. Some assessments of the aggregate economy or industry effects of R&D that share some of the methods of this appendix do not pass all of these tests.

Two relevant ones for this study relate to the returns from agricultural R&D.

The Western Australian Department of Food and Agriculture said that it was possible that almost half the value of agricultural output in Australia in 2003 could be attributed to new technology generated by domestic R&D since 1953. It noted that the compound value of the stream of benefits from domestic research from 1953 to 2003 would be $878 billion (2004 prices, sub. 44, pp. 3–5). This estimate is based on a key assumption, namely that domestic R&D is the major driver of MFP growth in Australian agriculture. For example, it is assumed that domestic R&D contributes 1.2 percentage points to annual MFP growth, just over half the long term trend growth in MFP of 2.3 per cent a year. This assumption is highly questionable. Domestic R&D is one of a range of drivers of MFP in agriculture including, improved management practices, better education and training, increases in farm size, greater capital intensity, shifts in the mix of crops produced, overseas and non-agricultural R&D all play a role (PC 2005). The submission does not provide supporting evidence for its assumption that domestic R&D spending contributes more than all other factors combined, nor does it engage in sensitivity analysis. However, the submission (sub. 44, p. i) does point out the possible fragility of its conclusions:

> There are many causes of productivity gain and often there are long lead times for successful research and innovation. Hence, it is difficult to make an unambiguous, irrefutable case of attribution for the role of publicly funded science and innovation in delivering productivity gain for agriculture.

The Australian Government Department of Agriculture, Fisheries and Forestry also examined agricultural MFP growth and made estimates of the impact of a reduction in government funding of agricultural R&D on MFP and GDP. This analysis undertaken for DAFF by ABARE assumed that *all* agricultural MFP growth could be attributed to domestic R&D spending (sub. DR190, Attachment 1, p. 11). In estimating the impacts of a removal of the government's co-contribution for agricultural R&D of $204.7 million in 2004-05, it was assumed that rural MFP would decline by 0.42 percentage points a year. This figure was calculated by multiplying annual agricultural MFP (assumed at 2.6 per cent a year, drought adjusted) by 0.16 — government rural R&D spending ($204.7 million) as a share of total domestic rural R&D ($1280 million) in the same year. In effect, this assumes that MFP in Australia's agricultural sector is entirely driven by domestic rural R&D. The submission does not provide supporting evidence for this assumption or sensitivity analysis.

These examples indicate the importance of assumptions for the outcomes of such modelling and the need to test the credibility of those assumptions for policy analysis.

G.6 Conclusion

Overall, the results of this semi-parametric method suggest that the marginal rates of return to R&D elicited through public support could easily be as high as 65 per cent. The results are influenced by priors about the substantial significance of other factors contributing to MFP growth — such as diffusion of ideas from foreign knowledge flows; innovation more broadly and the impacts of intensifying competition. Figures higher (lower) than 65 per cent are possible if other factors contributing to MFP growth play a lesser (greater) role. However, even when uncertainty about the parameters is taken into account, rates of return are mostly between 35 per cent and 100 per cent. Much larger values would imply that the huge flows of knowledge from overseas and from non-technological forms of innovation were unrealistically small relative to the flows from domestic R&D (even after accounting for absorption issues — see chapter 3 and appendix D). Much smaller values would risk ignoring the important role of domestic R&D as a generator of knowledge flows and in absorbing foreign flows of knowledge.

The results demonstrate that it is possible to reconcile high social rates of return on R&D with a modest relative contribution to growth of market sector GDP. We find that even with large rates of return, the actual contribution to Australia's cumulative productivity growth (as measured by conventional MFP estimates) of R&D elicited by public support is relatively small over the last two decades. It is of the order of 2.5 to 7.5 per cent[2] (so that the remaining 97.5 to 92.5 per cent of multifactor productivity growth can be attributed to other factors, including non-supported R&D).

It is this modest relative contribution to MFP growth, against the background of the statistical noise in MFP models, that explains why econometric methods will generally find it hard to pin down the impacts of R&D on growth with any precision — the key finding of Shanks and Zheng (2006). But it is worth noting that even modest contributions are worth many billions of dollars to current GDP — some $54 billion over the two decades in the standard results of this appendix. However, it should not be inferred that significant increases in public support would necessarily realise bigger gains — an issue that is explored in chapter 4.

[2] Corresponding to Ω=0.9 to 0.7.

H State level panel data estimation of the returns to public and private R&D

This appendix provides a statistical analysis of the impact of R&D on multifactor productivity (MFP) and economic growth among the Australian States and Territories.[1] It is complementary to the Commission's recent analysis of business R&D and MFP at the national level (Shanks and Zheng 2006). In simple terms this study addresses three questions:

- Does the R&D conducted in the private sector have any spillover benefit beyond the private gains to individual firms?
- Does the total amount of R&D (public plus private) influence productivity and economic growth?
- Can the effects of BERD, GOVERD and HERD be separately identified?

The statistical analysis presented here proceeds in four parts. The first part briefly locates this study within the context of existing work. The second part is concerned with the construction of the state level MFP estimates and the R&D capital stock estimates. The third part graphically inspects this data to see whether any basic relationships or trends can be observed. Finally, econometric techniques are used in order to quantify the effect of R&D whilst controlling for other influencing factors such as the business cycle, human capital or unobserved state specific effects.

H.1 Background

Numerous macroeconomic studies have found evidence of a significant return to aggregate or business R&D, but relatively few specifically consider the impact of public R&D (see Dowrick 2003 for a useful survey). Furthermore, Shanks and Zheng (2006) have recently demonstrated the profound difficulties involved in generating robust results within the Australian context. The use of state level panel

[1] For the sake of brevity, States and Territories are hereafter referred to simply as States.

data can potentially illuminate the macroeconomic return to the various types of R&D through the information contained within the interstate variation.

To the Commission’s knowledge, state level panel data has been used on two previous occasions to estimate a return to R&D within the Australian context:

- Louca (2003) finds evidence of a positive relationship between business R&D and MFP; and
- Burgio-Ficca (2004) finds evidence of a positive relationship between higher education R&D and gross state product.

Both a MFP model similar to Louca’s and a production function model similar to Burgio-Ficca’s are estimated in this appendix. However, the sample size and exact variables used are slightly different in order to most appropriately represent the economic relationships whilst taking into account the availability and quality of existing data.

Additionally, special attention is given to the small sample characteristics of panel estimation, as well as the propensity for this kind of data to yield spurious results. Various panel cointegration tests were conducted and the Dynamic Ordinary Least Squares (DOLS) estimator, which is designed to correct for small sample bias, was compared with the Ordinary Least Squares (OLS) estimator. As Louca (2003) and Burgio-Ficca (2004) use essentially the same data, the results reported here will have implications for the findings of those studies as well.

H.2 Data construction

State level MFP estimates

All variables referred to here are available from the ABS State Accounts (Cat no. 5204.0) and the ABS National Accounts (Cat no. 5220.0) with the exception of hours worked, which is from ABS Labour Force (Cat no. 6202.0). All dollar variables are measured in chain volume terms.

The state level multifactor MFP estimates pertain to the whole (public and private) economy and were constructed using the Tornqvist index number methodology. This entails taking the ratio of output to an index of capital and labour inputs:

$$MFP_t = \frac{Y_t}{I_t} \qquad (1)$$

where I_t is computed as a Tornqvist index, and is calculated recursively from the geometric mean of the growth rates of the labour input (l_t) and the capital input (k_t):

$$\frac{I_t}{I_{t-1}} = \left[\frac{k_t}{k_{t-1}}\right]^{W_t^k} \left[\frac{l_t}{l_{t-1}}\right]^{W_t^l} \qquad (2)$$

where W_t^k and W_t^l are respectively the average cost share of capital (S^k) and labour (S^l) in periods t and t-1. That is:

$$W_t^k = \frac{\left(S_t^k + S_{t-1}^k\right)}{2}, \quad W_t^l = \frac{\left(S_t^l + S_{t-1}^l\right)}{2}.$$

The cost share of capital (S_t^k) and labour (S_t^l) are calculated as

$$S_t^k = \frac{\text{Gross Operating Surplus}}{\text{Gross Operating Surplus + Compensation Of Employees}} \text{ and}$$

$$S_t^l = \frac{\text{Compensation Of Employees}}{\text{Gross Operating Surplus + Compensation Of Employees}} \text{ respectively.}$$

This implicitly assumes that the share of labour and capital within gross mixed income (unincorporated businesses or self-employed persons) is the same as it is for the rest of the economy.

Labour (L_t) is defined as the total number of hours worked per year. This is calculated by averaging over the 12 reference weeks surveyed by the ABS and multiplying this by 52.

The state capital stocks were calculated using the perpetual inventory method (PIM), which in its simplest form can be represented as:

$$k_t = \left(1 - \delta_t\right) k_{t-1} + i_t \,. \qquad (3)$$

The depreciation rate of capital (δ_t) is calculated as:

$$\delta_t = \frac{\text{National Consumption of Fixed Capital}_\text{t}}{\text{Net National Capital Stock}_\text{t-1}}$$

and is assumed to be the same across the States but is permitted to vary through time. Investment (i_t) is real total gross fixed capital accumulation.

Equation (3) requires a starting value (k_0) which is computed based on the assumption that the average growth rate (g) of the observed total gross fixed capital accumulation for the each State adequately describes its annual growth for the indefinitely long preceding unobserved series. In this case, the starting value of the capital stock is given by:

$$k_0 = \frac{i_0}{g + \delta}$$

Incorporating k_0 into (3) yields the state capital stocks, which are then normalised such that they sum to the national capital stock calculated by the ABS:

$$k_t^n = \frac{K_t}{\sum_{i=s} k_{i,t}} \times k_t$$

where k_t^n = the normalised capital stock series for State *s*, K_t = the ABS national capital stock at time *t*, $\sum_{i=s} k_{i,t}$ = the sum of all un-normalised state capital stocks at time *t*, and k_t = un-normalised capital stock for State *s* at time *t*.

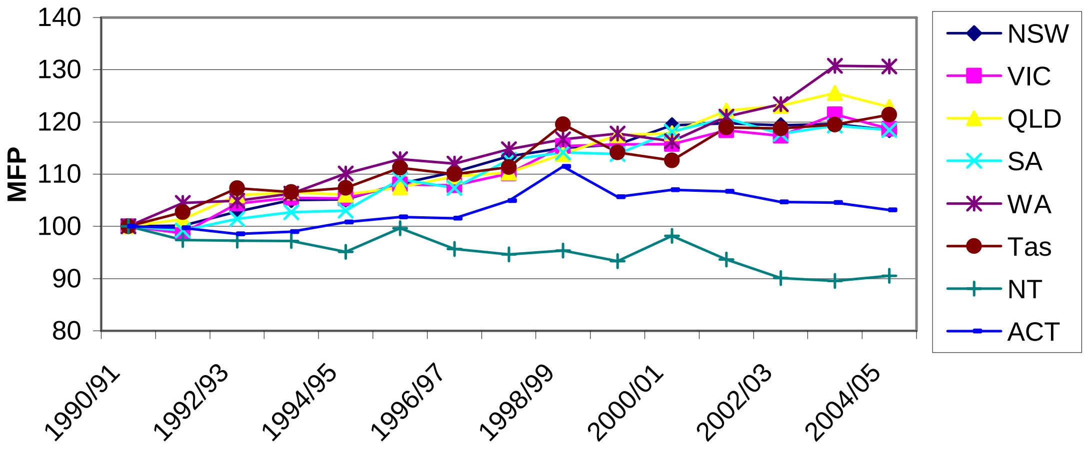
The state level MFP estimates derived through the calculations above come with some caveats. This formulation of MFP assumes a state level constant returns to scale production function and perfectly competitive markets. It is likely that these assumptions are more appropriate for some States than they are for others. Also, the available data constrain the state level MFP estimates to be of the whole state economy. This includes many sectors that are excluded from the ABS national MFP estimates on the basis that the growth in the volume of output is unsatisfactorily measured (Cat no. 5216.0).

The calculation of capital stock has two further limitations. Firstly, the assumption of a homogenous depreciation rate does not take into account the different industry structures, vintages and asset mixes across the States. Secondly, the calculation of the initial value of capital (k_0) is inevitably going to contain some degree of error, which will dissipate over time making it less problematic when long investment series are available. In this case, chain-linked real investment series at a state level are only available back to 1989, which will exacerbate this error.

Nevertheless, the estimation of MFP is essentially a question of the extent to which growth in output has outpaced growth in inputs. In this regard, despite the shortcomings of methodology and constraints of data availability and quality, the estimates presented here still provide valuable information concerning the productivity of the States. For the purposes of the econometric exercise, the inaccuracies of the MFP estimates can essentially be viewed as a measurement error of the dependent variable. The implication of this will be a loss of precision as well as estimates that will be biased towards zero, forcing us to be more conservative in our inference than we otherwise would have to be.

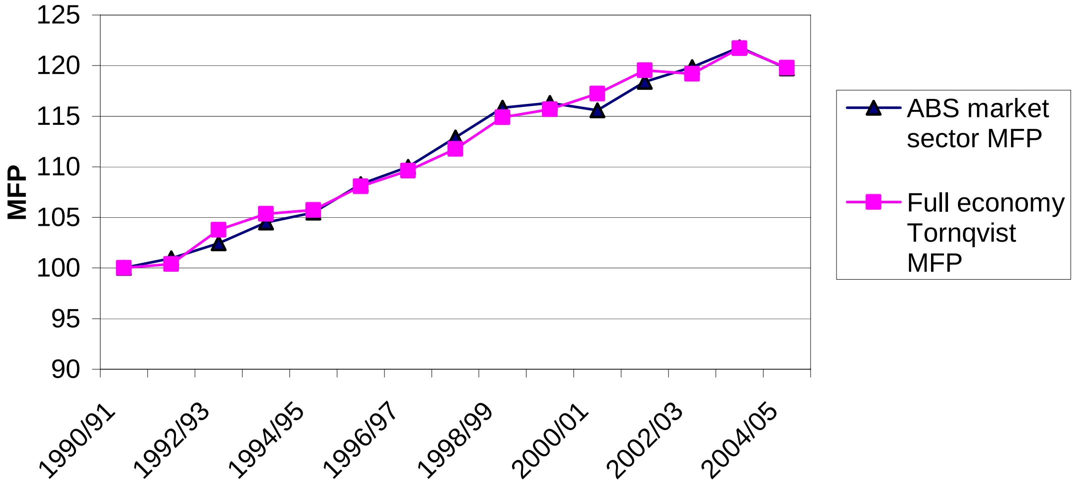
Figure H.1 illustrates the MFP series implied by the above calculations. All States exhibit growth in MFP over the period with the exception of the Northern Territory, which appears to have declined, and the ACT where MFP growth appears to have been stagnant. This is interpreted as stemming from an inability to measure MFP accurately in these States given their size and the structure of their economies. Applying the Tornqvist methodology to the Australian economy as a whole results in a MFP series which is close to the ABS market sector measure, as shown in figure H.2. This suggests that the whole economy story reasonably matches the market sector story for Australia in its entirety, although it does not necessarily offer a signal as to the quality of the individual state level estimates.

Figure H.1 **State level MFP estimates**



Data source: Commission estimates.

Figure H.2 **Full economy Tornqvist MFP estimate compared to the ABS market sector MFP estimate**



Data source: Commission estimates.

R&D stocks

When considering the impact of R&D upon MFP and GSP, simple use of expenditures ignores the cumulative nature of investment in knowledge, as well as the propensity of past investment in knowledge to depreciate or become less useful over time. For this reason some measure of the stock of R&D is usually used in order to reflect both historical investment behaviour as well as current. R&D capital stocks, like ordinary capital stocks, are calculated using the perpetual inventory method as described in equation (3) above. However, there is no obvious way in which the depreciation of the R&D stock can be measured and no theoretical indication of what it should be. Following recent papers by the OECD (Guellec and Pottelsberghe de la Potterie 2001 and Luintel and Khan 2005a) depreciation is arbitrarily set at 15 per cent.

Whilst BERD is available on a yearly basis at a state level (ABS Cat no. 8104.0), HERD, GOVERD and GERD (ABS Cat no. 8112.0) are only available bi-annually. In order to obtain a sufficient time series for the econometric analysis, annual data were generated by replacing the missing R&D expenditures with the average of the previous and following R&D expenditures. These expenditure series were then used to construct the stock series.

Both the ad-hoc selection of the process by which R&D expenditures become stocks, and the manner in which bi-annual data is transformed into annual data will have the effect of further introducing measurement error into the econometric model.

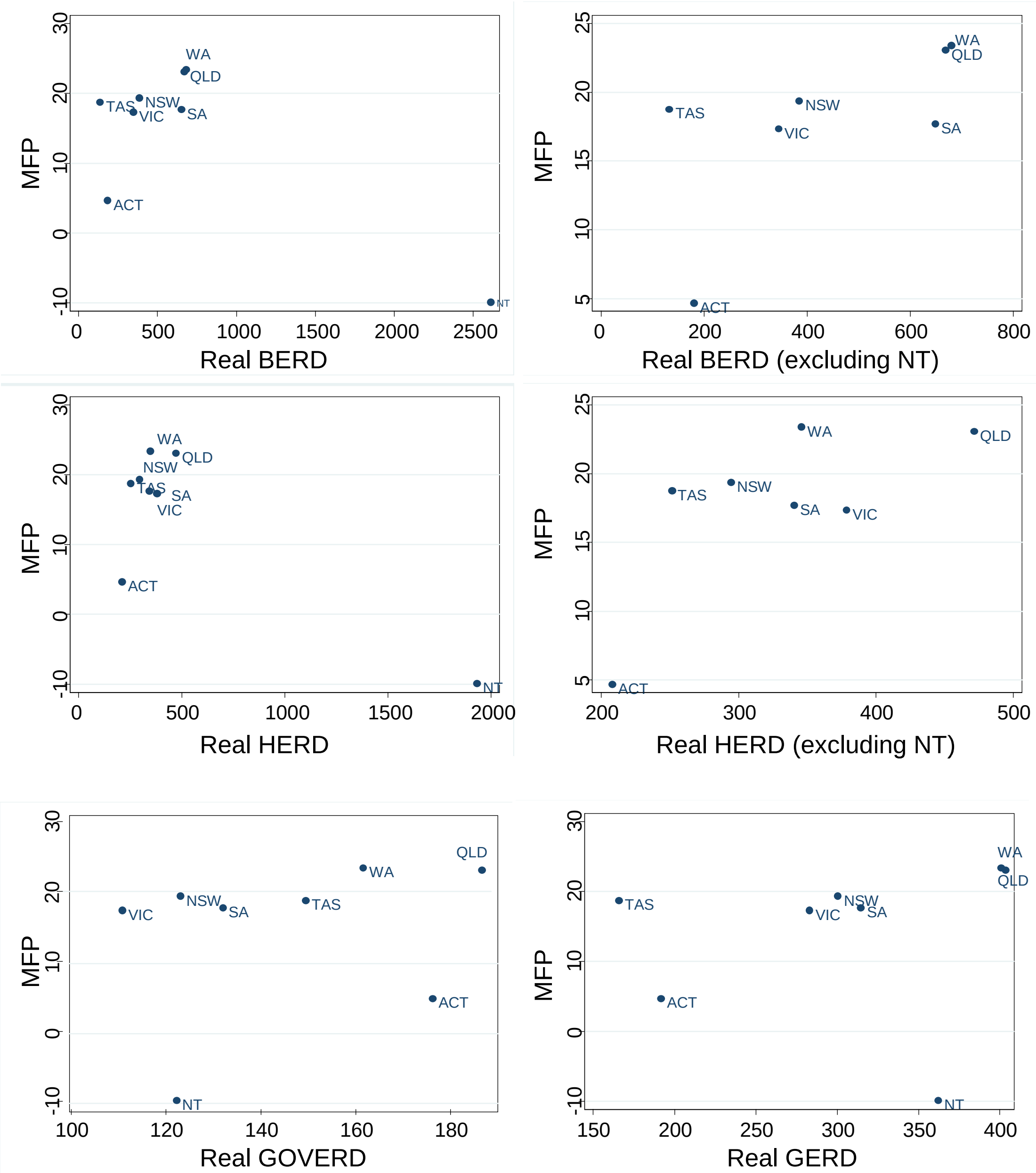
H.3 Descriptive statistics

Before proceeding with the econometric analysis, it is useful to see whether the raw data bear any evidence of a relationship between R&D and economic growth or MFP. Our effective sample is from 1990 (the earliest date for which MFP can be calculated) to 2002. Looking first at the long term relationship the obvious question is:

Have the States with the biggest percentage increase in R&D expenditure over the 12 year period also experienced the greatest percentage increase in MFP or GSP?

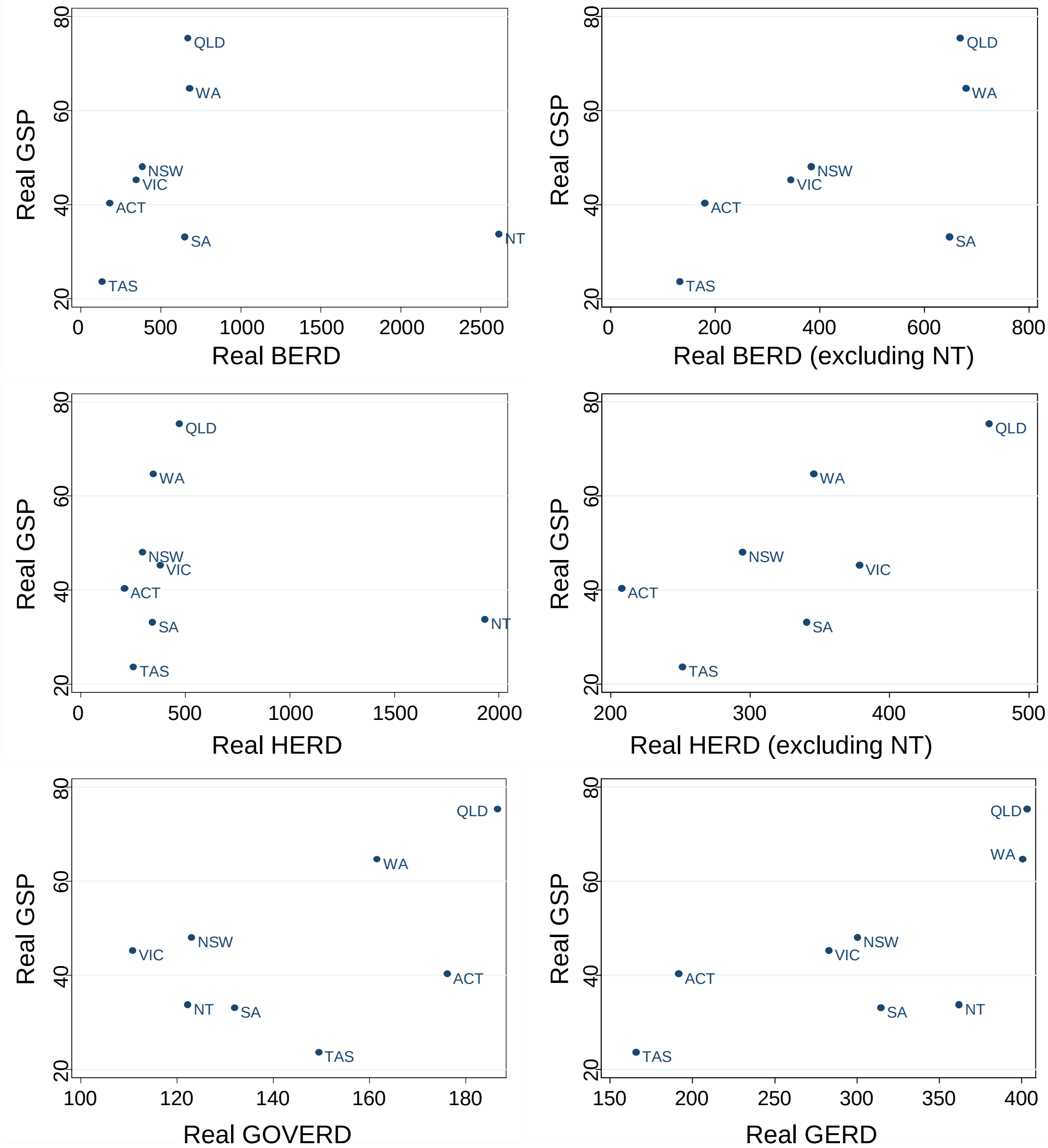
Figures H.3 and H.4 show that this generally appears to be true with the exception of the Northern Territory which has had considerable growth in all forms of R&D and very poor growth in MFP and GSP. Scatter plots containing BERD and HERD are plotted with and without the Northern Territory as the inclusion of this observation increases the scale of the plot such that the relative positions of the remaining States are obscured.

Figure H.3 **Percentage change in MFP and BERD, HERD, GOVERD and GERD from 1990 to 2002**



Data source: ABS (*Research and Experimental Development, All Sector Summary 8112.0); Commission estimates.*

Figure H.4 **Percentage change in GSP and BERD, HERD, GOVERD and GERD from 1990 to 2002**



Data source: ABS (*Research and Experimental Development, All Sector Summary,* 8112.0), ABS (*State Accounts,* 5220.0).

Table H.1 displays each State's rank in terms of the growth rates for MFP, GSP, BERD, GOVERD, HERD and GERD. Again we observe that the fastest growing States in terms of MFP and GSP also appear have the been the fastest growing States in terms of R&D with the exception of the Northern Territory whose relative economic performance does not seem to have matched its R&D record. The two fastest growers for MFP and GSP (Western Australia and Queensland) also hold the top two positions for overall GERD, whilst the slowest growers in MFP excluding

Northern Territory (that is, Victoria and ACT) hold the lowest two positions for GERD.

Table H.1 **Ranking of percentage change from 1990 to 2002**

State	*MFP*	*GSP*	*BERD*	*GOVERD*	*HERD*	*GERD*
WA	1	2	2	3	4	2
QLD	2	1	3	1	2	1
NSW	3	3	5	6	6	5
TAS	4	8	8	4	7	8
SA	5	7	4	5	5	4
VIC	6	4	6	8	3	6
ACT	7	5	7	2	8	7
NT	8	6	1	7	1	3

Source: Commission estimates based on ABS (*Research and Experimental Development, All Sector Summary,* 8112.0*) and ABS (State Accounts,* 5220.0*)*

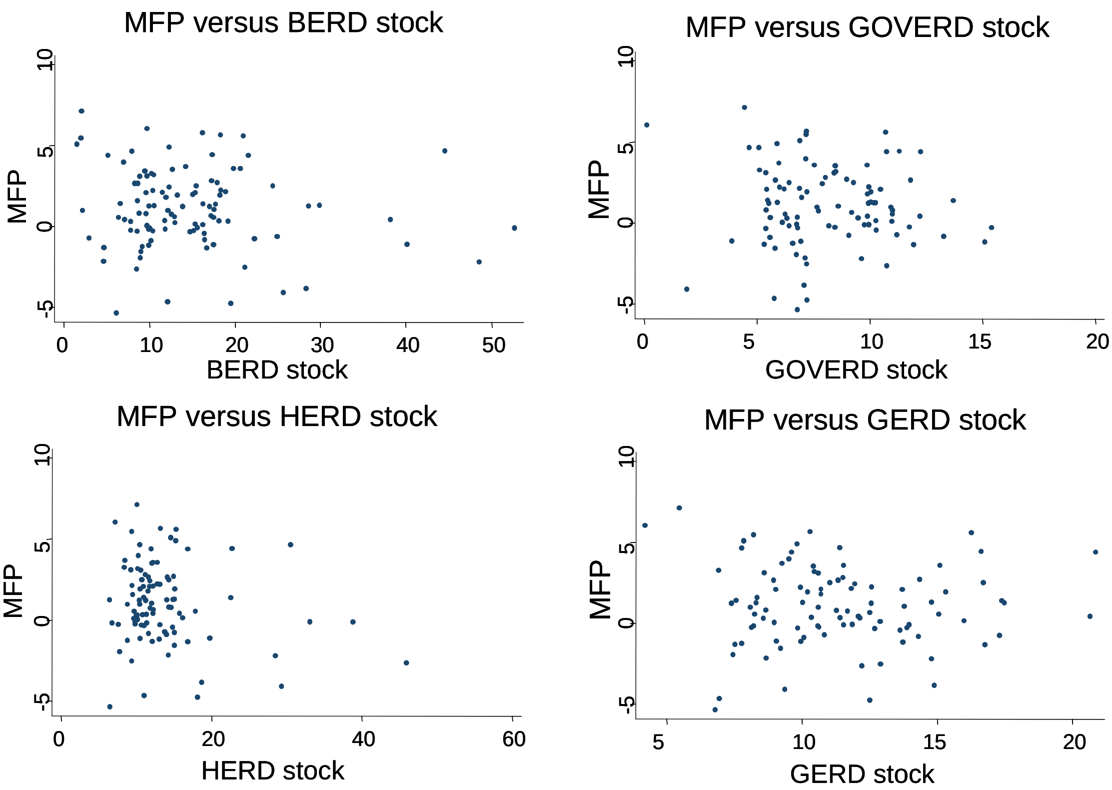
Clearly, we do not have sufficient evidence to suggest that R&D expenditures are significantly positively correlated to MFP and GSP, nor do we have any indication from this analysis as to the direction of causation, if any. Nevertheless, it does appear that those States that increased their R&D the most have experienced faster growth in GSP and MFP than those States which have increased their R&D the least. That is, upon casual inspection, the data appear consistent with the existence of a longer term relationship between R&D and productivity and growth.

For reasons noted in section H.2, the return to R&D is usually estimated through the use of R&D stocks. As R&D stocks take historical information into account, we can in theory capture the immediate impact of changes in these stocks upon MFP and GSP. As these variables all trend upwards over time, simply plotting them against each other illuminates little about their interrelationship. Differenced plots are useful in demonstrating whether a change in one variable is generally associated with a positive or negative change in another. This gives us an observation per State per time period and allows us to ask the question of the group:

Are periods with large increases in R&D stocks typically associated with larger increases in MFP or GSP than periods with only small increases in R&D stocks, regardless of State?

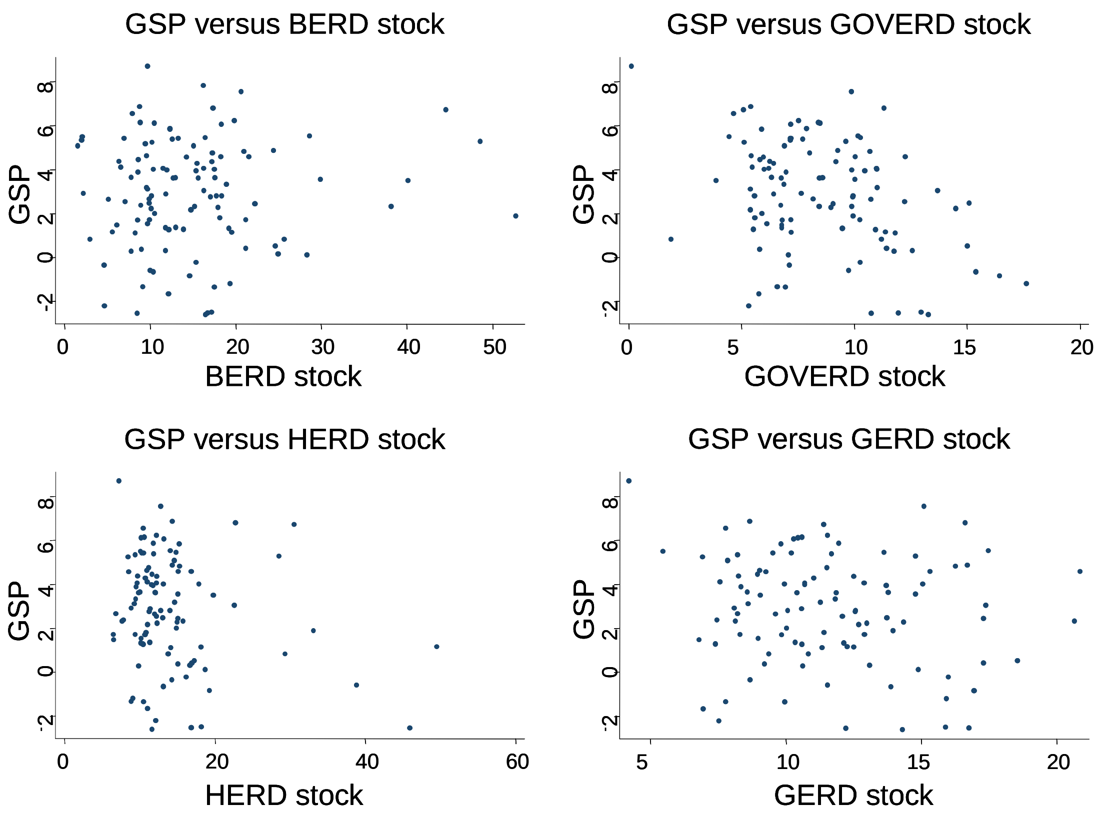
As seen in figures H.5 and H.6, there is little evidence that any form of R&D contemporaneously co-varies with either MFP or GSP in this way. Despite the fact that R&D stocks take historical information into account, it could be reasonably expected that changes in the R&D stock take some time to affect MFP and GSP. However, differenced plots of MFP and GSP upon lagged R&D exhibit the same basic pattern as those shown in figure H.5 and H.6 and are not reported here. This does not necessarily indicate that these variables have no influence upon each other given that we are essentially examining only their unconditional relationship in the short term. In order to control for the many factors that are likely to jointly influence MFP and GSP, more sophisticated econometric techniques are required. This is the focus of section H.4.

Figure H.5 **Percentage yearly change in MFP and BERD, HERD, GOVERD and GERD**



Data source: Commission estimates.

Figure H.6 **Percentage yearly change in GSP and BERD, HERD, GOVERD and GERD**



Data source: Commission estimates.

H.4 Econometric analysis

Theoretical model

The theory and empirical literature associated with the returns to R&D is well established and no further comment upon it is offered here. Interested readers can find detailed discussions in Dowrick (2003), Shanks and Zheng (2006) and the Industry Commission (1995). We seek to estimate the following models, both of which essentially yield elasticity estimates from which the returns to R&D can be imputed.

$$\ln MFP_{it} = \alpha \ln R_{it} + \beta XYZ_{it} + \lambda d_i + v_{it} \qquad \text{model (1)}$$

$$\ln GSP_{it} = \gamma_1 \ln K_{it} + \gamma_2 \ln L_{it} + \alpha \ln R_{it} + \beta XYZ_{it} + \lambda d_i + u_{it} \qquad \text{model (2)}$$

Model (1) is a simple specification of the determinants of MFP and model (2) estimates the state level production function. As MFP is calculated as an index, all R&D stocks in model (1) were transformed into an index with 1990 set to equal 100. This was not necessary in model (2). Both models control for individual state fixed effects through the inclusion of state dummy variables d_i.

The two models are theoretically equivalent, aside from the fact that model (1) assumes a constant returns to scale production function whereas model (2) does not restrict the elasticity of capital and labour in any way. The capital and labour information which is explicit in model (2) and embedded within MFP in model (1), includes the capital and labour used in the R&D process. In this sense, we are double counting labour and capital which, in the case of BERD, implies that any detected effect will in fact pertain to the 'excess' benefit of R&D beyond its private return. This is otherwise known as the spillover effect. In the case where the social return[2] to BERD is equal to its private return then it would be expected that the estimated elasticities of BERD in both models would be equal to zero. Thus, a positive elasticity estimate is indicative of the existence of positive spillovers.

The vector of control variables XYZ_{it} contains the rate of unionisation (*union*), the percentage of state residents with a post schooling qualification (*edu*), and a measure of the business cycle (*cycle*). The cycle variable is calculated using a Hodrick-Prescott filter (Hodrick and Prescott 1997) with the smoothing parameter set to 6.25, as suggested by Ravn and Uhlig (2002).

The vector R_{it} represents the different types of R&D that contribute to MFP and GSP growth including the BERD, HERD, GOVERD and GERD conducted within each State's jurisdiction, the R&D conducted in the rest of Australia (*AUS*) through which the domestic State benefits, and the R&D conducted in the rest of the world (*FOR*). The rest of Australia R&D variable (*AUS*) is simply the total GERD conducted in Australia minus that conducted in the State in question. The foreign R&D variable (*FOR*) is based on Lichtenberg and van Pottelsberghe (1998) and is taken from Shanks and Zheng (2006).

To avoid making a-priori assumptions about which types of the domestically conducted R&D are ultimately important to each State's economy, three different vectors of R_{it} are considered. In all three cases, both the interstate R&D stock and the international R&D stock are included.

2 In this instance, social return refers to economic benefit which is captured in the market sector but not necessarily taken into account by the private firms conducting R&D.

Case i: Only business R&D has an effect

It is likely that the imposed mechanism through which R&D expenditures become stocks (as described in section H.2) is less inappropriate in the case of BERD than in the case of HERD and GOVERD. This is because BERD is likely to have a shorter investment timeframe and is more likely to be oriented to market results that will be picked up by GSP and MFP data. As the Australian Government supports BERD through a number of means, estimating this relationship still has value in assessing the potential economic impact of the public support.

Case ii: The total amount of R&D conducted by both public and private agencies has an effect

The hypothesis here is that whilst both private and public research agencies have a significant economic impact, the individual effect of government, university and private sector R&D cannot be separated. This may be driven by the complex nature through which knowledge spills over from the public to the private sector or by increasing tendency by universities, public research agencies and the private sector towards joint partnerships.

Case iii: All forms of R&D have effects which can be separately identified

This formulation separates the R&D stocks into their BERD, GOVERD and HERD components. Whilst the likelihood of multicollinearity will hinder this approach, it offers the opportunity to examine the relative returns to different type of R&D.

The unit root and cointegrating properties of the data

As the macro-economic variables considered here are generally found to be non-stationary, the estimation of models (1) and (2) in logarithmic levels is valid only where the variables exhibit the property of cointegration. That is, the variables must share a common I(1) factor. In the absence of this property, OLS is likely to yield estimates that appear both highly significant and extremely precise, but are, in fact, completely spurious. This point is illustrated in box H.1.

To confirm that the data is in fact non-stationary, a range of diagnostic tests were performed. First augmented Dickey-Fuller tests were performed on ln*GSP*, ln*MFP* and all R&D variables for each State individually.[3] Whilst this generally indicated

[3] The use of information criteria to select the lag structure for these tests typically suggests longer lags than can be supported by the time series. As such, the Dicky-Fuller test, as well as the following panel unit root test were tested for sensitivity by separately employing 0 to 4 lags, with and without a time trend

the presence of a unit root in each series, Dickey-Fuller tests are known to have low power in the sense that they are biased towards a finding of non-stationarity. By setting cross series restrictions, panel unit root test can potentially provide stronger evidence of co-integration. Thus the following panel unit root tests were also used: the Multivariate Augmented Dickey-Fuller panel unit root test (Taylor and Sarno 1998); Levin-Lin-Chu test (2002); Im-Pesaran-Shin test (2003); and the Fisher test (Maddala and Wu 1999). These test the hypothesis that all series contain a unit root and with the exception of the Im-Pesaran-Shin test, they will reject this hypothesis if even one series is stationary. They are then, much less likely to falsely accept a null hypothesis of the data containing a unit root than Dicky-Fuller tests conducted on individual series. The results of these tests generally failed to reject the null hypothesis that all series contain a unit root.

The validity of our regression results rests crucially upon the suggested model specifications exhibiting a long run cointegrating relationship. One simple test of this can be conducted by applying the Engle and Granger Representation Theorem in which nonstationary variables can be said to be cointegrated if and only if they have an error correction representation. Engle and Granger (1987) suggest including the lagged residuals from the long run regression, as specified in models (1) and (2), in differenced versions of those same models. Evidence in favour of cointegration can be found if the coefficient on the residual terms is negative and significantly different than zero. The *t* statistics from this procedure are reported in table H.3 below and are found to be highly significant and of correct sign and magnitude, which suggests a cointegrating relationship is present.

In order to further investigate the presence of cointegration, residual-based tests are also generally performed. The five test statistics proposed by Kao (1999), as well as three test statistics proposed by Pedroni (1995), were calculated for all models and cases.[4] The test statistics unanimously reject the null hypothesis of no cointegration at 5 per cent level of significance, with almost all tests also rejecting the null at a 1 per cent level of significance. The results are reported in table H.2. However, Kao (1999) finds that when the time series dimension is small, as it is here, the tests will have low power and large size distortion. Thus, the test statistics presented in table H.2 represent only weak evidence in favour of a cointegrating relationship.

[4] All cointegration test were conducted using NPT 1.3, kindly made publicly available by Professor Chihwa Kao. See Chiang, M-H. and C. Kao 2002, “Nonstationary Panel Time Series Using NPT 1.3 A User Guide”, Center for Policy Research, Syracuse University, for details.

Table H.2 **Cointegration tests**

	Model 1	*Model 1*	*Model 1*	*Model 2*	*Model 2*	*Model 2*
	MFP eqn	*MFP eqn*	*MFP eqn*	*GSP eqn*	*GSP eqn*	*GSP eqn*
	Case i	*Case ii*	*Case iii*	*Case i*	*Case ii*	*Case iii*
Null Hypothesis : Equation is not cointegrated						
Kao (1999)						
DF_ρ	-3.42***	-3.42***	-3.6***	-3.1***	-2.8***	-3.31***
DF_t	-2.46***	-2.48***	-2.62***	-2.19**	-2**	-2.4***
DF_ρ^*	-5.07***	-5.15***	-5.06***	-4.59***	-4.2***	-4.37***
DF_t^*	-2.8***	-2.81***	-2.91***	-2.53***	-2.33**	-2.65***
ADF	-2.34***	-2.42***	-2.45***	-2**	-2**	-2.1**
Pedroni (1995)						
$t_{\rho_{NT}}$	-41.73***	-42.79***	-44.35***	-38.57***	-38.81***	-42.53***
$t_{\rho_{NT}}$ (1)	-12.19***	-12.1***	-12.56***	-11.84***	-11.78***	-12.48***
$t_{\rho_{NT}}$ (2)	-11.75***	-11.66***	-12.1***	-11.41***	-11.35***	-12.03***

*** statistical significance at 1 per cent or greater. ** significance at 5 per cent or greater. * significance at 10 per cent or greater

Source: Commission estimates made using NPT 1.3 software.

Box H.1 **Spurious regression and cointegration**

Consider two independent variables *x* and *y* for which random shocks do not dissipate over time and are therefore non-stationary. Such variables can represented as

$$x = u_0 + \alpha t + \sum_{j=1}^{t} u_j \quad (6)$$

$$y = v_0 + \gamma t + \sum_{j=1}^{t} v_j \quad (7)$$

Putting (6) in terms of the time trend *t* yields.

$$t = \frac{x_t - u_0 - \sum_{j=1}^{t} u_j}{\alpha}$$

(Continued next page)

Box H.1 **(continued)**

and substituting this into (7) gives

$$y_t = v_0 + \gamma \frac{x_t - u_0 - \sum_{j=1}^{t} u_j}{\alpha} + \sum_{j=1}^{t} v_t \quad \text{or}$$

$$y_t = \left(v_0 - \frac{u_0 \gamma}{\alpha} \right) + \frac{\gamma}{\alpha} x_t + \left(\sum_{j=1}^{t} v_j - \frac{\gamma}{\alpha} \sum_{j=1}^{t} u_j \right).$$

Regressing *x* on *y* will be likely to find a significant relationship, despite the fact they are independent series. In this case, testing for a relationship between *x* and *y* should be done in differences.

However, in the case where there exists a vector A such that $y_t - Ax_t$ is I(0) then y and *x* are said to be cointegrated. This implies that the distance between the two variables has a constant mean and they cannot drift arbitrarily far from each other in the long run. In this case the residuals from a regression of *x* on *y* will yield I(0) errors and we can legitimately use the levels data to estimate the long run relationship. A regression in differences of this data would still yield consistent estimates but would discard information about the long run relationship that is embodied in the levels data. In this instance, the existence of a true relationship between the variables is more likely to be rejected.

OLS estimation results

The results presented in table H.3 are robust to both model specification[5], and time series sample selection, but are sensitive to the exclusion of certain States.

In particular, the inclusion of the ACT and Northern Territory leads to much higher standard errors and counterintuitive results. This is likely to be driven by the fact that the growth in output in these States is less accurately measured given their size and structure. As such, the information they contain about the relationship between R&D and economic growth is likely to be misleading and the assumption of homogenous panels is likely to be compromised in their presence. Thus, these States were excluded from this analysis.

All models and cases were tested for serial correlation using the Arellano-Bond (1991) test and the testing procedure proposed in Wooldridge (2002) These tests

5 In particular, the key results presented here are robust to the inclusion of a time trend. Inclusion of a trend primarily impacted upon the foreign R&D estimates, which may be caused by this variable behaving in a similar fashion to a linear time trend.

suggested the presence of first order serial correlation but did not find evidence of higher order serial correlation. This is unsurprising as the modelling strategy employed here is focused on the long run relationship and omits the short run relationships, which are likely to be poorly defined and difficult to capture using conventional techniques. A variety of Generised Least Squares (GLS) techniques were used in order to strengthen the reliability of the inferences made about the estimated coefficients. As the primary effect of these procedures was to reduce estimated standard errors, with little difference to the estimated coefficients, the GLS outputs are omitted here in favour of a more parsimonious presentation.

The fact that both models provide similar estimated coefficients adds further plausibility to these results. Also, the estimated elasticities of capital and labour are quite close to summing to 1, which supports the assumption of constant returns to scale that was necessary in calculating MFP. The main difference between the two models is that the production function specification generally delivers slightly higher estimates than the MFP equation.

A prerequisite for the plausibility of the models estimate here is the significance of certain baseline variables for which we have a strong a priori expectation of their relevance. This amounts to getting a positive and significant coefficient for the business cycle variable in the MFP equation and, in the case of the production function, getting positive and significant coefficients on labour and capital that roughly correspond to their factor shares. These variables are all shown to be correctly signed and highly significant and whilst the coefficients on capital and labour are slightly different to their average factor share over the period[6], the average factor shares are within the 95 per cent confidence interval of these estimates.

The estimated coefficients for the other control variables, education and unionisation, are of expected sign and are stable irrespective of specification. Whilst education is highly significant in all models and cases, the rate of unionisation is only marginally significant in one instance.

The elasticity estimates of the various types of R&D appear to be of ‘reasonable’ magnitude and signed correctly with the exception of the rest of Australia R&D stock (AUS), which is found to be insignificant in all equations. Given the likelihood of interstate spillovers, this result may be driven by the small impact of interstate R&D relative to other types of R&D. It is also likely that the simple aggregation of interstate stocks insufficiently captures the relevance of the State’s R&D to each other’s economies.

[6] The average factor shares for labour and capital over the period are 0.62 and 0.38 respectively.

Table H.3 Results from static regression of all models and cases
Standard errors in parentheses

	Model 1 MFP eqn Case i	*Model 1 MFP eqn Case ii*	*Model 1 MFP eqn Case iii*	*Model 2 GSP eqn Case i*	*Model 2 GSP eqn Case ii*	*Model 2 GSP eqn Case iii*
$\ln L_t$				0.561***	0.475***	0.515***
				(0.073)	(0.079)	(0.074)
$\ln K_t$				0.441***	0.438***	0.464***
				(0.051)	(0.049)	(0.055)
$\ln BERD_{t-1}$	0.027***		0.015	0.028**		0.016
	(0.010)		(0.012)	(0.014)		(0.015)
$\ln GOVERD_{t-1}$			0.043			0.087*
			(0.047)			(0.052)
$\ln HERD_{t-1}$			0.024			0.009
			(0.032)			(0.038)
$\ln GERD_{t-1}$		0.058***			0.097***	
		(0.018)			(0.030)	
$\ln AUS_{t-1}$	0.031	0.003	-0.012	0.022	-0.037	-0.042
	(0.025)	(0.029)	(0.035)	(0.027)	(0.035)	(0.038)
$\ln FOR_{t-1}$	0.250	0.240	0.234	0.256	0.272*	0.264
	(0.152)	(0.150)	(0.157)	(0.160)	(0.154)	(0.159)
$Cycle_t$	0.913***	0.916***	0.933***	0.896***	0.916***	0.922***
	(0.122)	(0.120)	(0.122)	(0.127)	(0.122)	(0.125)
$Union_t$	-0.116	-0.143*	-0.130	-0.127	-0.158*	-0.167*
	(0.083)	(0.083)	(0.087)	(0.087)	(0.084)	(0.094)
Edu_t	0.002***	0.002***	0.002***	0.002**	0.002**	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	3.159***	3.203***	3.182***	-0.911	-0.312	-0.881
	(0.614)	(0.605)	(0.643)	(1.131)	(1.113)	(1.231)
R-squared	0.963	0.964	0.964	0.99	0.99	0.99
# of observations	84	84	84	84	84	84
ECM *t* stat[a]	-5.10	-5.97	-5.10	-3.23	-3.18	-2.85

*** statistical significance at 1 per cent or greater. ** significance at 5 per cent or greater. * significance at 10 per cent or greater. **a** Error Correction Model (ECM) regression output not reported.

There is limited evidence of international spillovers, with foreign R&D (*FOR*) found to be significant in case *i* and *ii* of model 2 at a 10 per cent level of significance, and bordering on significance at that level in all regressions.

Case *i* for both models presumes that of the domestic R&D conducted in each State, only BERD matters. The MFP model of this scenario most closely resembles the model estimated by Louca (2003) and, like Louca, a positive (albeit more modest) elasticity is found for BERD. The smaller magnitude of this estimate is possibly driven by the fact that human capital is ultimately omitted from his final specification whereby the effect of this omitted variable is likely to be picked up in the BERD coefficient. BERD is also found to be positive and significant in the analogous production function representation (model 2 case *i*).

Case *ii* tests the proposition that it is the total R&D conducted domestically in each State that matters, as opposed to that undertaken just by the business sector. The estimation results for case *ii* support this with the coefficient on GERD being positive and significant in both models. Interestingly, the estimated coefficient on GERD is higher than that of BERD from case *i*. Ostensibly, this suggests that the joint effort of public and private R&D agencies have a greater impact on MFP and growth than does the private sector alone. However, it could be that the major reason for this is simply that BERD is the biggest contributor to GERD.

Finally, case *iii* attempts to separate the effects of BERD, GOVERD and HERD. The estimated coefficients for these variable are all positive but are all found to be insignificant, even at a 10 per cent level of significance. The production function specification of this case most closely resembles Burgio-Ficca (2004), but does not support her findings. Whereas Burgio-Ficca was to able find significant and extremely large elasticities for both the pure and applied R&D, HERD spending is not found to be significant here.

Whilst evidence is found in favour of a significant effect stemming from BERD and GERD, it does not appear possible to separately identify the effect of BERD, GOVERD and HERD. The high degree of multicollinearity between these variables is likely to play a part in this finding, particularly between GOVERD and HERD which are largely driven by historical factors. Additionally, only a proportion of GOVERD and HERD are intended to have a direct economic impact, making their contribution more difficult to determine. Moreover, it is questionable whether the time period examined here of 13 years is sufficient to capture even the minority of the long term economic impacts of public research done at the basic level. There is anecdotal evidence that the recent trend towards greater interaction between public and private research agencies may result in the former conducting research with shorter time frames. However, collaborative R&D, which is likely to have a more immediate term impact, will almost certainly be linked to BERD, further concealing the individual sector's contributions.

There is some cause for concern as to the direction of causality between R&D and MFP and GSP. For example, businesses generating strong profits are likely to have a greater capacity to conduct R&D. Likewise, in times of strong economic growth, public research agencies are likely to face a more generous fiscal budget constraint. Lagging R&D stock by one period addresses this to some extent.

Dynamic ordinary least squares estimation

Kao (1999) finds that OLS estimation of the type implied by models one and two will provide consistent estimates, however, the associated *t* values will be divergent with a probability that goes to one as the sample size increases. Furthermore, the coefficient estimates will be biased in small samples, as is the case here. To deal with these issues, Kao (2000) proposes the use of a panel data version of DOLS. The results of this procedure are reported in table H.4.[7] There are a number of issues with the DOLS estimation, which, despite being theoretically appropriate, make it appear less credible than the OLS estimation. The results were very sensitive to choice of variables, time series and state selection, with the resulting estimates changing signs and falling in and out of significance. Furthermore, this estimator delivers a number of nonsensical results, with variables found to be highly significant but incorrectly signed. Finally, there is little coherence between models one and two, despite their theoretical equivalence.

It is likely that these deficiencies are caused in large part by the limitations of the data, given the sophistication of the procedure. This is particularly problematic with regards to sample size, as the differenced lags and leads used in DOLS results in lost observations, which critically reduces the information available for estimation relative to that available to OLS. With this is mind, the following analysis is based on the OLS estimates. However, given the known small sample bias, any analysis of OLS results need to be conditioned with an appropriate level of uncertainty.

[7] DOLS was also estimated using NPT 1.3.

Table H.4 **DOLS estimation**

	Model 1 MFP eqn Case i	*Model 1 MFP eqn Case ii*	*Model 1 MFP eqn Case iii*	*Model 2 GSP eqn Case i*	*Model 2 GSP eqn Case ii*	*Model 2 GSP eqn Case iii*
$\ln L_t$				0.830***	0.553***	0.422***
				(0.094)	(0.101)	(0.085)
$\ln K_t$				0.046	0.230***	0.356***
				(0.066)	(0.066)	(0.059)
$\ln BERD_{t-1}$	-0.001		-0.028**	0.163***		0.109***
	(0.014)		(0.015)	(0.017)		(0.016)
$\ln GOVERD_{t-1}$			0.351***			0.184***
			(0.062)			(0.056)
$\ln HERD_{t-1}$			-0.174***			0.037
			(0.034)			(0.036)
$\ln GERD_{t-1}$		-0.014			0.333**	
		(0.029)			(0.041)	
$\ln AUS_{t-1}$	-0.532***	-0.647***	-0.355***	0.337***	0.418***	0.331***
	(0.029)	(0.038)	(0.050)	(0.031)	(0.047)	(.050)
$\ln FOR_{t-1}$	3.301***	2.242***	2.285***	-3.402***	-5.473***	-6.108***
	(0.151)	(0.154)	(0.148)	(0.160)	(0.162)	(.141)
$Cycle_t$	1.562***	1.640***	1.563***	1.726***	1.712***	1.485***
	(0.171)	(0.174)	(0.158)	(0.170)	(0.170)	(.148)
$Union_t$	0.004	-0.109	-0.318**	0.447***	0.262***	0.353***
	(0.105)	(0.106)	(0.107)	(0.100)	(0.099)	(.096)
Edu_t	0.002**	0.003***	(0.002)*	0.021***	0.017***	0.021***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(.001)
Adjusted R square	0.934	0.942	0.956	0.974	0.980	0.992

*** statistical significance at 1 per cent or greater. ** significance at 5 per cent or greater. * significance at 10 per cent or greater

Source: Commission estimates made using NPT 1.3 software.

Rate of return estimates

An Australia-wide rate of return can be calculated from the OLS results in table H.3 by multiplying the estimated elasticities (ε) by the ratio of GDP to the R&D stock:

$$\text{Rate of return} = \varepsilon \frac{\text{GDP}}{\text{R\&D stock}}$$

At both a state and a national level this procedure will result in a rate of return series that is declining through time. This is demonstrated in figure H.7 for the BERD and GERD estimates that were found to be significant in case *i* and *ii* for both models.

The observed pattern is driven by two things:

- The regression analysis implicitly assumes that the R&D elasticities are constant over time.
- R&D stocks have grown faster than GDP over the period considered.

It is plausible that the dramatic growth in R&D has lead to diminishing returns, however the magnitude of the decline of the return to R&D and its starting point in 1990 are too large to be uncritically accepted. As pointed out by Coe and Helpman (1995), rates of return estimated in this fashion are sensitive to the benchmarking of capital stocks and are therefore less reliable than the elasticity estimates.

The average rate of return for all States and Australia as a whole over the entire time period are presented in table H.5. The Australia-wide average returns on BERD are calculated to be 164.8 per cent (model 1) and 140.6 per cent (model 2), whereas the average returns on GERD are 185.6 per cent (model 1) and 238 per cent (model 2). On the surface these rates of return appear very high, certainly higher than the private returns to other types of investments. However, as these returns pertain to spillovers, or the 'excess rate of return to society' beyond that considered by those actually making the investment decision, they are at least possible. Louca (2003) presents point estimates of 116 per cent in 1999 which are similar to those found here for the comparable case i in both models. However, Louca's 1990 point estimate of 173.4 per cent is much smaller than figure H.7 suggests.

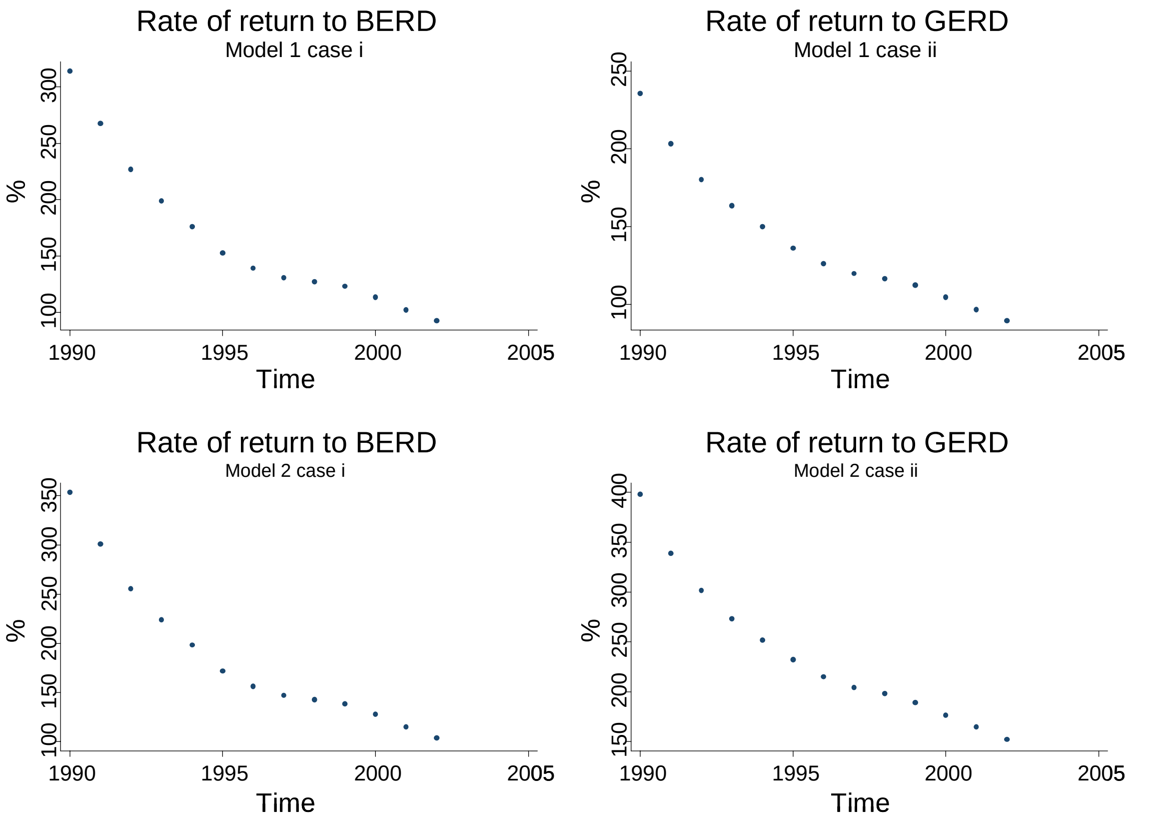
Table H.5 **The percentage rate of return for BERD and GERD**

Averaged through time

State	*MODEL 1 case i*	*MODEL 1 case ii*	*MODEL 2 case i*	*MODEL 2 case ii*
	BERD	GERD	BERD	GERD
NSW	157.1	162.3	176.9	274.7
VIC	113.3	121.1	127.6	205.0
QLD	317.2	190.8	357.0	322.9
SA	215.9	122.0	243.1	206.5
WA	201.6	174.5	226.9	295.4
TAS	240.3	110.4	270.6	186.8
AUS	164.9	140.7	185.6	238.1

Source: Commission estimates.

Figure H.7 **Rate of return to BERD and GERD**



Data source: Commission estimates.

Conclusion

The econometric analysis in this chapter finds tentative evidence in favour of a positive link between the economic growth and productivity of the Australian States and the amount of R&D conducted in them. Specifically, OLS estimation suggests that BERD and GERD have a statistically significant effect on GSP and MFP, and the tests of cointegration indicate that the relationship is not spurious. The results support the theoretical conjecture that firms are not able to fully appropriate the returns to R&D, resulting in spillovers. The elasticity estimates also suggest that MFP and GSP may be more responsive to changes to overall R&D (GERD) than they are to private R&D alone. This provides limited evidence that the R&D done by universities and public research agencies also affects measured GDP and productivity. However this effect cannot be separated out into its individual components: BERD, GOVERD and HERD.

The analysis undertaken did not find any significant relationship between both international and interstate R&D, and either MFP or GSP. However, it is far more likely that this stems from our inability to appropriately measure the relevant stocks than those stocks being irrelevant to the progress of each State's economy.

I What can be learnt from cost-benefit case studies?

This appendix examines case studies that attempt to estimate the value of research projects undertaken in public sector research agencies. Overwhelmingly, the most common evaluative tool is cost-benefit analysis (CBA), though this has several variants (such as those that employ real options analysis). However, increasingly, general equilibrium analysis is also being used to evaluate the economy-wide effects of portfolios of research activities.

The appendix begins with an overview of cost-benefit analysis (CBA) (I.1). It then examines the CBA studies — reviewing their methods, reliability and findings (I.2). The last section summarises the main lessons (I.3).

Chapter 4 distils the evidence from these case studies and considers some regression analysis based on metadata. Chapter 4 also reviews evidence put forward by study participants. This material is not repeated in this appendix.

CBA studies have several advantages over alternative measures of returns to research, such as econometric studies using economy-wide data. The advantages are that they may:

- provide insight into research investment decision making processes;
- explicitly list assumptions;
- make an attempt at quantifying costs as well as benefits;
- highlight the relative importance of different groups of beneficiaries — cost savings for consumers, cost savings for industry and industry profits (shareholders);
- reveal the impacts of less obvious influences on net benefits, such as competing foreign research and crowded-out private research;
- allow the implications of benefits for Australians/non-Australians to be separated;
- shed light on the riskiness of scientific research and the need to adopt a portfolio approach in order to generate net benefits;

- overcome many of the problems of macro-level studies of the relationship between scientific research and productivity; and
- shed light on the plausibility of claims of benefits and costs made for varying types of research.

On the other hand CBA studies also suffer from some drawbacks.

- Trying to estimate overall returns to R&D from a small number of CBA studies is likely to be misleading because of selection bias.
- CBA studies usually do not address the impacts of marginal projects. They tend to provide information about total costs and benefits (that is about average costs).
- They generally do not factor in the excess costs of raising taxes.
- Many CBA studies are undertaken before research is begun (ex ante studies). For these, costs, chances of technical success, paths to market and benefits to end consumers are often difficult to judge.
- There can be difficulties in attributing particular costs and benefits to specific projects.
- Counterfactuals are often hard to judge. Did a project crowd out private research? Would an outcome have been produced eventually by foreign research? Were other groups working on substitute technologies?
- More favourable cost-benefit ratios can be achieved by varying assumptions in reasonably arbitrary ways, which invites bias.

I.1 Overview of cost-benefit analysis methods used in case studies

There are several questions to be answered when determining the net benefits of research projects from a social perspective. They include determining: the scope of an evaluation; the gross social benefits and gross social costs; whether socially valuable projects will only proceed with government intervention; and whether alternative research or technologies are likely to displace outcomes before they can generate enough benefits to be worthwhile.

Research stages and evaluation scope

Research projects can involve complex histories from inception to outcomes. They usually involve large combinations of inputs, many of which are public good in nature, and often lead to multiple outcomes. All of this complicates the process of determining project boundaries for the purposes of undertaking CBA and, more importantly for this appendix, interpreting the results of different case studies.

Research projects may have several stages:

- pure basic research aimed at extending knowledge in specific scientific fields (usually without specific commercial applications in mind);
- preliminary mission-oriented (applied) research (either strategic or outcome-specific) with the aim of testing the feasibility of general approaches;
- strategic applied research to develop a set of related technical capabilities (related techniques/knowledge) with a range of possible applications;
- outcome-specific applied R&D devoted to solving specific problems by applying a set of techniques/knowledge previously developed; and
- adoption of research outcomes, which may involve additional costs for end users.

Boundaries can be drawn narrowly or broadly, with implications for the costs and benefits that are included in any case studies.

- Projects may draw upon prior basic research findings. In turn, those basic research findings may draw upon knowledge produced across entire scientific fields.
- Projects may draw upon ideas generated in related research projects undertaken concurrently by outside groups.
- Organisations may develop general scientific capabilities when conducting research projects (for example in plant genetics or materials technology), which may be used in later R&D projects.

The choices of scope depend on the purpose of any cost-benefit evaluation. For example, the scope of a CBA study will depend on whether it was intended to determine the benefits of proceeding with a particular applied project or investing in the development of a set of scientific capabilities (which may eventually lead to involvement in a range of applied projects).

The majority of the benefits of research are often generated from a few very successful projects. Because of this, it is often more sensible to examine the collective costs and benefits of a group of related projects. One approach would be to examine the entire costs of a broad area of research over a given period and the benefits of commercialised projects arising from that research area over the same period.

To determine benefits where the outcomes of publicly funded research are used as inputs for private R&D on commercial products, three approaches are used. First, both private and public costs can be compared with the benefits gained. Second, benefits can be apportioned according to the public research contribution. Finally, all of the benefits for final users can be attributed to the public contribution. In this last approach, private firms undertaking late stage development work are regarded as a link between public R&D outcomes and final users (Brown 1980).

Another consideration in some CBA studies is determining costs and benefits *for Australians* for research that is commercialised by foreign firms. If Australian research was the decisive factor eliciting foreign private R&D, then the Australian public research costs can be compared with the benefits for Australian consumers from the products or services generated and with royalties paid on Australian owned IP.

Determining the social benefits and costs of research programs

Undertaking CBA is similar to, but broader than, the kind of process a firm might undertake when considering launching a new product. A firm might consider how much a product costs to produce and how much consumers are likely to pay. In CBA, the calculation of net social benefits also includes benefits for which consumers cannot be made to pay and includes costs imposed without compensation. In these cases, methods need to be used to arrive at estimates of willingness to pay and willingness to accept costs in the hypothetical situation where payments can be enforced and where compensation is offered.

Because CBA is designed to provide information that allows decision makers to redirect resources from one set of uses to another in an informed way, the benefits of alternative courses of action need to be taken into account. In practice, the costs of government research programs are calculated as the foregone benefits of the alternative use of the resources employed in the program. Alternative uses for a particular publicly financed project include tax reductions, other government non-research expenditures and other publicly funded research.

The gross benefits of a project are then divided by gross costs to yield a benefit cost ratio (BCR). A BCR of greater than one indicates that there are positive net benefits from undertaking a project.

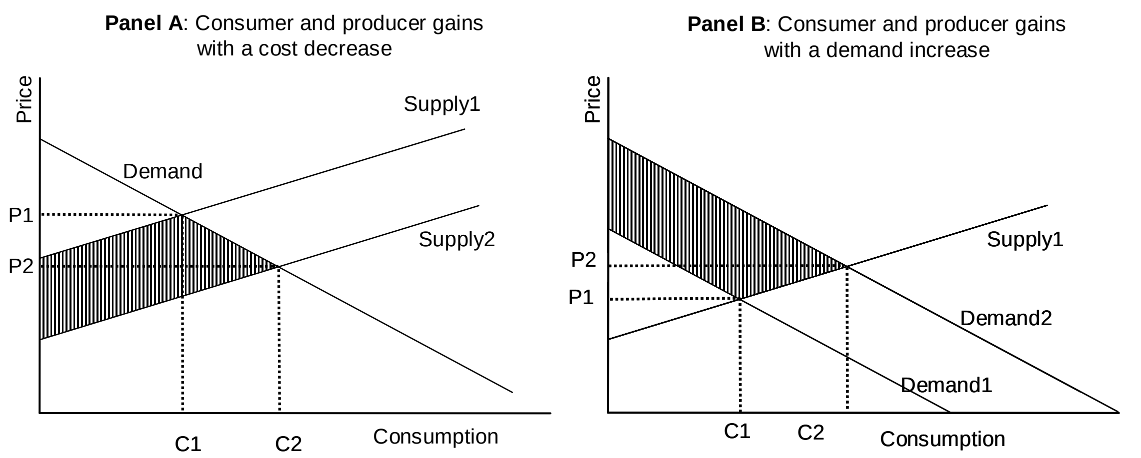
Consumer and producer surpluses

Benefits

In CBA, gross social benefits are usually calculated by estimating changes in consumer and producer surpluses. The main ways in which innovations resulting from R&D lead to benefits for consumers and producers are through:

- cheaper product or services for consumers (panel A, figure I.1);
- higher quality products or services for consumers where price rises are less than the additional amounts consumers are willing to pay for that additional quality (panel B, figure I.1);
- additional profits for Australian firms;
- licensing revenues for public research agencies; and
- positive spillovers — realised as reduced environmental or social costs to the community (for example, reductions in water pollution or diffusion of public health advice) — or realised as knowledge from one research project being used in other research or in the development of other products.

Figure I.1 **Measuring the gains**



Costs

Resource costs are simply measured as expenditures on project inputs. They include labour, equipment, intellectual property and overhead costs. These include the value of resources devoted to research and development activities borne by public research agencies and private partners. The costs also include the inefficiencies arising from the burden of taxes used to finance the project (the marginal excess burden or MEB). Estimates of the MEB (which also includes allowances for the administration costs of collecting taxes) vary, but a rough estimate of 20 per cent has been used in this study (chapter 3 and chapter 10).

Time-preferences

The notion of time-preferences for consumption relies on the observation that people prefer current to future consumption. This introduces a comparability problem between costs or benefits occurring in different years. To produce a standardised valuation, costs or benefits in each year are weighted by a factor that represents the relative value consumption in that year compared with the value of consumption in a nominated base year.[1] The time-preference rate, or discount rate, is usually set to reflect real interest rates (when discounting real expenditures), although this can vary. It is common in CBA studies to use real discount rates of between five and ten per cent.

Accounting for risks and options

It is possible to undertake CBA at any point during a research project. This introduces the problem of valuing costs and benefits when evaluations are undertaken before technical outcomes have been finalised or market impacts determined. Where benefits and costs are uncertain, the way of incorporating them into a CBA is to weight them by probabilities of success.

There are two main approaches. One is to consider a project as if it had already finished and treat the decision to go ahead as having been made at the start of the project.

The second approach is an options or contingent approach. This takes account of the fact that project managers rarely have to pre-commit all resources at the start, but can vary funding and the nature of the project at various stages during a project’s progress. The options approach (used extensively by ACIL Tasman 2006e) has several major insights and advantages. Its main advantage is a more realistic treatment of research project decision making, in particular, the possibility of stopping research projects and saving costs if interim research outcomes are poor. Since the research process itself will provide better information about a project’s chances of success — it makes sense to stage research projects with decisions to

[1] As an example consider a project that involves spending $1 a year for three years. If the last year were designated as the base year, then a discount rate of five per cent would value the first year’s spending at $1.10, the second year’s at $1.05 and the third year’s at $1.00. The overall base year present value of costs would then be $3.15.

increase resources being based upon knowledge generated during initial research periods. Typical stages might include a feasibility period, a period of early research involving only a few researchers, a period of more intensive research where resources are increased and finally periods of development that may require large expenditures. The staged nature of research means that ex ante costs and benefits should be weighted by their probabilities of being incurred or generated, rather than being considered as being fixed once a project has started (as is usual in traditional CBA). Because of this, the options approach will tend to yield lower estimates of the ex ante costs of research projects. Consequently, the options approach tends to produce higher ex ante estimates of net benefits than standard CBA.

In both of these cost-benefit approaches the probabilities of success are often very difficult to judge. The usual way of handling this problem is through sensitivity analysis, where a range of likely values are estimated.

Counterfactuals: additionality and technological displacement

CBA studies should take account of outcomes under counterfactuals — what would have happened in the absence of the project — comparing these with outcomes associated with the project. The key issues are additionality and technological displacement.

Additionality

Additionality measures the extent to which a research project is genuinely new or has crowded out a project that would have taken place under the counterfactual. This can arise when the private returns to a project are sufficiently high to create strong private incentives for private funding. Where complete crowding out occurs, a publicly funded project elicits no benefits (nor involves direct costs) because it merely displaces those associated with a crowded-out private project. Second, as it still occasions the inefficiency of tax financing, the net benefits of such projects will be negative.

Technological displacement

It is also important to consider whether competing research is being undertaken overseas or is be likely to be undertaken overseas in the near future. Technical change is occurring all the time at a rapid pace. As technological opportunities emerge they are normally pursued by many public research groups around the world. In this context, opportunities for socially beneficial Australian public intervention often require careful targeting.

In this situation, Australian research projects will only be beneficial if, in their absence, overseas research would not have not produced similar results without a significant delay. This counterfactual approach involves a judgment about what would have happened in the absence of the research project. One implication of this approach is that the incremental benefits of public intervention are usually displaced after a limited number of years. Exceptions are more likely where research is undertaken into Australian-specific problems, which are of little interest to other countries.

Another source of displacement arises when substitute technologies overtake particular technical approaches and render them obsolete. This means that counterfactuals extend not just to the likelihood of foreign research producing similar technical outcomes, but that a range of approaches may eventually lead to better ways of achieving particular outcomes.

The difficulty with the counterfactual approach is that the actions of overseas research efforts and their chances of success can be difficult to judge accurately. Better CBA studies are based on wide consultation with relevant experts in the research/technology fields in question, and employ sensitivity analysis to take account of the increased uncertainty.

General equilibrium models

Another method used to analyse the returns from public R&D is general equilibrium (GE) modelling. This has, for example, been applied to the CRC program. GE models calculate impacts on prices, production, consumption and investment across different industries when resources are directed into alternative uses. For a program to be considered successful, it must cause real GDP, consumption or investment to rise across the entire economy.

The main features of GE models are that they:

- compare the differences in GDP, consumption or investment between a without-government-program model and a with-government-program model; and
- incorporate direct (first round) effects and secondary effects (for example in the CRC evaluations, the direct effects were cost-reductions, profit increases and export and domestic sales increases identified for firms using CRC innovations).

One of the main differences between CBA and GE analysis is the treatment of welfare gains. One commonly used measure of welfare gain in GE models is the change in real consumption between with-program and without-program models. This differs from CBA, which uses changes in consumer and producer surpluses.

Real consumption increases can be expressed as a ratio per dollar of program expenditures. A ratio of greater than zero indicates a successful program. This differs from the success criteria for CBA studies, which is a BCR of greater than one.

I.2 Findings from cost-benefit studies of returns to publicly funded research

Overview of available cost-benefit studies

CBA studies were identified for research projects undertaken by CSIRO, CRCs, RRDCs and some State agricultural departments. These bodies specialise in mission-oriented strategic and applied R&D projects, with the goal of generating public good or commercially-useful outcomes.[2]

Evaluation studies of university research did not yield much information on commercialised projects. This reflects universities' greater concentration on curiosity-driven research and applied social research, rather than on fully commercialised outputs. Instead, existing university research evaluations concentrated on evaluating the efficiency with which research outputs (mainly publications) were produced (these issues are discussed in chapter 4 and appendix K).

A variety of CSIRO research areas were the subject of studies. These included: agricultural crop research; entomology; wool manufacturing technologies; automated mining equipment; industrial processing; advanced vehicle technologies; visual processing for road maintenance; pharmaceuticals; and animal health research.

The latest CRC program evaluations (Allen Consulting 2005a; Insight Economics 2006) used a general equilibrium approach to determine the overall impacts generated by CRC research to date. Information collected in the evaluations included identified direct benefits from a number of CRCs and total CRC grant expenditures from 1991 to 2005.

[2] Strategic research is longer term and considered likely to produce a range of applied innovations in broadly related technological areas (such as machine tools or cleaner power generation technologies and so on). Applied research is aimed at generating useable innovations and may be strategic or outcome specific. Applied research differs in emphasis from basic research, which has as its main aim advancing the frontiers of knowledge in various scientific fields.

Other field-specific CRC studies included studies of fisheries and weed management research. Detailed information was also obtained for grains, cattle breeding, rice, cotton and fisheries research projects undertaken by RRDCs and State agricultural departments.

The coverage of the case studies was found to be small compared with the total research output of these agencies. For example, CSIRO successfully produced, on average, 81 new technologies or products per year in the three years from 2002-03 to 2004-05 (while these technologies or products were not yet at the utilisation or commercialisation stage, a significant proportion of these are likely to become utilised/commercialised). The total number of identified CBA studies for research conducted over the 1980s and 1990s was 41 studies.

Methods used to calculate benefits among the selected case studies

The CBA studies collected used a variety of methods to estimate the consumer and producer surplus benefits from the introduction of research outcomes. Some of these studies were undertaken before adoption and some after. Those undertaken before were likely to be less precise because it was necessary to make assumptions about likely adoption levels.

The studies generally fall into three main categories: studies undertaken before research has been completed (referred to as ex ante studies); studies undertaken after research has been successfully completed, but before the research outcomes have been have been adopted; and studies undertaken after research has been completed and research outcomes adopted in the market or otherwise utilised. The last two kinds are both usually referred to as ex post studies.

In this appendix we use a different categorisation of CBA studies. A key factor affecting assessment of benefits is the rate of adoption of innovations. Determining how widely an innovation has been adopted can generally only be known with accuracy some time after research outcomes have been commercialised or otherwise utilised. Hence, for this analysis, studies undertaken before this point are referred to as ex ante utilisation studies and those after as ex post utilisation studies.

Many of the agricultural projects involved research that increased the yield of crops. The method used to determine benefits in these cases was usually a fixed cost saving model. Costs are divided into variable costs (seed, fertiliser, herbicides, insecticides, fuels, repairs, labour and insurance) and fixed costs (capital costs of land, buildings and machinery). The ratios of fixed costs to original yield and fixed costs to post-adoption yield are then calculated and the difference taken as a measure of the benefits associated with improved crop yield. For example a crop might require $50 of fixed costs per tonne prior to adoption and $45 per tonne after adoption. The difference, $5.00 per tonne, is then the per tonne reduction in fixed costs resulting from the improvement in crop yield. Usually, as an approximation, the prevailing price is used in these calculations and it is assumed that world wide consumption of the crop does not change.

Other cost benefit studies adopted a more straight-forward method of measuring cost-savings, estimating pre and post adoption costs per unit of adoption or per unit of resources used in production. For example, these might be cost savings per patient or percentage reductions in fuel use in ceramics kilns where oxygen sensors are used. These average cost savings were then multiplied by adoption numbers (for example, numbers of patients using) or total resources used in production (for example, fuel used by ceramics manufacturers using oxygen sensors).

Table I.1 below describes the methods used in the selected case-studies in more detail.

Table I.1 **Methods used to calculate benefits in selected CBA studies**

Eight Projects in CSIRO's Division of Wool Technologies

- Benefits are usually from increased yields. These reduce costs per amount of production (ie costs per kg etc).
- Adoption periods start between 1995 and 1990 (based on start or planned start of commercialisation).
- Assumptions were made about the year in which maximum adoption will be achieved.
- Assume sales and benefits continue for at least 15 years.
- Counterfactual — Without CSIRO research the process would have been introduced 15 years later.
- Usually assume wool growers will be able to appropriate 30% of the benefits initially accruing to wool processors.

Ten projects in CSIRO's Institute of Plant Production and Processing

- Reduction in cost because of:
  - increased yields;
  - lower spraying costs; and
  - reductions in labour costs.
- Benefits were counted for 40 years from date of commercialisation.
- Counterfactual was usually the status quo.
- For most case studies there were data on adoption levels in 1990.
- Often this was set as the ceiling adoption level, otherwise a ceiling adoption level was estimated/assumed.
- A linear adoption pattern up to the ceiling level was assumed.

Twelve CSIRO entomology research programs

- Reductions in costs because of:
  - reduced production losses (leading to yield increases and falls in fixed costs); and
  - reduced spraying and other pest control costs.
- Production loss estimates:
  - area of crop planted;
  - average value of production;
  - proportion of crop lost because of infestation; and
  - proportion of infestations avoided.
- Control savings estimates:
  - area of crop or pasture treated;
  - average spraying costs per Ha; and
  - spray reductions allowed by the introduction of natural controls.
- Displacement periods were included for some studies.

Table Continued

Table I.1 (continued)

Sixteen grains research projects

- Benefits are from increased yields and reduced spraying costs.
- Fixed costs are calculated by subtracting variable costs from the average total price over the last five years.
- Prices are farm-gate prices.
- Reductions in fixed costs per tonne of production result when yields increase.
- Average cost reductions per tonne are multiplied by total production to calculate total benefits.
- Benefit periods usually ranged from around ten to forty years.
- Displacement periods were included for ten studies and ranged from 2 to 27 years.

Three weed prevention programs in the CRC for Weed Management Systems

- Estimates were made for:
– potential areas particular weeds can affect;
– costs caused per hectare;
– reductions in spraying costs per hectare; and
– proportions of overall weed infestations prevented.

Six agricultural research projects

Beef cattle genetic technologies in Australia

- Information was obtained on improvements in the genetic characteristics of beef cattle herds shown as indexes.
- Average cost reductions (food reductions, reduced fixed costs through faster growth) per index unit of genetic change have been established through studies.
- Total benefits were calculated for genetic improvement in southern herds and from improvements in the breed mix of southern herds.

Feed efficiency for cattle

- Genetic characteristics index information was collected.
- Studies gave an indication of feed efficiency for cattle of varying genetic makeup.
- This information was used to estimate a rate of feed efficiency improvement per index unit of genetic improvement.
- Annual cost savings of superior breeds were incorporated into a farm budget model along with costs of purchasing superior breeding stock to estimate overall benefits.

Wheat breeding program

- Collected information on adoption of improved wheat varieties (area sown and tonnage of production).
- Collected information from studies showing improvements in yields for improved varieties.
- Collected information from studies showing price premiums for improved varieties.
- Benefits were only attributed to varieties developed in NSW.
- The proportion of growth due to varieties developed outside NSW was deducted.
- Also estimated the proportion of value gain generated from improved varieties and the proportion generated from improved farm management practices and improved inputs.

Table Continued

Table I.1 (continued)

Bovigam

- Bovigam is a diagnostic blood test for bovine tuberculosis. It supercedes an older immune reaction test that required reinspection of cattle after several days and involved additional costs of holding and reinspecting cattle.
- Savings were made in mustering costs for the bovine tuberculosis eradication program in Northern Australia.
- Royalties from overseas sales were included less production costs. Production costs were assumed to be fifty per cent of royalties.

Growing crops after rice

- Opportunistic wheat can be grown after rice is harvested. It has the benefit of reducing water runoff into the water table from fields after rice production. Rising water tables can cause salt damage to paddocks. Farmers also benefit directly from additional earnings.
- The average area of the rice crop was estimated.
- Average prices were collected for rice, wheat, canola, wool and lamb.
- Gross margins were taken from NSW agriculture handbooks.
- A number of typical rotations were modelled for three rice growing regions. The modelling was then repeated with wheat included in various rotations. The average additional amount of wheat grown that could be grown was then estimated.
- Additional profits from wheat crops less profits from other uses of fallow rice paddocks were estimated.

Test for nitrogen status in rice

- Information on the total area under rice and the average price was collected.
- A decision tree was developed that showed likely applications of fertiliser when farmers were uncertain whether it was needed or not. This was then compared with likely applications when farmers were able to monitor nitrogen levels using the new test.
- Adoption was assumed to be by 70 per cent of farmers.
- Savings in nitrogen costs were calculated.

Six CSIRO manufacturing, industrial, scientific equipment and transport research projects

Solospun

- Solospun is a cheaper process for spinning wool garments.
- Benefits were from reductions in spinning costs and royalty payments.
- The worldwide quantity of yarn used in the process that the Solospun technique can be applied to — warp spinning of wool garments (as opposed to weft spinning) — was estimated.
- The maximum adoption rate of the Solospun process was estimated (seven per cent by 2015).
- Cost reductions from using the process were estimated to be 20 per cent.
- Royalties per Solospun attachment were estimated.
- Reduction in costs had the potential to reduce fabric prices and increase demand.
- The increased demand for Australian wool as a result of the price drop was estimated (using an elasticity of demand of -1.1).
- Wool exports and prices were taken from ABARE trend forecasts.
- Using the above estimates, benefits from additional sales for Australian wool producers were estimated.

Table Continued

Table I.1 (continued)

$SIRO_2$ oxygen sensor

- Reduction in fuel costs for ceramics producers were estimated.
- The proportion of ceramics manufacturers using the probes for combustion control, to reduce fuel costs, rather than atmosphere control was estimated.
- Specific cost savings from using the sensors were reported by two firms.
- Adoption was estimated from surveys of probe manufacturers.
- A displacement period of 15 years was used.

Atomic Absorption Spectrometer

- AA spectrometers are scientific instruments that can be found in nearly every scientific and industrial laboratory. They detect the concentration of extremely dilute substances in solution and are used in an extremely broad range of routine testing and experimental procedures.
- Users of the AA spectrometer were identified.
- A sample were interviewed to determine resulting productivity gains. These gains came from reduced testing costs and increases in the number of tests.
- Where prices had fallen and numbers of tests had increased, productivity benefits were calculated from increases in consumer surplus. Consumer surpluses were calculated assuming the elasticity of demand was one. A demand curve was traced between the old and the new price-quantity points and the consumer surplus was found by calculating the area under the curve and above the original price and quantity lines.
- Total gains were calculated by multiplying average productivity gains by a weighted average value for each instrument in use.
- Instrument numbers were obtained from the manufacturer. Future sales were also estimated.
- Royalties from overseas sales were collected from the manufacturer.

Supercapacitors

- The benefits of the project are the royalties CSIRO will receive.
- Current sales are known.
- The global market was estimated ($2 billion by 2006).
- Adoption of CSIRO supercapacitors was assumed to be between five and ten per cent of the total market.

Road crack testing vehicle

- Quantified benefits include:
  - reductions in road maintenance expenditures as a result of identifying and repairing road damage early, before damage becomes more serious;
  - reductions in minor accidents caused by poor road conditions; and
  - reductions in vehicle servicing required because of rough road conditions.
- Assumed RoadCrack vehicles would be adopted in all States within five years of initial introduction.
- National expenditures on road maintenance were estimated.
- The costs of major and minor road repairs were estimated.
- The proportion of early road cracks identified was estimated to be 60 per cent.
- Assumed five per cent of minor accidents and one per cent of vehicle repairs would be avoided.

Table Continued

Table I.1 (continued)

Exelogram

- The Exelogram security feature for banknotes and identity-documents (such as passports) makes counterfeiting and forgery more difficult.
- Benefits were estimated from royalties received by CSIRO between 1991 and 2004.
- There were losses from legal challenges made by the firm Charter Pacific that had initially been given an option to raise funding to commercialise the Exelogram technology.

Three CSIRO robotic mining research programs

- Benefits were from reductions in costs and reductions in down-time caused by deaths and injuries.
- Estimates were made for:
  – the proportion of mines that the processes being automated are used in;
  – the proportion of mine production accounted for by the processes;
  – reductions in labour costs;
  – reductions in down time caused by preventing deaths and injuries; and
  – capital costs of the robotic mining equipment.
- Cost-saving benefits were calculated by multiplying percentage cost-savings by total labour and downtime costs for mine processes adopting the robotic technologies.
- Installation costs were included for the Automated Vehicle and Longwall Mining studies. The Rapid Roadway project was assumed to have no additional adoption costs (the robotic equipment was assumed to cost the same as alternative non-automated equipment).
- It was estimated that CSIRO’s involvement in the research brought forward adoption of the technologies by five years

CSIRO pharmaceutical research

Anti-influenza drug research

- Reduction in medication costs were estimated.
- Reduction in the numbers of work days lost were estimated.
- Royalty payments from overseas sales were estimated.
- The research was assumed to have brought forward the introduction of Relenza and Tamiflu by four years.
- Numbers visiting doctors for influenza were calculated using influenza case rates, population numbers and the proportion of those with influenza that visit a doctor. Of these the proportion that visit within 48 hours of catching influenza was then estimated since this is the group that can be treated effectively with Relenza or Tamiflu.
- Reductions in alternative medication costs and doctors visits were estimated for the treatment group.
- The proportion of those with influenza that go on to be hospitalised was used to calculate the proportion of the treatment group that would otherwise have been hospitalised. Savings in hospital costs were estimated.
- The estimated costs of purchasing Relenza or Tamiflu was deducted from calculated benefits.
- Benefits from stockpiling Relenza and Tamiflu were calculated as being the consumer surplus generated from government stockpiling expenditures. The consumer surplus was estimated by assuming every dollar of expenditure generated a dollar of consumer surplus.

Sources: Collins and Collins (1999); Johnston, Healy, I’ons and McGregor (1992); CIE (2001a,b); CIE (2003a); Mills and Yapp (1996).

Quality of estimates made in cost-benefit studies

An analysis was undertaken of the quality of information used in calculating the benefits of the selected projects (table I.2). Higher quality sources included scientific trials (examples include studies that show yield increases for new crop varieties) and company surveys (often used to determine sales volumes). Approximations were considered as slightly less reliable, but still fairly reliable (examples include estimates of yields or prices of new crop varieties based upon yields or prices of older crop varieties). In some cases, the opinions of researchers or industry experts were sought where hard data were not available. The least reliable form of estimation were assumptions made with little supporting data (examples include assumptions of likely market adoption rates where sales have not yet started).

Overall, the analysis confirms that projects that take an ex ante utilisation approach are less reliable than those conducted some time after utilisation has occurred. This is not to say that future benefits can never be estimated. In cases where adoption rates have been observed for a number of years, predictions about future adoption rates are less uncertain.

For the adoption/sales estimates, most assumptions with little supporting evidence were made where benefits were being measured ex ante (table I.2).

Overall there were 36 ex post studies and 39 ex ante studies (tables I.3 to I.7b). Studies of projects from CSIRO’s Institute of Plant Production and Processing and Entomology Division were nearly all ex post utilisation. Most of the grains research and other agricultural research studies were ex ante utilisation (the main exception being the beef cattle genetics study). Four of the eleven non-agricultural studies were ex post utilisation.

There were a greater proportion of assumptions made to produce estimates for average benefits (benefits per unit of production) in the CBA studies of the CSIRO Division of Wool Technologies’ research and the CRC for Weed Management Systems’ research.

Most of the displacement estimates were based on assumptions with little supporting evidence.

Table I.2 **Counts of estimates made in selected case studies**

Studies		*Estimates of benefits per unit of production*[a]	*Estimates of market size*	*Estimates of adoption or sales*	*Additionality and other counterfactual scenarios*
Eight projects in the CSIRO's Division of Wool Technologies	Studies/surveys/facts	1	1	5	
	Expert opinions				
	Approximations[b]	11	2	2	
	Assumptions[c]	6	1	22	8
	Not stated	1			
	Total	**19**	**4**	**29**	**8**
Eleven projects in CSIRO's Institute of Plant Production and Processing	Studies/surveys/facts	9		13	
	Expert opinions	2		9	
	Approximations	17	1	7	4
	Assumptions	1		14	14
	Total	**29**	**1**	**43**	**18**
Three weed prevention programs in the CRC for Weed Management Systems	Studies/surveys/facts	1			
	Expert opinions	1			
	Approximations	5		3	
	Assumptions	7		6	3
	Total	**14**	**0**	**9**	**3**
Five CSIRO robotic mining research programs	Studies/surveys/facts	1	1		
	Expert opinions				
	Approximations	18	3	4	
	Assumptions	3		5	3
	Total	**22**	**4**	**9**	**3**
Six CSIRO manufacturing, industrial or transport research projects	Studies/surveys/facts	4		4	
	Expert opinions			1	1
	Approximations	8	6	1	1
	Assumptions	5		8	3
	Total	**17**	**6**	**14**	**5**
CSIRO anti-influenza drug research	Studies/surveys/facts	1	1	2	
	Expert opinions				1
	Approximations	2		1	
	Assumptions	2	1	3	1
	Total	**5**	**2**	**6**	**2**

[a] Includes estimates of yield increases, cost savings, price premiums for additional quality, royalties and adoption costs. [b] Approximation based on relevant knowledge. [c] Assumption with little supporting evidence.

Sources: Collins and Collins (1999); Johnston, Healy, I'ons and McGregor (1992); CIE (2001a,b); CIE (2003a); Mills and Yapp (1996); Commission estimates.

Selection of cost-benefit case studies

During the selection of case studies an attempt was made to exclude low quality studies.

Most of the CBA case studies first estimated average benefits before converting these to total benefits. Examples of average benefits include percentage yield increases, cost savings per unit of production, and cost savings per customer or patient. Average benefits were then multiplied by estimated adoption numbers to estimate total benefits. Examples of adoption estimates include tonnes of production, numbers of units sold, and numbers of patients treated.

Methods of estimating average benefits varied widely, including: agricultural studies of new crop varieties to test percentage yield improvements; calculating the amount of medication or hospitalisation avoided when a patient is treated with a drug; and calculating cost savings per laboratory test when using cheaper testing techniques are used.

All studies that contained estimates of average benefits were included in the analysis presented here, subject to an assessment of the quality of adoption estimates and the inclusion of sensible counterfactuals. However, some studies, while qualitatively sure of the benefits of an innovation, could not quantify the amount of that benefit. In such cases, some studies included guesses about the average benefits, often expressed as a percentage cost saving. Studies of this type were omitted.

Estimates of returns from individual case studies

Individual case studies examined in more detail were taken from studies of research projects undertaken by CSIRO, CRCs, RRDCs and State agricultural departments. The calculated returns to selected research projects are shown below in tables I.3 to I.7b. A summary of total benefits and costs across all individual case studies, broken down into ex post and ex ante groupings, is provided in table I.8.

Table I.3 **Cost-benefit studies from CSIRO's Institute of Plant Production and Processing**

Base case estimates, 2005 base year

	Research period	*Discount rate*	*Costs*[a]	*Benefits*	*BCR*[b]	*IRR*[c]
		%	$m	$m		
Take-all control in wheat	1978–1990	5	15.0	1 154.8	77.0	149.3
Disease resistant lucerne	1973–1986	5	18.4	55.8	3.0	11.3
Nematode-tolerant grape-vine rootstock	1960–1974	5	11.1	237.8	21.4	23.6
Chickpeas	1972–1990	5	26.5	138.4	5.2	15.1
Improved Phalaris grasses	1955–1990	5	83.8	504.0	6.0	16.7
Mechanical grape pruning	1972–1992	5	6.7	280.9	42.0	46.2
Wood fibre for cement sheeting (replaces asbestos)	1978–1982	5	3.7	227.3	61.3	75.7
Break crops for wheat farming	1981–2002	5	64.3	995.5	15.5	45.8
Stylo pastures	1967–1983	5	51.2	200.4	3.9	13.6
Grazfeed — farm management computer program	1985–1990	5	6.0	395.9	65.7	84.8
SIRATAC — cotton pest control computer program	1973–1989	5	44.3	76.8	1.7	12.9
ENTOMOLOGIC — cotton pest control computer program	1992–2001	5	15.4	237.9	15.4	85.8
Cotton breeding and transgenic cotton varieties	1974–2001	5	78.1	5 588.6	71.6	28.3
Biological control of Echium weed species (including Patterson's Curse)	1972–1995	5	26.6	1 052.1	39.6	15.8

a The MEB has been included by multiplying costs by 1.2. **b** Benefit Cost Ratio. **c** The internal rate of return (IRR) is the discount rate that when applied to the stream of costs and the stream of benefits equalises the present value of costs and benefits.

Sources: Johnston, Healy, I'ons and McGregor (1992); CIE (2002); Marsden, Martin, Parham, Ridsdill Smith and Johnston (1980).

Table I.4 **Cost-benefit studies for CSIROs Division of Entomology**

Base case estimates, 2005 base year

	Research period	*Discount rate*	*Costs*[a]	*Benefits*	*BCR*
			$m	$m	
Blowfly control with Diazinon	1960	5	0.1	81.5	716.7
Cattle tick research — acaricides	1960–75	5	14.9	53.6	3.6
Cattle tick research — resistant cattle	1960–75	5	32.5	32.2	1.0
Scarab beetle research	1962–75	5	8.1	1.4	0.2
Locust investigations	1960–75	5	14.1	31.3	2.2
Subterranean clover stunt virus research	1958–66	5	2.6	0.5	0.2
Oriental fruit moth control	1970–78	5	1.0	5.2	5.4
Fruit fly control	ns	5	16.6	16.6	1.0
White wax scale control	1964–72	5	4.4	9.5	2.2
Orchard mite control	1968–75	5	2.8	136.1	48.8
Phasmatid research	1959–61	5	6.3	1.9	0.3
Control of Sirex in pine plantations	1963–71	5	22.0	105.2	4.8
Skeleton weed control	1966–73	5	11.0	1 767.3	160.1

a The MEB has been included by multiplying costs by 1.2.

Source: IAC and CSIRO (1980).

Table I.5 **Cost-benefit studies for grains research**

Base case estimates

	Research period[a]	*Dis-count rate*	*Costs*[b]	*Benefits*	*BCR*	*IRR*
			$m	$m		
National chickpea breeding program	1992–1994	5	1.1	15.3	14.4	54.3
Suppression of graindust	ns	5	0.5	39.3	84.0	119.2
Development of disease resistance in faba beans and peas	ns	5	2.5	212.2	86.2	72.5
One-pass sowing and fertiliser application technique	1989–1994	5	1.4	196.9	136.4	10.5
Lupin breeding and evaluation	1975–1991	5	40.2	397.8	9.9	ns
Development of a package for brown spot control in lupins	1988–1993	5	1.6	14.4	8.8	ns
Breeding special purpose oat cultivars with resistance and tolerance to cereal cyst nematode	1985–1992	5	3.0	173.1	57.3	47.5
Research into yellow spot resistance in wheat	1981–1992	5	4.9	316.6	65.2	35.0
high yield wheat package and lupin extension projects	1987–1990	5	2.0	62.6	31.8	170.8
Evaluation of noodle quality of wheat	1988–ns	5	3.4	26.5	7.8	31.4
Wheat variety improvement in Victoria	1983–1992	5	4.3	11.0	2.6	70.4
Quality assessment of central and southern NSW wheat-breeding program	1992–1994	5	0.7	1.9	2.9	33.7
Evaluation of internationally improved maize and wheat germplasm	1991–1992	5	1.8	42.2	23.4	43.3
Regional wheat variety trials in central west NSW	1984–1987	5	0.7	2.3	3.5	28.3
Increasing crop production on acidic and compacted soils	1976–1981		0.6	290.4	464.5	467.5
Selection of disease-resistant barley variety	1976–1981	5	2.6	378.4	144.9	53.3

a Where research was continuing end years were estimated. **b** The MEB has been included by multiplying costs by 1.2.

Source: GRDC (1992).

Table I.6 **Other agricultural cost-benefit studies**

Base case estimates, 2005 base year

	Research period	*Dis-count rate*	*Costs*[a]	*Benefits*	*BCR*	*IRR*
Weeds management CRC			$m	$m		
Competitive cropping for weed control	1992–1994	5	6.2	143.0	23.1	35.8
Vulpia	ns	5	2.9	569.5	196.7	51.7
Patterson's curse (CRC extension)	ns	5	8.3	297.5	36.0	15.8
CRC's weed information system — Mexican feather grass	1989–1994	5	1.9	45.3	23.5	26.7
CRC's weed information system — Cotton thistle spread	1975–1991	5	1.9	49.7	25.8	24.2
Control of Bitou bush	1988–1993	5	3.0	51.7	17.0	24.2
Fisheries research						
Transport and storage of live penaeid prawns	1988–91	6	1.4	28.9	20.9	ns
Hatchery and nursery culture for the silver lived pearl oyster	1982–91	8	7.3	112.4	15.4	ns
Pearl diving safety	1990–94	6	0.7	6.7	9.2	ns
Spanner crab fisheries research	1981–91	6	2.0	3.4	1.7	ns
Southern shark stock assessment program	1986–88	6	2.4	9.7	4.1	ns
Control of maturation in Atlantic salmon	2001–06	8	17.1	64.5	3.8	ns
Research into causes of amoebic gill disease	2001–05	8	1.0	21.6	20.7	ns
Development of techniques to assess sediment conditions	2001–05	8	2.4	1.4	0.6	ns
Commercialisation trials for manufactured tuna feed	2001–ns	8	2.0	0	0	ns
Other						
Beef cattle breeding	1971–2002	7	464.5	1 448.4	3.1	15.8
Net feed efficiency in feed cattle	1990–2020	4	27.6	176.3	6.4	ns
Wheat breeding program	1980–1993	4	57.9	406.4	7.0	ns
Research into growing crops after rice	1997–2002	7	1.26	6.3	5.0	ns
Test for nitrogen status in rice	1997–2002	7	18.8	44.1	2.3	ns
Bovigam — tuberculosis test	1986–1989	5	47.1	179.4	3.8	35.8

a The MEB has been included by multiplying costs by 1.2.

Sources: CIE (2001b); ABARE (1995); FERM (2006); Brennan, Martin and Mullen (2004); Farquharson et al (2003); Griffith et al (2004); Singh, Williams, Mullen and Faour (2002); CIE (2003a).

Table I.7a **Non-agricultural cost-benefit studies**

Base case estimates, 2005 base year

		Research period	*Dis-count rate*	*Costs*[a]	*Benefits*	*BCR*
				$m	$m	
1	$SIRO_2$ Oxygen sensor[b]	1972–1986	5	22.4	35.7	1.6
2	Supercapacitors	1994–2001	5	66.0	491.0	7.4
3	Solospun	1993–1999	5	5.2	0.1	0.02
4	Exelogram	1989–2002	5	40.2	5.1	0.1
5	Rapid roadway development[c]	1995–2001	5	4.8	16.4	3.4
6	Longwall mining automation[c]	1994–2007	5	6.8	313.7	46.4
7	Automated underground vehicles[c]	1995–2001	5	12.9	16.8	1.3
8	Road crack vehicle	1993–2001	5	5.8	440.4	76.5
9	Relenza anti-influenza drug[d e]	1975–1990	5	110.4	65.5	0.6
10	PolyNovo medical polymers	2001–2004	6	18.8	44.1	2.3
11	Atomic absorption spectrometer	1953–1970	5	34.1	227.1	6.7

[a] The MEB has been included by multiplying costs by 1.2. [b] Benefits are most likely understated because of data problems. [c] Information on the timing of costs and benefits were used to convert from a 10 per cent to 5 per cent discount rate. [d] Based on CBA undertaken by the Productivity Commission using a four year displacement period. If the displacement period is increased to seven years the BCR rises to 1.05. [e] Benefits from demonstrating the effectiveness of the rational drug design approach were not included.

Sources: CIE (2001a); CIE (2003a); Mills and Yapp (1996); Farquharson, Griffith, Barwick, Banks and Holmes (2003); ACIL Tasman (2006e).

Table I.7b **Non-agricultural cost-benefit studies**

		IRR	*Study year*	*Industry sector*	*Ex post or ex ante utilisation*	*Dis-place-ment period*
						Years
1	$SIRO_2$ Oxygen sensor	ns	1996	Industrial	ex post	14
2	Supercapacitors	28.3	2003	Transport	ex ante	na
3	Solospun	ns	2003	Manufacturing	ex ante[a]	nc
4	Exelogram	ns	2003	Manufacturing	ex post	na
5	Rapid roadway development	ns	2006	Mining	ex ante	5
6	Longwall mining automation	ns	2006	Mining	ex ante	5
7	Automated underground vehicles	ns	2006	Mining	ex ante[a]	5
8	Road crack vehicle	37.5	2001	Transport	ex ante	nc
9	Relenza anti-influenza drug	ns	1996	Pharmaceuticals	ex post	4
10	PolyNovo medical polymers	ns	2006	Medical	ex ante	2 to 5[b]
11	Atomic absorption spectrometer	ns	1969	Scientific equipment	ex post	2

[a] The technology had been available for only two years at the time of the study. [b] displacement periods varied across a number of medical polymer products. ns — not stated. nc — not considered. na — not applicable.

Sources: CIE (2001a); CIE (2003a); Mills and Yapp (1996); ACIL Tasman (2006a); ACIL Tasman (2006f); Brown (1969).

Table I.8 **Total benefits and costs across all individual case studies**
Base case or midrange estimates, 2005 base year

	Costs	*Benefits*	*BCR*
	$m	$m	
Ex post studies	1 393.1	16 162.6	11.6
Ex ante studies	299.6	4 782.4	16.0
All studies	**1 692.7**	**20 945.0**	**12.4**

Treatment of displacement in the case studies

While not always stated, the studies of Institute of Plant Production and Processing and GRDC research projects make implicit assumptions about additionality and displacement. They assume complete additionality — that is, they assume private research bodies would not have the incentives to undertake similar research programs. The research was also assumed to be unique to Australia. The plant diseases that necessitated most of the research were largely specific to Australia and so there was little interest overseas in addressing these problems.

In contrast, the non-agricultural studies were more likely to consider a counterfactual in which technological displacement occurred. Usually it was assumed that the technologies developed (or substitutes for them) would have been delayed by only some years in the absence of publicly supported Australian research efforts.

Two case studies involving the same project provide a lucid illustration of different treatments of displacement. An updated CBA study of CSIRO's automated mining research projects was recently conducted and found a lower BCR (ACIL Tasman 2006a). The main reason for this was the updated study made the assumption of only a temporary (five year) market advantage, whereas the original study assumed an effectively infinitely-lived one (a secondary reason was that adoption rates were slower than originally estimated, but this was not a decisive factor in the differences between the old and new studies).

The updated study also examined the question of additionality and concluded that, since the great majority of the returns were private and large, industry could have been convinced to support the entire research costs. The costs and benefits of the project, setting aside the additionality issue, are shown in table I.9 — showing that the new estimate of the BCR is around one seventh of the original.

Table I.9 **Comparison of automated mining original and updated cost-benefit studies**

2005 base year

	Research period	*Dis-count rate*	*Displace-ment period*	*Costs*	*Benefits*	*BCR*
		%	Years	$m	$m	
Automated mining (old)[a]	1994–2007	5	none	53.9	5 191.8	96.4
Automated mining (new)	1994–2007	5	5	24.9	342.5	13.8

a The original study includes an extra research project not covered in the updated study. Three-quarters of the research costs were privately funded.

Sources: CIE (2001a); ACIL Tasman (2006a).

Estimates of returns from portfolio cost-benefit studies

Because large research organisation run many research projects, only a few of which generally contribute to the majority of returns, portfolio CBA studies give a better idea of overall returns than do individual CBA studies.

The study of CSIRO Division of Wool Technologies research projects was a portfolio CBA study, with total benefits being compared with overall divisional research expenditures over a comparison period (1993-94 to 1997-98). Of the 109 projects undertaken within the division over the period, eight were commercialised and were expected to return economic and social benefits.

The studies of the CSIRO Institute of Plant Production and Processing and of the CSIRO Division of Entomology can also be used to estimate minimum portfolio CBA ratios. Aggregated benefits can be compared with total divisional spending over the time period the research projects were being undertaken.

The Institute of Plant Production and Processing CBA studies (Johnston, Healy, I'ons and McGregor 1992) were used to obtain a portfolio estimate for the combined CSIRO divisions of Soils, Plant Industry, Horticulture and Tropical Crops & Pastures (table I.10). These estimates are minimum ones because the CBA studies only covered a subset of the divisions' research projects. Divisions within the Institute of Plant Production and Processing were responsible for at least 24 projects that resulted in new technologies being transferred to industry. Of these, ten were evaluated in the 1992 study, and we have included eight of these in the portfolio comparison (those from the relevant divisions that were undertaken in the comparison period). Most of those not examined were difficult to quantify, since they produced outcomes of a non-market, public good nature. Similarly, the study of the CSIRO's Entomology Division provides a minimum estimate because it examined only 13 out of a total of 40 projects (Marsden, Martin, Parham, Ridsdill Smith and Johnston 1980), while costs for all projects were included.

Table I.10 **Portfolio cost-benefit estimates**

ex post utilisation studies, adjusted to 2005 base year

	Authors	*Comparison period*	*Dis-count rate*	*Expend-itures*	*Costs*	*BCR*
				$m	$m	
CSIRO divisions of Soils, Plant Industry, Horticulture and Tropical Crops & Pastures (divisional costs)	Jonston, Healy, I'ons and McGregor (1992)	1970 to 1990	5	3549.0 **a,b,c**	2865.1 (at least)**d**	0.8-1.0+**d**
CSIRO Entomology Division	IAC (1980)	1960 to 1975	5	508.2	2252.3	4.4

a Costs were multiplied by 1.2 to take account of the MEB. **b** Costs were estimated using staffing numbers (obtained between 1983 and 1990) and divisional expenditures (including head office overheads) in 1989-90. It was assumed that real expenditures per staff member were the same over the comparison period as they were in 1989-90. It was also assumed staffing numbers remained the same between 1970 and 1983. Estimated expenditures were then turned into present values in each year and these yearly present values summed to arrive at the total cost figure. One research project was largely conducted within the research period, but had prior expenditures. These expenditures were added to the overall costs. **c** Benefits were included for those research projects conducted during the comparison period (one research project conducted before 1970 was excluded). **d** These figures are based on the costs of all the relevant CSIRO divisions, but benefits for only eight of 22 successful research projects over the comparison period. There were also another 14 successful projects that were not evaluated, hence 0.8 is clearly an underestimate of the BCR for the divisions collectively. If only the costs for the evaluated research projects ($362.1 million in 2005 prices) are used then the CBA ratio is 7.9.

Sources: Johnston, Healy, I'ons and McGregor (1992); Marsden, Martin, Parham, Ridsdill Smith and Johnston (1980); Commission estimates.

Other studies have also examined the returns from a broad area of research — such as CSIRO flagships — rather than individual projects (table I.11).

Table I.11 **Ex ante utilisation studies of CSIRO flagships and divisions**
Adjusted to a 2005 base year

	Authors	*Comparison period*	*Discount rate*	*Costs*	*Benefits*	*BCR*	*Benefits taking additionality into account*
				$m	$m		
CSIRO Wool Division	DJ and BA Collins (1999)	1993-94 to 1997-98	6	356.2	717.6	2.0	lower
CSIRO Preventative Health Flagship[a]	ACIL Tasman (2006d)	2003-04 to 2006-07	6	83.0	359.2	4.3	same
CSIRO Light Metals Flagship[a]	ACIL Tasman (2006c)	2003-04 to 2007-08	6	14.3	444.7	31.1	lower
CSIRO Water For a Healthy Country Flagship[a]	ACIL Tasman (2006e)	2003-04 to 2007-08	6	around 170	around 860	at least 5.0	same
Australian Cotton CRC	BDA Group (2004)	1999-00 to 2003-04	6	90.2	611.7	6.8	lower

[a] Studies use an options approach. That is, possible outcomes are weighted by probability of success and project expenditures are weighted by their probability of being incurred (which take into account scenarios where projects are cancelled).

Sources: Collins and Collins (1999); ACIL Tasman (2006e); ACIL Tasman (2006c); ACIL Tasman (2006d); BDA Group (2004).

Evaluation of benefits produced by CRCs

Estimates of the returns to the CRC program as a whole have been produced by Insight Economics (2006) and Allen Consulting (2005a) — but using the GE approach described earlier. The benefits were determined by running a base GE model, which reflects the current state of the economy (ie with the CRC program and current levels of activity) and comparing this with a counterfactual model without CRCs. In the counterfactual model the identified productivity, output and profits gains associated with CRC research are removed, increasing costs and reducing output and profits in the appropriate industry sectors. In the 'without-CRCs model' it is assumed that the CRC grants are not spent and that taxes or government expenditures are reduced by an equivalent amount. The remaining CRC funding is assumed to continue to be directed into CRC partners' own R&D efforts.

The difference in GDP, consumption or investment between the base and counterfactual models are measures of the effects of the CRC grant expenditures. Dividing net rises in GDP, consumption or investment by the amount of grants yields an amount per dollar of grant expenditures. The welfare increase caused by a policy change in GE models is approximately equivalent to the increase in real consumption.[3]

The Insight Economics evaluation

The Insight Economics study identified three types of CRC arrangements, each of which had separate benefits.

- First, in some CRCs, it was judged that the research expenditures of the constituent members would have produced zero beneficial outcomes in the absence of CRC funding (at least in the period under consideration). In this instance, any benefits associated with the CRCs were ascribed fully to the grant funds that elicited the formation of the CRC. None of the benefits were apportioned to the contributing funds of the partner members.
- Second, in other CRCs, it was assumed that the partners would have produced valuable benefits in the absence of the CRC program, but that these benefits were magnified by the increase of funding associated with the CRC grants.
- Finally, in some instances, CRCs were causally linked to circumstances where an Australian firm won contracts to supply a multinational company partly due to technology and research support provided by a CRC. A proportion of the benefits were then ascribed to the CRC grants underlying the formation of the CRC.

Insight Economics' evaluation produced three tiers of benefits that progressively encompassed these types of CRC arrangements, starting with the first type of CRC above. (The study also assessed non-quantifiable benefits separately.) The third tier estimate gives the most complete measure of the CRC program, suggesting that every dollar of CRC grants increased real consumption by $1.24. In contrast, their first tier estimate was an increase in real consumption of $0.97.

This GE analysis was based on a different, and more appropriate, treatment of grant financing under the counterfactual than that used in the Allen Consulting evaluation (discussed below). The Insight Economics evaluation assumed that taxes would have been lower in the absence of the program, whereas the Allen Consulting

[3] Where consumption is taken to include private consumption and government expenditure and where a long enough time period is examined so that investments pay off in higher consumption.

evaluation assumed that government spending would have been higher under the counterfactual (by the amount of CRC grants foregone).

However, the method for apportioning benefits associated with the first tier of benefits is dubious (a problem shared with the Allen Consulting evaluation below). Agglomeration benefits of CRCs may well be significant, but it is highly improbable that many circumstances arise when the partners in CRCs would have produced research of zero value in the absence of the program. Accordingly, the Commission has adjusted downwards Insight Economics' first tier estimates. The Commission has apportioned the total CRC benefits in proportion to the share of CRC grant funds to total CRC funding. This problem does not affect the other types of CRC benefits included in tiers two and three.

In this case, the Commission estimates that a better indication of the value of the CRC program, based on the raw results of the Insight Economics evaluation, is 51 cents of consumption benefits per dollar of CRC grant funds, comprising:

- 24 cents of consumption benefits per dollar of CRC grant funds[4] (tier 1). If there are large agglomeration benefits this could be an underestimate; and
- 27 cents of consumption benefits per dollar of CRC grant funds (the increments from tiers 2 and 3).

The Allen Consulting evaluation

The Allen Consulting evaluation identified $908 million in direct benefits induced by CRC innovations ($832 in cost savings to industry, $46 million in income from intellectual property and $30 million in savings on government expenditures). If the direct benefits were the only realised gains, this suggests a BCR of about 0.5 (the total costs for the CRC program from 1992–2005 were $1.92 billion) — a significant net resource loss.

However, when the feedback effects of these direct gains — modelled as productivity effects transmitted across the economy — are included in the GE model, the study finds an increase in real consumption of $0.40 for every dollar of CRC grants, representing a net benefit from the program.

4 Insight Economics reports $11.1 billion in cash and in kind expended/committed by CRC partners (including grant funds) from 1990-01 to 2010-11 and $2.7 billion in CRC grants expended/committed for the same period. Using these figures as a basis for apportionment suggests that the benefits more reasonably ascribed to the CRC program are Insight Economics' raw first tier gains of $0.97 per dollar of grant expenditure *times* 2.7/11.1 = $0.24 per dollar of grant expenditure.

The Allen Consulting study, which was equivalent to the first tier Insight Economics study, also did not apportion benefits. Using the same adjustment approach as for Insight Economics yields an adjusted net increase in real consumption of $0.10 per dollar of grant expenditures.

Other questions

While the evaluations above concentrated on measurable economic benefits, these alone are likely to understate the total benefits produced by the CRCs. There were a number of public good outcomes that could not be quantified and these could be large. For example, these included reducing the risks of severe disease outbreaks; strategies to reduced risk of damage to the barrier reef; and the development of options to reduce carbon emissions from coal based power generation.

On the other hand, the evaluations assume full additionality and zero technological displacement. That is, they assume in the absence of the CRCs research, private firms and other research groups would not have been able to achieve similar outcomes, even over a fifteen year period. This appears unlikely, as at least some of the projects are likely to have involved rivalrous efforts by foreign teams. Accounting for rivalry would tend to lower the GE ratio.

I.3 Lessons from cost-benefit case studies

Returns to publicly funded research

The studies suggest that publicly funded research has produced positive benefits through a range of mechanisms including the introduction of new crop varieties and farming techniques; improvements to the productivity of cattle through selective breeding; cost-savings for large Australian industrial operations; and through decreased maintenance costs for public infrastructure. Benefits were also expected from research into preventative health; improved water management; improved fisheries management; aluminium, magnesium and titanium production; and cost-savings from the automation of large mining operations.

The 75 individual CBA case studies examined in this appendix had a weighted average BCR of 12.4. But such studies are subject to biases because of the mix of ex ante and ex post studies, selection biases and deficient assumptions. The bias is likely to be upwards because of the exclusion of unsuccessful projects. Chapter 4 presents more detailed analysis of the sources and possible nature of these biases through regression analysis.

In contrast, the portfolio studies analysed had a weighted BCR of 1.7. Some of the portfolio studies underestimated average returns to R&D — because not all successful projects were included, while full portfolio costs were counted. Overall, results from the portfolio studies are probably the more reliable.

Qualitative findings about research impacts and processes

Australian-specific public-good research

In some cases, the issues of international technological displacement discussed earlier are likely to be small. For example, overseas research groups are unlikely to have had sufficient incentives to work on problems associated with Australian-specific agricultural diseases. Without the research, the improved crop varieties introduced to combat these diseases would have been significantly delayed or would never have occurred.

The same was true for cattle breeding research to improve the fitness of Australian herds undertaken by State agricultural departments and CSIRO, as well as for CSIRO research into sustainable fishery practices.

Research with the potential to accelerate the introduction of new technologies

There were a number of examples of public research projects that were able to accelerate the introduction of new technologies with possible net social benefits.

The involvement of public sector research agencies may accelerate the introduction of socially beneficial technologies where:

- they undertake strategic research that involves significant resources but leads to freely available outcomes (private firms may be reluctant to invest where returns from outcomes cannot be appropriated) and where these outcomes allow subsequent innovation by private firms;
- public sector research agencies are able to identify emerging research approaches that allow the development of techniques that overcome previously intractable problems and where they can develop these approaches in ways that encourages them to be transferred to others;
- public research agencies have built up multiple areas of expertise that allow them to solve particular problems more quickly and effectively than outside groups. For instance, the development of a more robust oxygen sensor by CSIRO was based on its experience in high temperature ceramics research; and
- a large number of exploratory research projects are required in order to identify

the few with commercial potential. The resulting knowledge of prospective research areas may be of a public good nature in the sense that it could be exploited by a number of firms.

An example of a public research project that fits several of the above situations (research based on emerging science that could be used by several firms and became freely available) is described in box I.1.

A major question when public research agencies become involved in research projects with commercial orientations is the identification of the point in a project when the future benefits become sufficiently appropriable by businesses. At this time:

- the intellectual property should be sold to the private sector for their future development;
- full private funding of public sector research should be required on a contract basis; or
- where private partners are difficult to find or intellectual property is hard to negotiate, the best option may be to give research findings away free of charge and allow diffuse private sector development.

Large private returns

There were large private returns to some research efforts, potentially from the start. While these projects involve substantial private contributions, it could be argued that their entire costs should have been provided by industry.

An example was the cotton breeding research projects. These projects produced large returns to farmers in the form of increased yields (reducing costs per kilogram of cotton lint produced) and reduced spraying costs. These benefits also allowed the seed for the improved varieties to be sold at a premium. There is a real possibility that this research could have been fully funded by seed wholesalers or farmer’s groups.

Private returns in the form of reduced production costs make up the majority (98 per cent) of the currently anticipated returns from CSIRO’s automated mining research projects. The returns were also significant — the majority of which were production cost-reductions that would increase profits. In fact, the majority of the research and adoption costs (75 per cent) were funded from industry sources.

Private returns were also significant in the case of the gravity thickener research programs. Subsequently, these returned $295 million in cost savings and other benefits for mineral processors in return for a reasonably small outlay.

Box I.1 **CSIRO research allowed the development of anti-influenza drugs**

CSIRO worked with the Australian National University and Biota to develop an anti-influenza drug, *Relenza* using an approach, based on neuraminidase inhibitors, that had previously been abandoned. It was able to do this because of the advent of technologies able to image proteins at high resolution and a breakthrough in the ability to prepare the neuramindase molecule in a form that could be imaged.

CSIRO researchers mapped and characterised the structure of the influenza neuramindase and determined that it would not readily mutate in response to highly-specific neuramindase inhibitors. Researchers at CSIRO and Biota then developed Relenza based upon this information. The drug was subsequently licensed to Glaxo Smith Kline (then Glaxo) for commercial exploitation through clinical trials, production, marketing and distribution.

The CSIRO research, which constituted the bulk of the costs needed to develop a neuramindase inhibitor to the pre-clinical trials stage, was publicly available once it had been completed.

Later research by the firm Gilead in the United States produced the competing neuraminidase inhibitor *Tamiflu*. Clinical trials, production, marketing and distribution were undertaken by Roche Pharmaceuticals.

Both Relenza and Tamiflu were approved for sale in the US late 1999. Relenza was approved for sale in Australia in early 1999 and Tamiflu in early 2000.

The CSIRO mapping work underpinned the development of both Relenza and Tamiflu.

The work on Tamiflu was motivated by the success of Biota in developing Relenza and gaining a commercialisation agreement with Glaxo Smith Kline.

For a variety of reasons, the Tamiflu acquired around 97 per cent of the global market. The spillovers from the initial research were very large in this case, albeit largely captured by foreign firms.

Nevertheless, Australians benefit from being able to purchase effective anti-influenza medications — reducing illness, medical expenses, hospitalisations, deaths and work loss. There are also benefits from the Government’s current stockpiling of anti-influenza drugs as a preventative measure against a possible avian-influenza pandemic.

In addition, the design of Relenza was one of the first practical applications of the discovery of pharmaceuticals through the rational drug design approach (where new drugs are found based upon an understanding of the structure of their biological targets, rather than through random testing). The successful design of Relenza is likely to have influenced other research groups to adopt this approach.

Sources: Biota (2006); Colman (1983), Moscona (2005); Mendel et al. (1998); Lew et al. (2000); Von Itzstein et al (1993).

One possibility is the adoption of a contingent repayment mechanism. Under this mechanism, research organisations could, on a discretionary basis, offer to cover a proportion of research costs upfront, but insist on these costs being returned if projects do turn out to have high private returns. This would be appropriate where private returns are considered large, but private firms are still unwilling to cover all research costs, perhaps because of a lack of knowledge about the true potential of particular research projects.

Reliability

The CBA studies examined were of varying reliability. Unreliability could result from a lack of information, which required many assumptions to be made, or from unrealistic assumptions about counterfactuals. One of the main causes of uncertainty was that many evaluations were conducted before new products or techniques had been commercialised for long enough to determine adoption and benefits in practice.

The use of ex post utilisation studies should increase reliability by reducing the need to make assumptions. On the other hand, a potential danger of the ex post approach is that research organisations could tend to select successful, rather than unsuccessful projects, for evaluation, which would lead to an upwardly biased view of returns. Solutions to this problem include either the random selection of projects or the portfolio approach — where returns to all significant research projects are found and are compared with overall portfolio costs. Ex ante utilisation studies will, of course, still be required for research management and planning purposes.

The reliability of studies could also be improved by improving transparency through: including independent reviewers; publishing reports; and clearly showing all information sources and calculations.

The problem of marginal returns

Another issue is the marginal returns from projects, which is the most relevant for deciding whether additional funds should be provided to public agencies. In theory, marginal projects should have the least ex ante priority in a research agency. Consequently, it should be possible to measure the returns to marginal projects as a group by considering the ex post returns to those projects with the lowest ex ante priorities. The major practical problem is that such a process of evaluation requires reasonably accurate measurement of returns for projects, and either honest disclosure by the research body or an independent assessment.

J Patent and innovation indicators

J.1 Patent indicators

Patent indicators, such as the number of patents granted to residents of a country, are among the most frequently used measures of innovation performance. They are seen as particularly useful in reflecting levels of inventive activity and diffusion of knowledge in countries, industries and firms. Some examples of how patent indicators have been applied are:

- the number of US patents per million population in the Australian Innovation Scorecard 2004 prepared by the Australian Government;
- the number of triadic patent families for each OECD country in the OECD Main Science and Technology Indicators 2006 and the OECD Science, Technology and Industry Scoreboard 2005; and
- the number of applications for Australian patents in the Australian Patent Applications Scoreboard 2004 prepared by the Intellectual Property Research Institute of Australia and the Melbourne Institute of Applied Economic and Social Research.

Such patent measures provide valuable indicators. Patents by their nature are closely linked to inventions. They cover a broad range of technologies on which there are few other sources of data. The contents of patent documents are a rich source of information, such as on the applicant, inventor and technology category. And finally, patent data, particularly over time, are reasonably accessible from patent offices.

However, as several participants have noted (for example, Jensen et al. sub. 9, p. 18; the Australian Business Foundation sub. 72, p. 2; NT Government et al. sub. 23, p. 15; and Macquarie University sub. 47, p. 4), patent indicators have limitations that make assessments of the level of innovation in a country, over time comparisons, and comparisons across countries, industries and firms quite difficult.

One major limitation is that patents vary in terms of their technological and economic value. Many patents represent marginal technological advancements, which may or may not be realised commercially. Some of these advancements may lead to a major change in an industry.

Various value-adjusting approaches have been used to deal with this limitation to make patents more homogenous. These include using patent citations (references in new patents to earlier patents, which were significant in the development of that area of technological knowledge), 'triadic patent families' (see later), and renewed patents.

A second limitation is that patent indicators do not directly measure innovation but inventions. Patents do not necessarily lead to new products or processes. Rather than being indicators of innovation system performance, they are indicators of inventions or inventive activity.

A third limitation of patent indicators is that they do not provide adequate coverage of inventive activity as many inventions are simply not patented. There are several reasons for this.

- Not all inventions are legally patentable. The basic legal requirements for patentability are that the invention must be novel, contain an inventive step (or be non-obvious), be capable of industrial application and not be in excluded fields (for example, scientific theories and mathematical methods are not regarded as inventions and cannot be patented at the European Patent Office).
- Other forms of intellectual property rights such as copyright and protection of designs might be used to protect the invention. A large proportion of innovations in computer software, for example, is protected by copyright, rather than patent. However, this is as much to do with the legal requirements of patents as firms' strategic choices.
- Inventors may protect their inventions using methods other than patents, such as using secrecy, using complex product design or process systems, or exploiting technological lead time and firm-specific skills. What they do will depend on the costs of patenting relative to using such alternative methods.

A fourth limitation is that patent indicators tend to reflect inventive activity in the private rather than in the public sector. Public sector research agencies and universities will generally have different objectives in regard to their research efforts than that of firms. This may mean that inventive activity in the public sector is not always fully translated into patents.

A fifth limitation of patent indicators is the increasing strategic use of patents by firms in the United States, which has little to do with innovation. One such strategic use is 'patent flooding', where a firm files many patent applications claiming slight variations on a rival's key technology, which increases the credibility of any threat to litigate against infringement (Jensen and Webster 2004, p. 17).

A final set of limitations relates to the use of data from patent offices.

- As patent regimes are not consistent across countries or over time, patent data are also not consistent. Regimes differ in terms of the scope of patents covered, as well as the costs and administrative procedures associated with patent applications. And regimes can change or be amended over time. This limitation can be partly overcome by obtaining data from a single patent office.
- Data from patent offices significantly over-represent domestic inventive activity and, thus, have a 'home advantage' bias. For example, Australian inventors acquire a higher proportion of patent grants in Australia than in other countries. This limitation can be overcome through the use of non-resident patent grants.
- Data from patent offices tend to over-represent dominant trading partners. Because of the cost of applying for patents, inventors seek patents in countries only when they perceive a market to be of particular value. A solution to this problem is to use non-resident patent data from the United States. The United States is the prime market for inventors from all over the world. As DEST (2004a, p. 14) noted, 'Because the US is the largest market in the world, registering a patent there tends to indicate that the invention is capable of competing with the best'.

Bearing these limitations in mind, the remainder of this section looks at Australia's performance in terms of patent indicators using available data from the US Trademarks and Patents Office, the OECD, and the Intellectual Property Research Institute of Australia and the Melbourne Institute of Applied Economic and Social Research.

US non-resident patent grants

Data from the US Patent and Trademark Office show that the number of US non-resident patent grants in 2005 was concentrated within a small number of countries (table J.1). Japan, Germany, Taiwan, South Korea, the United Kingdom, Canada and France accounted collectively for just over 80 per cent of US non-resident grants. Japan alone represented 42 per cent. Australia's share of US non-resident grants was around 1.4 per cent.

Table J.1 **US non-resident patent grants, 2005**

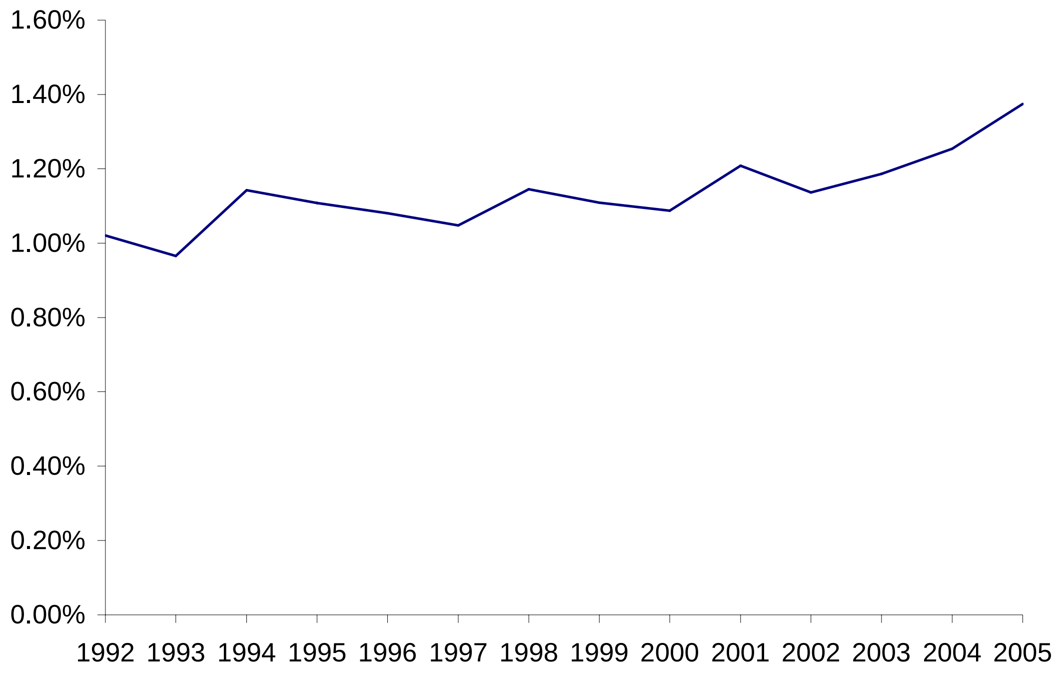
Originating country	*Number*	*Share of US non-resident patent grants*	*Average annual growth in share of US non-resident patent grants 1992 to 2005*
		%	%
Japan	31 834	42.4	-0.8
Germany	9 575	12.7	-1.3
Taiwan	5 993	8.0	15.0
South Korea	4 591	6.1	29.1
United Kingdom	3 560	4.7	-0.9
Canada	3 177	4.2	-0.5
France	3 106	4.1	-2.8
Italy	1 591	2.1	-2.0
Netherlands	1 200	1.6	-1.4
Sweden	1 189	1.6	0.4
Switzerland	1 106	1.5	-3.2
Australia	**1 033**	**1.4**	**2.5**
Israel	976	1.3	5.8
Finland	751	1.0	2.0
Hong Kong	596	0.8	10.2
Belgium	577	0.8	0.1
China	565	0.8	56.7
Austria	491	0.7	-1.5
Denmark	473	0.6	0.8
India	403	0.5	70.6
Singapore	377	0.5	42.7
Spain	318	0.4	2.7
Norway	242	0.3	2.1
Ireland	169	0.2	6.8
Russia	154	0.2	20.5[a]
New Zealand	143	0.2	3.9
South Africa	108	0.1	-2.2
Other	857	1.1	not estimated
Total US non-resident patents	**75 155**	**100.0**	**not estimated**

a Estimated over the period 1994 and 2005.

Sources: US Patent and Trademark Office patent database; Commission estimates.

Between 1992 and 2005, total US non-resident patent grants increased by around 55 per cent, from 48 720 to 75 155, or an average annual increase of 4 per cent. Very strong average annual increases in country shares were experienced by India, China, Singapore and South Korea. But average annual decreases in country shares were evident for Japan, many European countries and Canada (table J.1). Australia's share of US non-resident grants has experienced a slight average annual increase of 2.5 per cent (table J.1 and figure J.1).

Figure J.1 **Australia's share of US non-resident patent grants 1992 to 2005**



Data source: US Patent and Trademark Office patent database.

If data from the European Patents Office were used, the United States would be in the top position in table J.1 with 48 000 patent grants in 2005 relative to countries with US non-resident patent grants. Grants to US residents from the European Patents Office were 50 per cent more than grants to Japanese residents in 2003 (the latest available data). This relativity was then applied to the number of grants to Japanese residents in 2005 from the US Patents and Trademark Office to derive the hypothetical number of patent grants held by the United States. (Data from the US Patent and Trademark Office were not used given that data would have led to an overrepresentation of US inventive activity due to a home advantage bias.)

Rather than using numbers or shares of US non-residential grants, US non-resident patent grants per million population could be used to provide a normalised measure for comparing countries of different population sizes. The Australian Innovation Scorecard 2004 (DEST 2004a), for example, reports US patents per million population for Australia and other OECD countries. According to this indicator, US patent grants to Australian residents fell marginally between 2002 and 2004 from 54 to 53 patent grants per million population. In 2004, Australia was substantially below the OECD leader (the United States) with 340 US patents per million population and the OECD average of 152 US patents per million population. Australia's ranking in 2004 was 18, unchanged since 2002.

Although using US non-resident patent grants can ameliorate the limitations of patent indicators arising from biases due to home advantage and dominant trading partners, the other limitations of patent indicators noted earlier — particularly that of heterogeneity in the technological and economic value of patents — continue. A further limitation with using patent grants, rather than patent applications, is that the number may be unduly affected by the administrative process of the US Patent and Trademark Office.

Triadic patent families

The OECD uses triadic patent families to improve the quality and international comparability of patent indicators. A triadic patent family is a set of patents filed at the European Patent Office and the Japan Patent Office, and granted by the US Patent and Trademark Office.

Using triadic patent families has two major advantages:

- they remove home advantage and trading partner biases, because only patents applied for in the same set of countries are included in the 'family'; and
- they improve homogeneity of the patent data as patents in the triadic family typically have high value. Applicants only take on the additional costs and delays of extending protection to other countries if they deem that to be worthwhile.

Data show that most triadic patent applications by OECD countries in 2003 were by the United States, Japan and Germany, which accounted for around 80 per cent of the total (table J.2). Australia's share was less than 1 per cent. Australia's position relative to top tier countries is shown in figure J.2.

Table J.2 **Triadic patent families, 2003, OECD countries**[a]

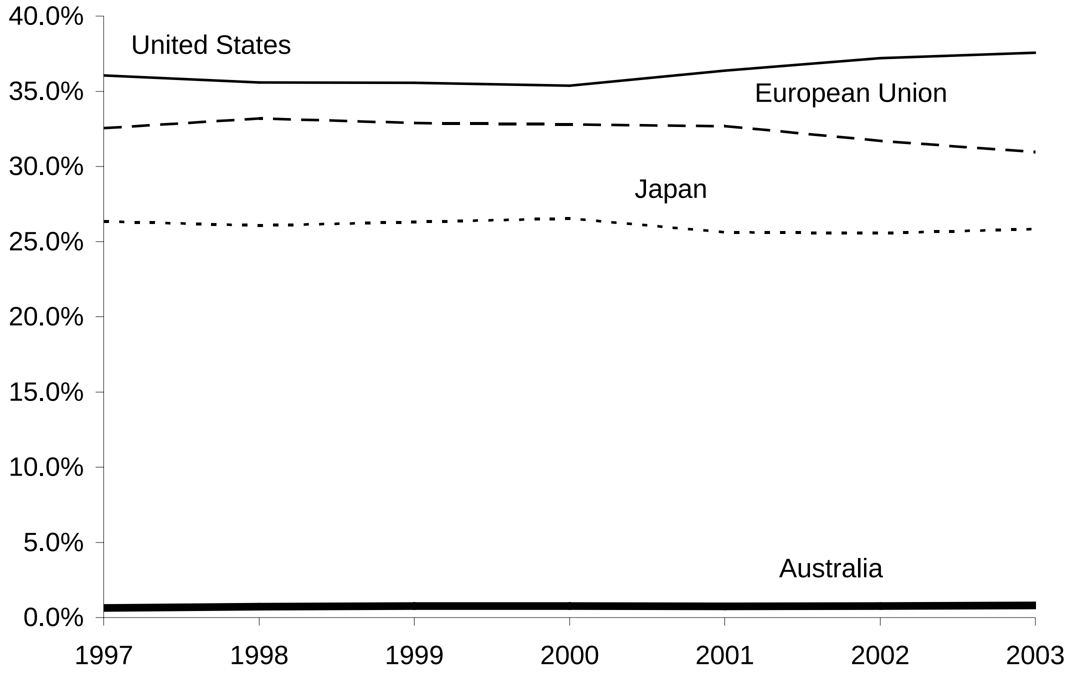
OECD country	*Number*	*Share*	*Average annual growth in share 1997 to 2003*
		%	%
United States	19 701	37.6	0.6
Japan	13 557	25.8	-0.3
Germany	7 248	13.8	0.2
France	2 379	4.5	-1.9
United Kingdom	1 973	3.8	-0.3
Netherlands	1 017	1.9	-0.2
Switzerland	904	1.7	-1.3
Korea	839	1.6	7.9
Italy	816	1.6	-1.7
Sweden	794	1.5	-3.8
Canada	733	1.4	0.3
Finland	635	1.2	2.1
Belgium	471	0.9	-1.7
Australia	**422**	**0.8**	**3.6**
Austria	288	0.5	-1.5
Denmark	211	0.4	-3.2
Spain	119	0.2	-1.1
Norway	110	0.2	-0.8
Ireland	62	0.1	5.1
New Zealand	52	0.1	0.3
Hungary	22	0.0	-6.8
Luxembourg	18	0.0	-0.2
Mexico	16	0.0	-0.8
Czeck Republic	14	0.0	-0.4
Poland	11	0.0	-0.9
Greece	10	0.0	-3.3
Iceland	9	0.0	10.3
Portugal	8	0.0	0.3
Turkey	8	0.0	14.9
Slovak Republic	2	0.0	-7.0
Total	**52 449**	**100.0**	**not estimated**

[a] The reference date for the application is the priority date — the date of the first international filing of a patent.

Source: OECD (2006c, table 65).

Between 1997 and 2003, total triadic patent applications by OECD countries increased by around 31 per cent, from 40 165 to 52 449, or an average annual increase of 4.4 per cent. Large average annual increases in country shares were experienced by low patenting countries such as Turkey, Iceland and South Korea. Average annual decreases were evident for Japan and many European countries (table J.2). Marginal increases were experienced by the United States and Germany. Australia's share of triadic patent applications has grown substantially at an average annual increase of 4 per cent (table J.2).

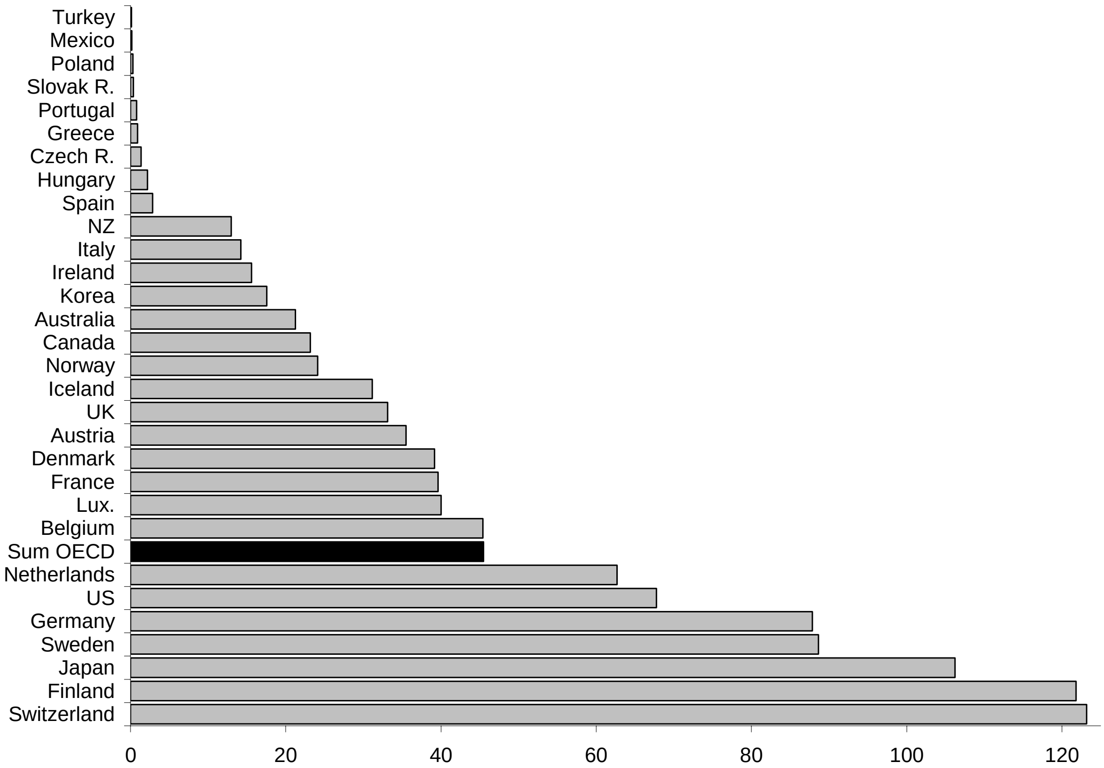
Figure J.2 **Shares of triadic patent families, 1997 to 2003, OECD**



Data source: OECD (2006c, table 65).

The data can also be expressed relative to population (figure J.3) to enable comparisons between countries of different population sizes. Using this indicator, the OECD average was around 45 triadic patent applications per million population. Leading countries were Switzerland, Finland, Japan and Sweden. Countries with very low triadic patent applications per million population (less than one) included Turkey, Mexico and Poland. Australia was below the OECD average, with about 21 triadic patent applications per million population.

Figure J.3 **Triadic patent families per million population, 2003, OECD countries**



Data source: OECD (2006c, table 65; 2005).

Patent applications filed in Australia

A patent indicator that has been used by the Intellectual Property Research Institute of Australia and the Melbourne Institute of Applied Economic and Social Research in their Australian Patent Applications Scoreboard 2004 is the number of patent applications filed in Australia that are PCT and non-PCT, and Australian and non-Australian. A PCT application is an application for an Australian patent filed under the Patent Cooperation Treaty, whereas a non-PCT application is an application for an Australian patent that is filed directly with the Australian Patent Office. PCT applications make it possible to seek patents in a large number of countries by filing a single application. Further discussion of the Patent Cooperation Treaty is given in the appendix N on the intellectual property system.

Table J.3 shows that PCT applications dominated, accounting for around 74 cent of total applications filed in Australia in 2003. This dominance is likely to continue (figure J.4). In the period between 1986 and 2003, the share of non-PCT applications declined by 3.8 per cent per annum on average. On the other hand, the share of PCT applications increased by 24.8 per cent per annum on average.

Table J.3 **Patent applications filed in Australia, 2003[a]**

Patent type	*Number*	*Share of total applications*	*Average annual growth in share of total applications, 1986 to 2003*
		%	%
Australian non-PCT	1340	6.2	-1.5
Non-Australian non-PCT	4401	20.1	-4.1
Australian PCT	1130	5.2	13.7
Non-Australian PCT	14 695	68.1	26.3
Total	**21 566**	**100.0**	

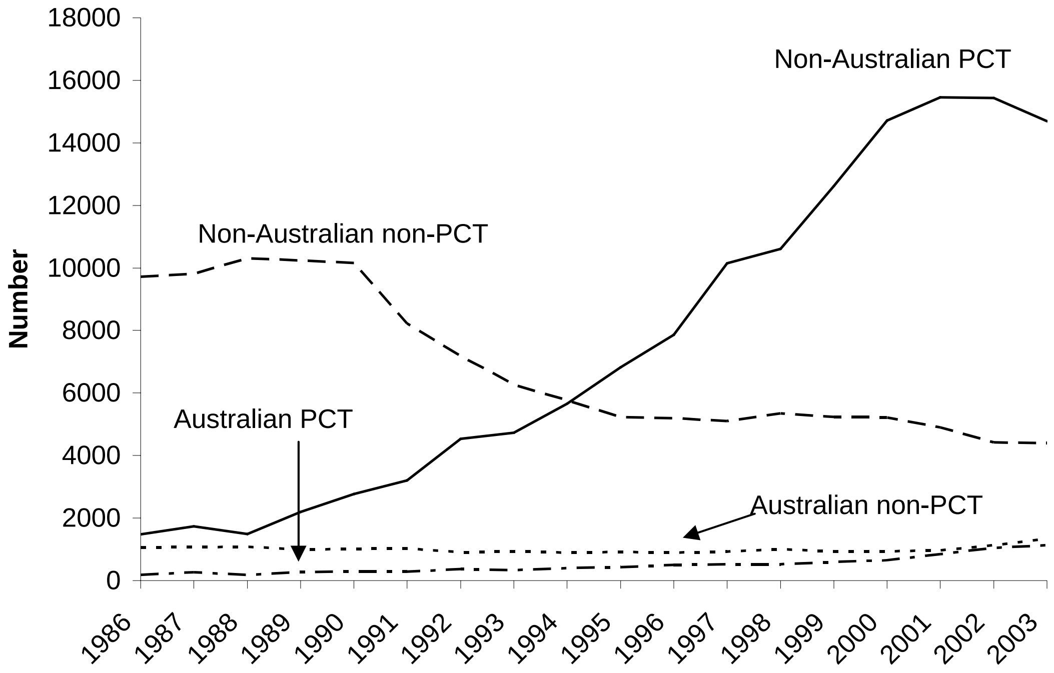
[a] The table covers standard complete applications in a given year.

Source: IPRIA and Melbourne Institute of Applied Economic and Social Research (2004).

Most patent applications filed in Australia, whether PCT or non-PCT, were by non-Australian residents at about 89 per cent of the total, with the Australian resident share of patent applications at about 11 per cent of the total in 2003. In the period 1986 to 2003, the share of Australian applications in total applications grew by around 0.8 per cent per annum on average, whereas the share of non-Australian applications declined by 0.1 per cent per annum.

However, the Australian share of patent applications is likely to overstate Australian inventive activity, due to the home advantage bias. It would be better if information on Australian patenting applications were derived from a non-Australian patent office.

Figure J.4 **Australian patent applications, 1986 to 2003**



Data source: IPRIA and Melbourne Institute of Applied Economic and Social Research (2004).

Summing up

The patent indicators above tell a consistent story about Australia's performance in this particular dimension — that is, Australia's share of patents relative to other countries, is very small, albeit growing.

The triadic patent-based indicator developed by the OECD appears to be the most useful in terms of reducing biases in patent data due to home country advantage and the influence of dominant trading partners, as well as dealing with the variable technological and economic value of patents. Australia's share of triadic patent applications, although small at less than 1 per cent, has nonetheless grown since 1997 at about 4 per cent per year on average. However, the number of triadic patent applications per million population for Australia is well below the OECD average.

J.2 Innovation Index

For a number of years, the Intellectual Property Research Institute of Australia has funded the development and estimation of an Australian Innovation Index (commencing with Gans and Stern 2003), which in turn is based on work done in the United States by Porter and Stern (1999). The Index uses information from a number of countries to establish a relationship between past innovative inputs and more recent innovative output. As Gans noted: '… the resulting measure [the index] will indicate how effective the mix and level of current inputs will be in generating future innovation' (sub. 10, p. 12).

The Innovation Index, as recently presented in Gans and Hayes (2006), was estimated in two stages.

In the first stage, a statistical model of a country's 'innovative capacity' was developed. This involved creating a database of variables relating to innovative capacity for 29 OECD countries from 1973 to 2005. This data were used to perform a time series/cross sectional regression analysis determining the significant influences on innovation output and the weights associated with each driver of innovative capacity (p. 4). Drivers include R&D expenditure, R&D personnel per million people, public expenditure on secondary and tertiary education as a percentage of GDP, IP protection, R&D funding by industry, and R&D performed by universities.

The innovative output of the country was measured by the level of international patenting; specifically, the number of patents granted (per million persons) in a given year to individuals or firms from a country by the US Patent and Trademarks Office. It is a lagged measure in that 'the innovation environment pertinent for the patent grant is the environment that prevailed at the time of application' (p. 3). Based on advice from the Office, a two year lag was used.

The second stage involved calculating the Innovation Index using the results of the regression analysis in the first stage. The Index for a given country in a given year was derived from the *predicted value* for that country based on its weights. This predicted value is then exponentiated (since the regression is log-log) and divided by the population of the country (POP). Thus the Index for each country followed the formula:

$$\text{Innovation Index}_t = \exp(\hat{Y}_t)/\text{POP}_t \text{ and } \hat{Y}_t = X_{t-2}\,\beta$$

where $\hat{Y}_t$ is the predicted value of innovative output, X is the set of variables used to explain innovative output, β is the set of weights derived from the regression analysis in stage I, and POP is the population of the country in millions of people.

Because of the way in which innovative output is measured, the Index literally means the 'expected number of international patent grants per million persons given a country's configuration of national policies and resource commitments 2 years before' (p. 5).

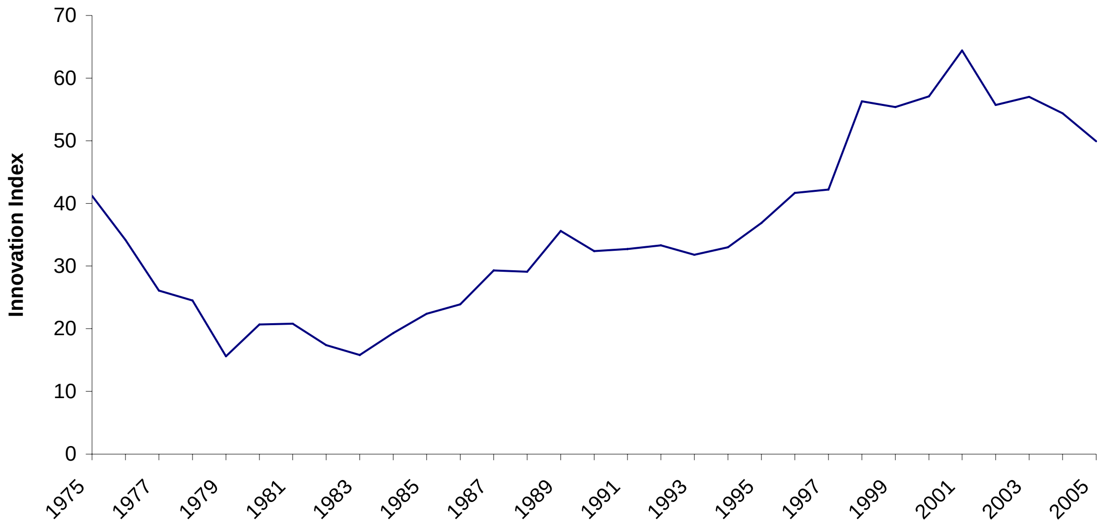
According to Gans and Hayes' estimates of the Innovation Index for 2005, Australia was ranked 15th of 28 OECD countries (table J.4). Over a thirty year period, Australia's Innovation Index peaked in 2001 (figure J.5). It has since declined slightly. Gans and Hayes attributed this to 'stagnating' R&D expenditure, a decline in the 'perception' of intellectual property protection, and a continuing decline in public spending on secondary and tertiary education as a proportion of GDP (2006, pp. 9–10).

Table J.4 **Innovation Index, 2005, OECD countries**

Country	*Innovation Index*	*Rank*
United States	194.7	1
Finland	171.7	2
Sweden	142.1	3
Japan	136.2	4
Switzerland	132.2	5
Denmark	121.3	6
Germany	96.1	7
Norway	92.0	8
Canada	90.5	9
France	68.8	10
Iceland	61.4	11
Belgium	57.9	12
Netherlands	56.6	13
Austria	50.4	14
Australia	**49.9**	**15**
United Kingdom	43.4	16
Ireland	33.4	17
New Zealand	24.1	18
South Korea	20.9	19
Spain	18.3	20
Italy	17.4	21
Greece	7.9	22
Portugal	5.9	23
Czech Republic	5.8	24
Hungary	4.1	25
Slovak Republic	2.7	26
Poland	2.3	27
Mexico	0.9	28

Source: Gans and Hayes (2006, p. 8).

Figure J.5 **Australia's Innovation Index, 1975 to 2005**



Data source: Gans and Hayes (2006, table A.5).

The capacity of the Innovation Index to explain how changes in the local policy or industrial environment have led to changes in innovation is its greatest strength, and provides a unique and useful tool in the Australian context. For example, it highlights some of the important links between sophisticated technologically-capable human capital and innovation (Gans sub. 10, pp. 13–14). It can be similarly useful in assessing what might happen to patenting activity were some of its underlying determinants to be changed through policy (as in Gans and Stern 2003).

As a summary measure of relative international innovativeness in its own right, the measure has some limitations (box J.1). One notable limitation is that if the gap between the observed patents per capita and the estimated Index (or the estimated patents per capita) is small, it might be more simple and valid to use observed patenting per capita as the indicator rather than the estimated Index. This would have the added advantage that, in looking at historical movements, it would be possible to include the unexplained changes as well as the explained changes in patenting.

Box J.1 **Simple might be better**

The Innovation Index measure is really only a predictor of international patenting. Gans and Hayes (2005) are aware this is the case, but argue it should not be interpreted that way:

> … it is important not to interpret the Innovation Index as a tool to predict the exact number of international patents that will be granted to a country in any particular year. Instead, the Index provides an indication of the relative capability of the economy to produce innovative outputs based on the historical relationship between the elements of national innovative capacity present in a country and the outputs of the innovative process. (p. 22)

However, consider the following simple way of representing their model: $\hat{Y}_i = \hat{\alpha} + \hat{\beta}X \quad and \quad Y_i = \hat{Y}_i + \varepsilon_i$ for *i* countries where Y is a patent measure, $\hat{\beta}$ is an estimated vector of weights associated with a set of underlying determinants of patenting X, and the errors, ε, are the extent to which actual and predicted patenting activity diverge from each other.[1] Gans and Hayes use $\hat{Y}_i$ for each country as the innovation index. The goal of the model building stage was to find a set of variables that usefully explain Y (in effect to discover a reasonable depiction of the underlying data generation process (DGP) for patents). The most compelling basis for using $\hat{Y}_i$ would be if X were observed for all countries and time periods, but not always Y (or if the model was in some sense a latent variables model, like Tobit). Then $\hat{Y}_i$ could be constructed. However, there are no cases where X is available that Y is not.

In that case, whether $\hat{Y}_i$ is preferred to Y as the preferred innovation index will depend on the outcomes from the modelling exercise. First, if it is hard to find a good match to the underlying DGP then ε is large and most of the variation in $\hat{Y}$ over time and between countries represents omitted important factors. Any innovation index constructed this way would risk missing out on the major factors underlying a country's innovative capability.

Second, if the model includes all of the theoretically sensible right hand side variables, but ε is still large because of noise, then the model could be seen as a noise extraction model (smoothing Y). This would still require that ε is statistically well behaved (homoscedasticty, absence of serial correlation etc). (An alternative, however, would be to use any of a range of widely available noise extraction methods to derive $\hat{Y}$.)

Third, if ε is small, then $\hat{Y}$ and Y are nearly the same across time and countries. Where ε is large, possible explanations include measurement errors in both Y and X and missing determinants of patenting X.

In this context, it might be simpler and more valid to use actual Y rather than $\hat{Y}$ as at least an alternative innovation index, since they are available anyway. However, the model itself is a very useful contribution because it allows the determinants of Y to be estimated.

[1] This characterisation abstracts from the panel data aspects of the model, but without any consequence for the observations being made.

However, Gans said, after noting the divergences between actual and estimated patents per capita (or Innovation Index) for 2005 (table J.5):

> … there is important policy information in the estimated numbers that the actuals cannot give. In particular, the Innovation Index can provide an appreciation of whether the policy parameters that are currently in place are ones that are likely to improve the capacity to innovate or not. For instance, the actual performance of Denmark appears relatively low compared to its potential as described by the Innovation Index, while the reverse conclusion would be drawn for South Korea. For these reasons, the Index will be a more stable measure of innovative performance. (sub. DR127, pp. 4–5)

Table J.5 **Actual patents per capita and the Innovation Index, OECD countries, 2005**

Country	*Actual patents per million population (Y)*	*Estimated patents per million population ($\hat{Y}_i$)*	*The gap as a proportion of actual patents per capita*
			%
Japan	237.1	136.2	42.6
United States	222.3	194.7	12.4
Finland	137.3	171.7	-25.1
Switzerland	133.7	132.2	1.1
Sweden	124.5	142.1	-14.1
Germany	109.2	96.1	12.0
South Korea	90.1	20.9	76.8
Luxembourg	89.8	0	100.0
Canada	89.7	90.5	-0.9
Iceland	67.8	61.4	9.4
Denmark	66.1	121.3	-83.5
Netherlands	60.8	56.6	6.9
Austria	56.3	50.4	10.5
United Kingdom	52.3	43.4	17.0
Belgium	49.6	57.9	-16.7
Norway	47.6	92	-93.3
France	47.2	68.8	-45.8
Australia	44.8	49.9	-11.4
Ireland	37.6	33.4	11.2
New Zealand	29.7	24.1	18.9
Italy	22.6	17.4	23.0
Spain	6.3	18.3	-190.5
Hungary	4.6	4.1	10.9
Czech Republic	2.5	5.8	-132.0
Greece	1.4	7.9	-464.3
Portugal	1	5.9	-490.0
Mexico	0.8	0.9	-12.5
Poland	0.6	2.3	-283.3
Turkey	0.1	0	100.0
Slovak Republic	0	2.7	not able to be estimated

Sources: Gans (sub. DR127, p. 4); Commission estimates.

The Innovation Index may well reflect government policies that are conducive to innovation. But it is notable from table J.5 that some countries often highlighted for their innovation success — such as Finland — appear to perform worse than the determinants of patenting would suggest, whereas others — such as Australia — are only slight ‘underperformers’. Moreover, low income per capita European countries such as Portugal, Greece, Turkey and Spain have severe apparent underperformance. Factors to explain the gaps include measurement errors as well as missing determinants in the model used to estimate the Innovation Index.

A complementary approach is to consider multifactor productivity (MFP) models as a broader measure of innovation. In principal, MFP has some advantages. First, MFP is fundamentally achieved from learning and changed practices of one kind or another, which is the essence of broad definitions of innovation (chapter 1). MFP captures innovation that takes the form of daily learning by businesses, catch-up, and technologies that are kept secret in addition to those that are patented.

Second, unlike the Innovation Index, MFP is, by definition realised as gains in economic growth and prosperity, whereas the capacity of patenting to realise such gains depends on other contingent policy and environmental factors. This is revealed by the panel data analysis of Luintel and Khan (2005a), which shows that the responsiveness of MFP itself to innovativeness indexes varies considerably from country to country (table J.6). Australia has a level of responsiveness that is 8th out of 20 countries. The Gans and Hayes measure of patenting (in effect, their Innovation Index) might be exploited in a similar model, though the Commission has not attempted to do this.

Table J.6 **MFP and 'new-to-the-world' knowledge stocks**[a]

	Elasticity of MFP wrt domestic knowledge stock measured as PIM[b] *on triadic patents*	*Triadic patents*	*Patents per 1000 researchers*	*Patents per PPP*[c] *billion dollars of R&D*	*Rank: elasticity*	*Rank: patents per researcher*	*Rank: patents per R&D dollar*
Australia	**0.246**	**183**	**4.0**	**35.5**	**8**	**18**	**16**
Austria	0.243	184	15.3	69.9	9	5	8
Belgium	0.218	253	12.7	69.2	10	8	9
Canada	0.205	308	4.4	29.4	11	17	18
Denmark	0.304	138	10.6	68.8	6	11	10
Finland	0.309	198	12.4	90.0	5	10	6
France	0.095	1732	13.5	62.1	17	7	11
Germany	0.067	4254	21.6	107.0	18	2	2
Ireland	1.102	24	4.8	39.4	1	15	15
Italy	0.156	568	8.2	43.6	13	14	14
Japan	0.057	8057	14.3	105.5	19	6	3
Netherlands	0.141	645	21.5	99.8	14	3	4
NZ	1.037	20	3.3	29.1	2	19	19
Norway	0.480	60	4.6	34.3	4	16	17
Spain	0.483	65	1.7	14.2	3	20	20
Sweden	0.159	533	19.0	92.0	12	4	5
Switzerland	0.127	737	40.9	154.5	15	1	1
UK	0.101	1397	10.1	58.6	16	13	12
US	0.048	10280	10.6	55.0	20	12	13
Mean	0.294	1560	12.5	70.8	7	9	7

[a] Based on triadic patents. [b] PIM is purchasing inventory method. [c] PPP is purchasing power parity.

Source: Luintel and Khan (2005a).

J.3 Innovation counts and surveys

Innovation counts (or the number of innovations) provide a more direct measure of innovation performance than patent indicators and the Innovation Index. They measure the ultimate end of a process of innovation. As noted earlier, patent indicators merely represent inventions, which may or may not be transformed into new products or processes.

Sources of data for innovation counts include innovation surveys of businesses and studies that sample the new product sections of trade and technical journals. The oldest example of journal-based innovation counts is the US Small Business Administration's Innovation Data Based complied in 1982 by the Future's Group (Jensen and Webster 2004, p. 18).

The ABS Innovation Survey (for example, ABS 2006d) contains a range of data on innovation by Australian businesses such as the proportion of businesses innovating or the proportion of businesses introducing new or significantly improved goods or services, operational processes, or organisational processes. They do not contain innovation counts as such, but counts of businesses that are innovating.

For example, table J.7 shows the proportion of businesses innovating, by innovation type and by selected business characteristics. Around 34 per cent of businesses in 2004 and 2005 were innovating. Of these innovating businesses, around 19 per cent introduced new or significantly improved goods or services and 46 per cent introduced new or significantly improved operational or organisational processes.

Table J.7 **Innovating businesses, 2004 and 2005, by innovation type and selected business characteristic**

Business characteristic		*Innovating businesses that introduced or implemented any new or significantly improved:*		
	Proportion of businesses innovating	*Goods or services*	*Operational processes*	*Organisational processes*
	%	%	%	%
Employment size				
5 to 19 persons	28.4	15.8	16.9	20.7
20 to 99 persons	46.6	29.2	34.4	35.6
100 or more persons	51.5	28.9	34.7	40.0
Industry				
Mining	31.4	10.6	17.6	22.2
Manufacturing	41.7	26.9	27.3	27.9
Electricity, gas and water supply	48.8	23.0	31.5	40.7
Construction	30.8	16.5	22.0	26.2
Wholesale trade	43.4	25.5	26.4	33.2
Retail trade	27.5	15.8	15.4	18.8
Accommodation, cafes and restaurants	35.6	23.6	25.0	27.8
Transport and storage	34.0	18.1	25.1	26.9
Communication services	35.5	28.5	25.3	27.1
Finance and insurance	37.9	18.9	25.7	30.7
Property and business services	30.3	16.4	20.1	22.6
Cultural and recreational services	32.9	18.0	18.9	26.3
Total businesses	**33.5**	**19.4**	**21.6**	**24.9**

Source: ABS (2006d, *Innovation in Australian Business 2005*, Cat no. 8158.0, December, table 1.2).

Table J.8 shows the degree of novelty of new goods and services and processes introduced by innovating businesses. Between 74 and 94 per cent of innovating businesses introduced new goods, services or processes that were 'new to the business', whereas between 0.3 and 8 per cent of businesses introduced new goods, services or processes that were 'new to the world'.

Table J.8 **Innovation by degree of novelty, 2004 and 2005**[a, b]

Degree of novelty	*Innovating businesses that introduced or implemented new:*		
	Goods or services	*Operational processes*	*Organisational processes*
	%	%	%
New to the business only	74.0	87.4	93.9
New to the industry	20.0	10.8	5.5
New to Australia	15.2	3.6	0.8
New to the world	7.7	0.8	0.3

a Excludes businesses that only reported innovative activity not yet complete or abandoned. **b** Businesses could provide more than one answer to each question.

Source: ABS (2006d, *Innovation in Australian Business 2005*, Cat no. 8158.0, December, table 2.13).

Like patent indicators, innovation counts also suffer from limitations. One limitation is that the quality of innovations can vary in terms of their technological and economic significance. Thus, the proportion of innovating businesses introducing new or significantly improved goods or services in table J.6 does not reveal much about the economic value of the innovation. Another limitation is that innovation counts can be very costly to produce and may only be available for selected years or countries (Acs et al. 2000, p. 2). Were the ABS Innovation Survey consistently undertaken for a longer period of time, it would provide a better indication of trends in innovation amongst businesses.

K Publications and scientific performance

K.1 Introduction

The statistical analysis of scientific publications, bibliometrics, has long been used as a performance indicator to gauge the impact and output of scientific knowledge.

The publication of scientific literature is important as it:

- provides scientific knowledge to firms and organisations with the capacity to absorb it;
- is accessible to many users and is easily disseminated;
- provides a permanent store of knowledge that can be exploited years after it is actually produced;
- provides pointers to key researchers and practitioners; and
- certifies the origin of ideas, which is important in determining status and promotion within the institutions producing research outputs.

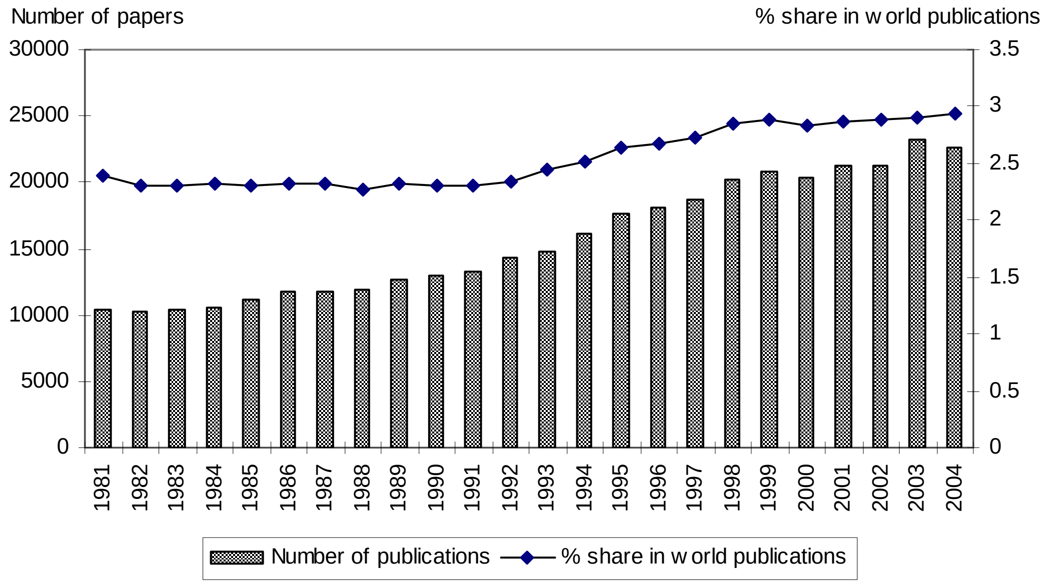
While the output of scientific publications and the citation of these publications provide a useful gauge of performance, they are not able to answer any single evaluative question in their own right (Butler 2001). Also, there may be certain ‘counting’ problems in using such measures including the overuse of citations of renowned publications at the expense of quality papers by less well-known authors, the sometimes insular view of scientists in citing their own nationals as a first preference, the tendency for ‘self citation’, ‘citation circles’ in which a group of academics cites each others work and the inability of such measures to take into account the prestige of the relevant journal.

Nevertheless, the analysis of publications and citations is useful in providing a relative indicator of Australia’s scientific performance and output at the international level and by sector.

K.2 Australia's international performance

The total number of Australian scientific publications increased steadily between 1981 and 2004, although the upward trend stalled briefly between 1999 and 2002. Australia's share of world scientific publications increased over the same period from just over 2 per cent to nearly 3 per cent (see figure K.1).

Figure K.1 **Australia's number and share in world scientific publications**



Data source: DEST (2005a).

Relative to other countries' share of world scientific publications, Australia ranks 11th behind the United States, which accounts for a third of the world's scientific publications, Japan, the United Kingdom and Germany and ahead of the Netherlands, South Korea, Sweden and Switzerland. Taking into account population, Australia ranks 9th on the number of scientific publications produced per million population. In relation to the number of researchers, Australia is ranked 9th by scientific publications produced per full-time researcher and Australia is ranked 6th on the number of scientific publications produced per US $million in GDP (see table K.1).

Table K.1 **Australia's relative scientific publication performance**

		Share of world scientific publications, 2000-2004		*Number of scientific publications per million population, 2000-2004*		*Scientific publications per FTE researcher, 2003*		*Scientific publications per $ million GDP (PPP), 2004*
1	United States	33.63	Switzerland	1 930	Switzerland	0.57	Switzerland	0.058
2	Japan	9.38	Sweden	1 700	Italy	0.48	Sweden	0.057
3	UK	9.04	Denmark	1 467	Netherlands	0.47	Denmark	0.045
4	Germany	8.63	Finland	1 435	UK	0.45	Netherlands	0.038
5	France	6.18	Iceland	1 272	Belgium	0.34	UK	0.037
6	China	4.68	Netherlands	1 212	Sweden	0.33	**Australia**	**0.035**
7	Canada	4.49	UK	1 152	Denmark	0.32	Canada	0.033
8	Italy	4.33	Norway	1 132	Canada	0.31	Belgium	0.032
9	Russia	3.24	**Australia**	**1 114**	**Australia**	**0.31**	Germany	0.028
10	Spain	3.08	New Zealand	1 113	Spain	0.26	France	0.027
11	**Australia**	**2.89**	Canada	1 092	Germany	0.25	Spain	0.021
12	Netherlands	2.58	Belgium	1 013	France	0.25	United States	0.021
13	India	2.39	Austria	925	United States	0.2	Italy	0.020
14	South Korea	2.15	United States	888	Japan	0.11	Japan	0.019
15	Sweden	2.01	Germany	790	South Korea	0.11	South Korea	0.016
16	Switzerland	1.86	France	464	Russia	0.05	Russia	0.016
17	Belgium	1.38	Ireland	738	China	0.04	India	0.005
18	Denmark	1.04	Spain	577	India	na	China	0.004

Sources: DEST (2005a); OECD (2006c); and World Bank 2006, *World Development Indicators Database*.

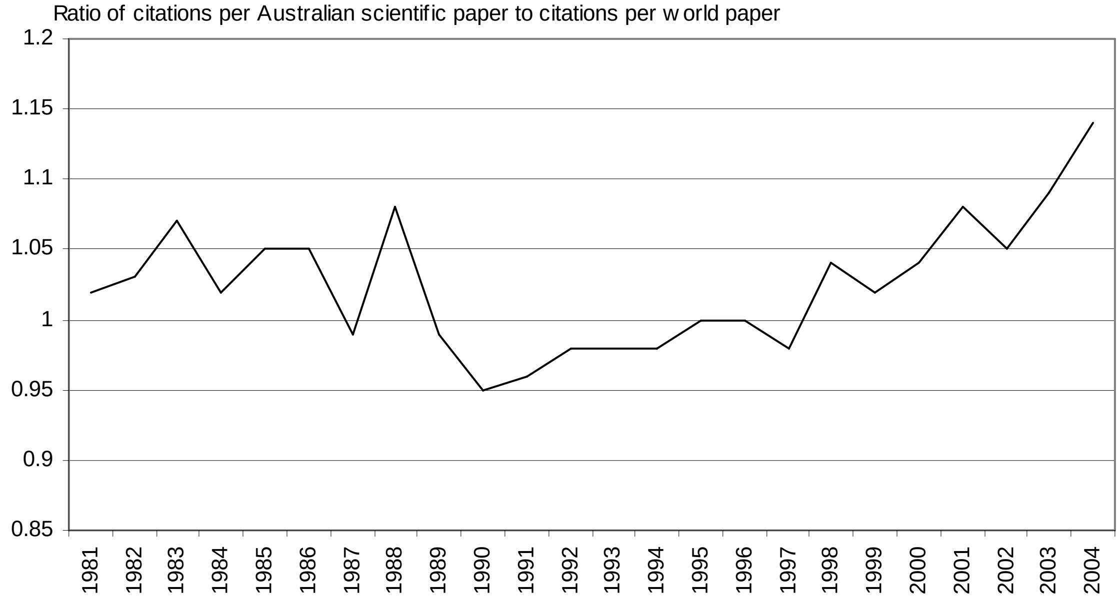
Citations impact, the number of times other scientists within the academic research community cite a research paper, provide an indication of the impact of the paper and an indicator of scientific performance. The CSIRO said:

> … citations provide a fairly direct measure of scientific impact, as the number of citations is a direct measure of the extent to which other scientists are drawing upon the work of the cited scientist in their own work. (sub. 50, p. 70)

One means of measuring this citation impact is from the ratio of citations of Australian scientific publications to the world average rate of citation. For most of the period 1981 to 2004, the Australian citation impact, while fairly volatile, was above the world average. For a period in the early 1990s it fell below the world average and has trended upwards since this period and was 1.14 times the world average in 2004 (see figure K.2).

The ARC (sub. 73) noted that Australia had achieved a relatively high scientific impact, as measured by citations of their published outputs, relative to its wealth.

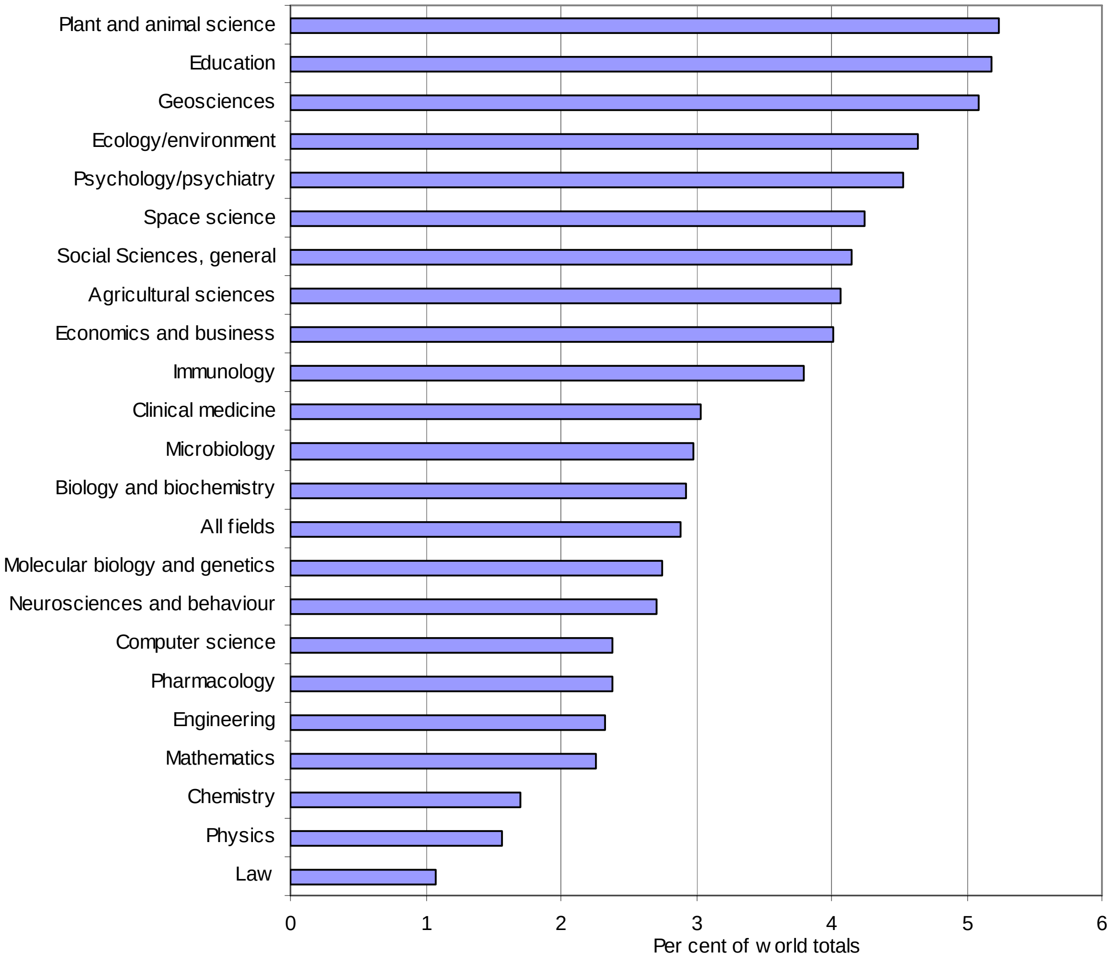
Figure K.2 **Impact of Australian scientific publications relative to the world, 1981 to 2004**



Data source: DEST (2005a).

By field of research, Australian research publications in plant and animal sciences, education and geosciences accounted for over five per cent of the world total in these fields between 2000 and 2004. Australian research publications in ecology and environment, psychology and psychiatry, space sciences and agriculture were also relatively numerous accounting for over 4 per cent of the total world publication in these fields over this period (see figure K.3).

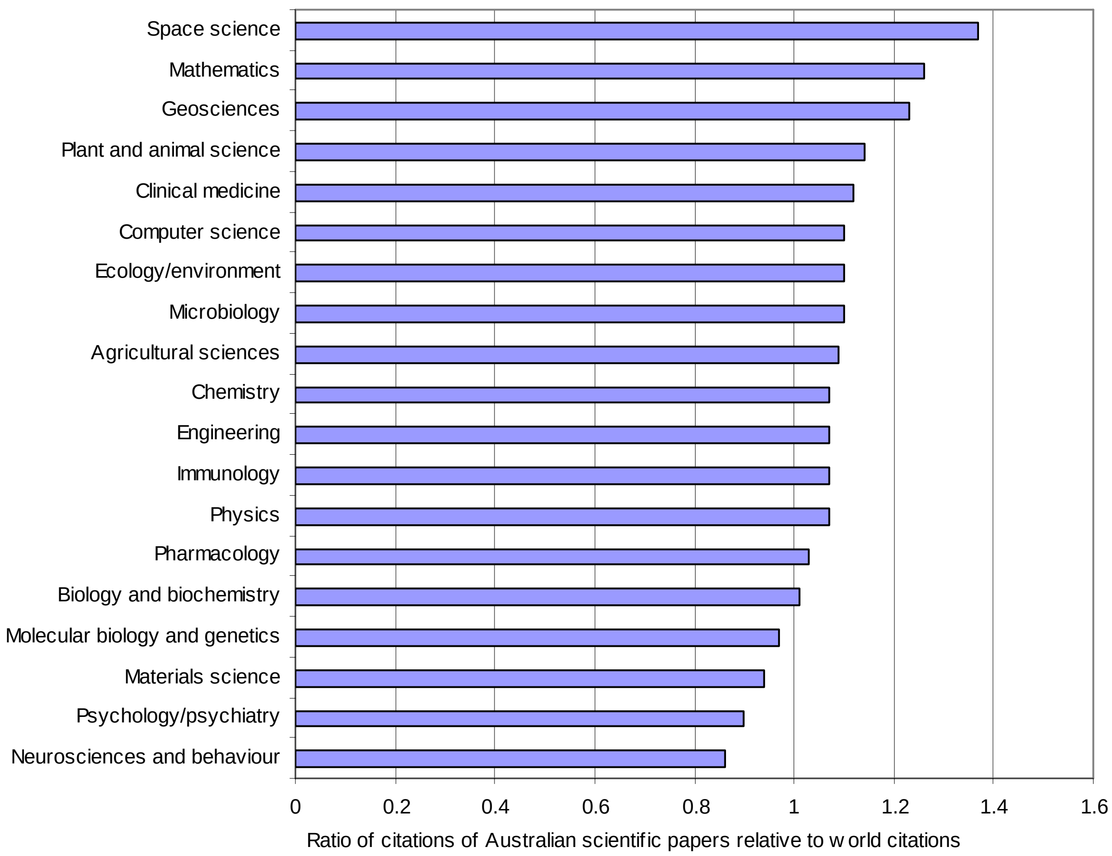
Figure K.3 **Australian scientific publications as a share of world totals — by field of research, 2000-2004.**



Data source: DEST (2005a).

The relative impact of Australian scientific publications by field of research, based on the ratio of Australian citations to the world average in each field, indicates that Australia performed above the world rate in a number of fields, in particular space sciences, mathematics, geosciences, plant and animal sciences, clinical medicine and microbiology between 2000 and 2004 (see figure K.4). For example, in space sciences the index of 1.37 means that Australian research publications in space sciences were cited at 1.37 times the world rate for papers in that field (DEST 2005a).

Figure K.4 **Impact of Australian scientific publications relative to world — by field of research, 2000-2004**



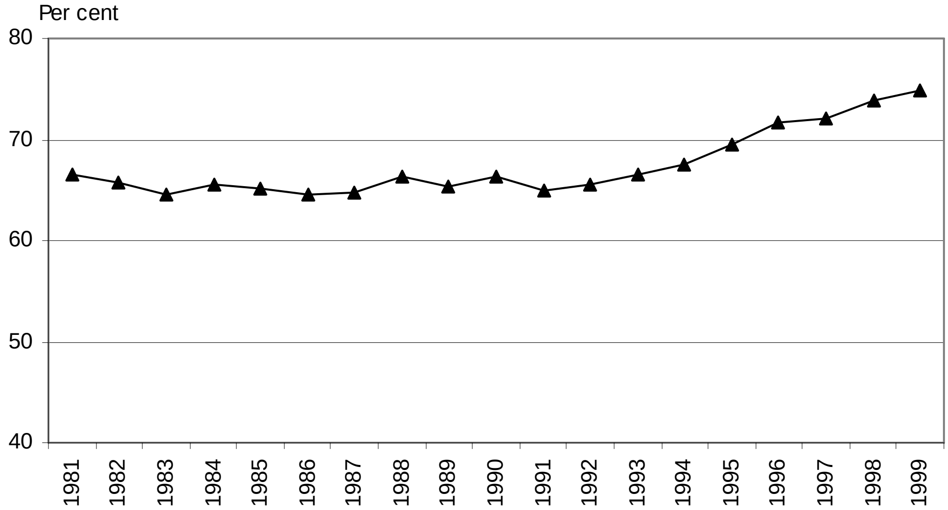
Data source: DEST (2005a).

By field of research, both as a share of world totals and by citation impact, Australia tends to perform well in plant and animal science, geosciences, space science and clinical medicine. Some of these fields of research are linked to Australia's natural endowments, such as plant and animal sciences and geosciences, where as others such as space sciences and clinical medicine indicate that Australia has been able to develop and build on capabilities in other areas.

K.3 Distribution of Australia's research effort

The university sector produces the vast majority of Australia's science publications. Analysis by Butler (2001) of Australian publications in the Science Citation Index found that universities dominated the output of Australian science publications. In the early 1980s universities accounted for around two-thirds of these publications increasing to just under three-quarters by the end of the 1990s (see figure K.5)

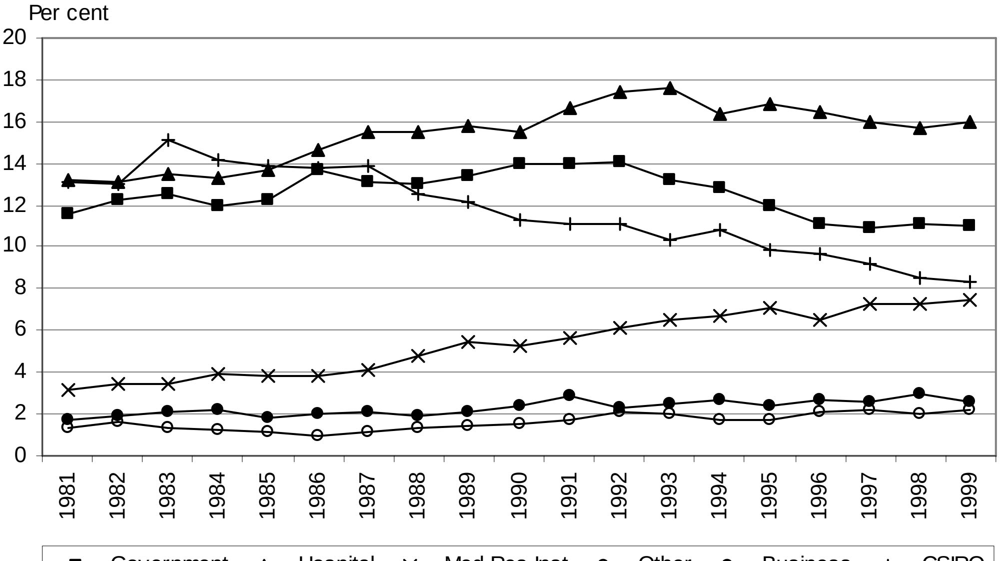
Figure K.5 **Universities' share of Australian publications in the Science Citation Index, 1981 to 1999**



Data source: Butler (2001).

Of the non-university sector, the hospital sector accounted for 16 to 18 per cent of scientific publications during the 1990s followed by government and the CSIRO, although the latter's share declined in this period. The medical research sector's share increased between 1981 and the end of the 1990s and accounted for around 8 per cent of the scientific publications in 1999 (see figure K.6).

Figure K.6 **Non university sector's share of Australian publications in the Sciences Citation Index, 1981 to 1999**



Data source: Butler (2001).

K.4 Collaboration

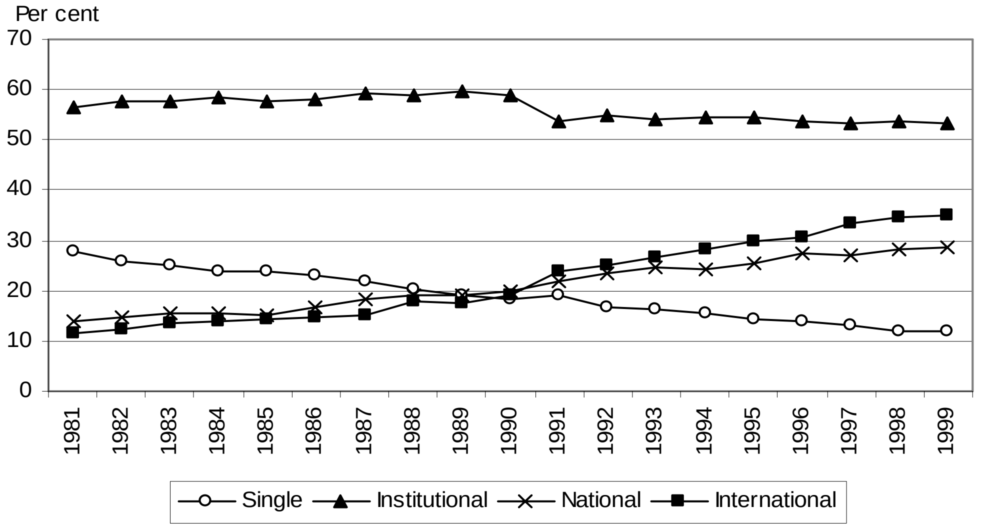
Publications data also provide an indication of the level of collaboration in scientific research. Analysis of the Science Citation Index by Butler (2001) distinguished between different types of authors of scientific publications along the following lines to indicate trends in the level of collaboration:

- Single – one author only (no collaboration);
- Institutional – more than one author from the same institution;
- National – more than one Australian institution listed in the author address; and
- International – more than one country listed in the author address.

This classification system is not exclusive and a publication involving collaboration between several Australian institutions and an overseas institution is included as both national and international.

The analysis found that over time research collaboration had increased. The single author paper was declining rapidly while collaborations between institutions at both the national and international level had increased markedly (see figure K.7).

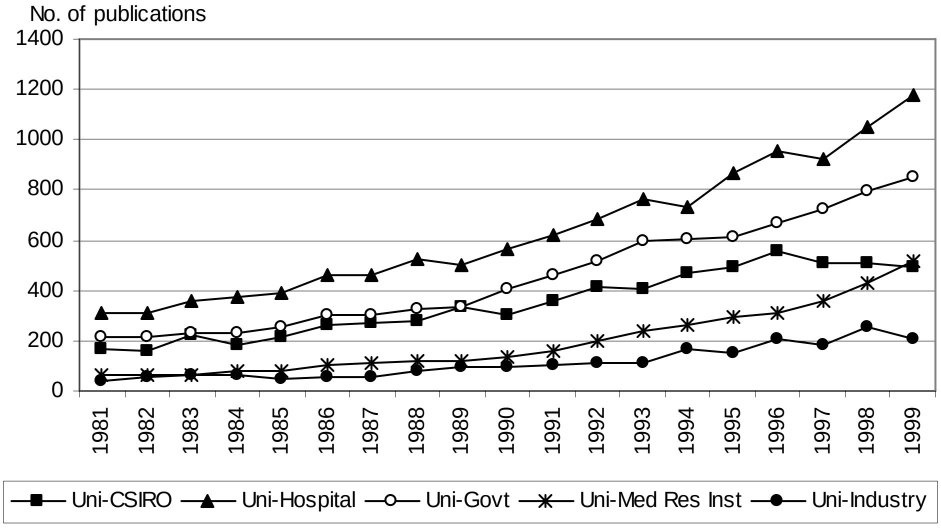
Figure K.7 **Levels of collaboration in Australian publications in the Science Citation Index, 1981 to 1999**



Data source: Butler (2001).

This analysis of authors of scientific publications also found that there had been increasing collaboration between the university sector and other sectors during the 1980s and 1990s. Collaborations between the university sector and government departments and agencies increased in this period and it appears that collaborations between universities and CSIRO began to decline in the latter half of the 1990s. Collaborations between the universities and industry trended upwards over the same period (see figure K.8).

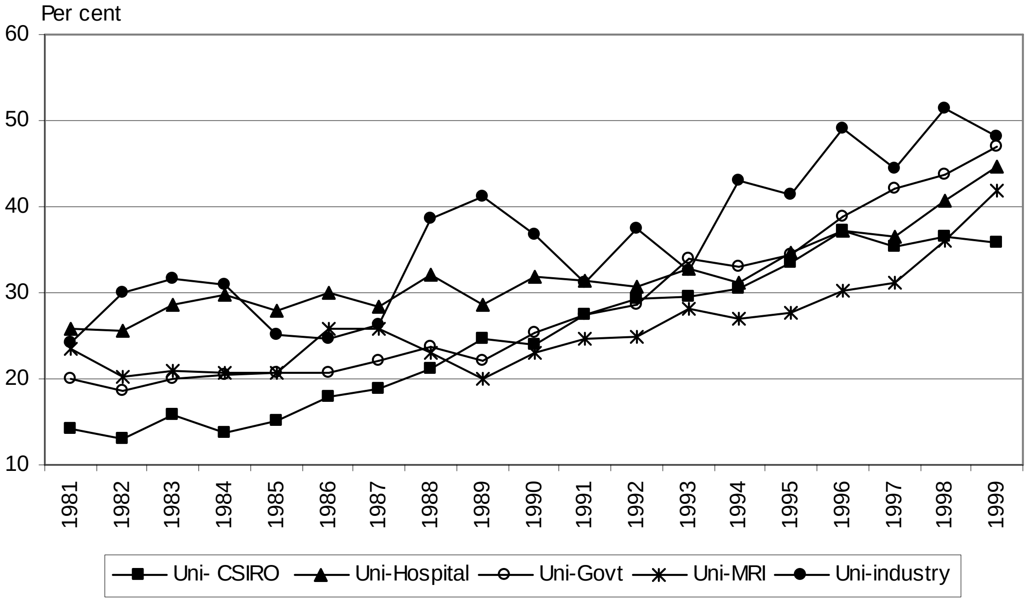
Figure K.8 **Selected sectors collaboration with universities in Science Citation Index publications, 1981 to 1999**



Data source: Butler (2001).

As a share of each sectors' total publications in the Science Citation Index, the level of collaboration with the university sector increased for most sectors between 1981 and 1999, although for CSIRO the level of collaboration remained flat in the latter half of the 1990s. The level of collaboration between industry and the university sector, as a share of industry publications in the Science Citation Index, while above that of the other sectors, was particularly volatile on a year-to-year basis due to the relatively small number of industry publications included in the Science Citation Index (see figure K.9).

Figure K.9 **Selected sectors collaboration with universities in the Science Citation Index publications as a share of their total publications in the Science Citation Index, 1981 to 1999**



Data source: Butler (2001).

L Science and innovation workforce

This appendix looks at the major supply side issues surrounding the science and innovation workforce and their possible implications on the ability of the system to deliver this workforce. These include the decline in the study of science and mathematics in the final years of high school and other school related issues, the number of graduates produced by the university sector, the impact of Australia's so called 'brain drain' and the size of the overall workforce. It then discusses the overall demand for these workers in the context of employment prospects and occupational shortages.

L.1 Supply issues

Many of the issues surrounding the science and innovation (S&I) workforce relate to ensuring that there are adequate numbers of appropriately trained scientists, engineers and related professionals and are encapsulated in the ongoing concern that skill shortages will ultimately affect Australia's ability to create and absorb scientific knowledge and undertake innovative activities.

Problems in the classroom — school related issues

The study of science and mathematics in the final years of high school is important as it provides the pathway to tertiary study in these areas and a broader scientific and mathematical literacy in the wider population. However, there have been widespread concerns relating to the number of students undertaking these subjects, as well as a lack of adequately trained science and mathematics teachers in senior high school (DEST 2003b and 2006c, Harris, Jensz and Baldwin 2005).

Declining year 12 participation in maths and science

There has been a steady decline in the proportion of year 12 students studying science since the mid 1970s. Enrolments in year 12 biology decreased from 58 per cent to 25 per cent between 1976 and 2002, in chemistry from around 30 per cent to 18 per cent and in physics from nearly 28 per cent to 18 per cent over the same period. However, between 2000 and 2004 the participation rates in year 12 science have remained fairly stable. A number of reasons as to the decline in the study of science in the final year of high school have been put forward including poor experiences in earlier years of high school, perceptions that it is ‘too hard’, not being engaged with the curriculum, poor career advice based on limited knowledge of career options and peer group and/or family pressures (DEST 2003b, 2006c and sub. 87).

In respect of year 12 mathematics, overall participation rates were high and there were increases in elementary mathematics and a moderate decline in advanced mathematics during the 1990s (DEST 2003b).

More recent analysis undertaken for the International Centre for Excellence for Education in Mathematics and the Australian Mathematical Sciences Institute indicates that the move into elementary mathematics was continuing with the proportion of year 12 students studying higher level mathematics (advanced and intermediate) declining from 41 per cent to 34 per cent between 1995 and 2004. Those studying advanced mathematics declined from just over 14 per cent to just under 12 per cent over the same period (Barrington 2006).

However, while the proportion of year 12 students studying science and intermediate and advanced mathematics has declined, because of the strong growth in year 12 retention rates more students are studying these subjects in the final years of high school than was the case 20 years ago. As high school retention rates have increased, a wider range of subjects, including more vocationally orientated subjects, have been introduced to meet the needs of a more academically diverse student body. As a result, students continuing through to year 12 have a wider range of subjects to choose from than in the past which has lessened the appeal of the more traditional senior high school science and advanced mathematics subjects. Nevertheless, these subjects will continue to attract those students seeking to enter university courses — many which due to high demand for places attract the more highly qualified school leavers — where the study of high school science and/or non-elementary mathematics is an entry requirement.

There have been concerns that there will be further declines in students studying advanced mathematics as some universities, such as the University of Sydney and the University of New South Wales, no longer require advanced mathematics, or other specific high school subject areas including science subjects, as a prerequisite for their undergraduate courses. Instead, these high school subject areas that previously were prerequisites are now recommended areas of study or an assumed knowledge with the use of bridging courses provided by the university to acquire this knowledge where students have not studied these subjects at high school.

Of course, while this may appear to be a 'softening' of entry requirements in those universities where prerequisites were previously required, it would be extremely difficult to succeed in many undergraduate courses without the required background knowledge in science and mathematics whether obtained through high school studies or through a university bridging course.

Shortages of qualified teachers

Most jurisdictions face shortages in high school mathematics and science teachers, particularly in the area of physics and chemistry (DEST 2003b). These shortages are likely to be exacerbated due to the demographics of the teaching workforce as those older male teachers most heavily involved in teaching science and mathematics retire in the coming years. Such trends are not confined to Australia, with many other OECD countries facing similar shortages of secondary school mathematics and science teachers (MCEETYA 2004).

In addition to shortages, there are concerns that many teachers teaching senior high school science and mathematics are inadequately trained. In a report prepared for the Australian Council of Deans of Sciences, Harris, Jensz and Baldwin (2005) found that many senior high school physics and chemistry teachers lacked adequate qualifications. In a follow up report on the qualifications of mathematics teachers in secondary schools, Harris and Jensz (2006) found that while the qualifications of those teaching high school mathematics was more encouraging than those teaching science, around 20 per cent of all mathematics teachers had not studied mathematics beyond first year at university.

According to DEST (sub. 87) there was a strong perception that Australia lacked sufficient suitably qualified secondary school science and mathematics teachers which had adverse impacts on student engagement in science, engineering and technology. Importantly, the lack of suitably qualified teachers in these areas limited the ability of the system to expand to increase the number of students studying mathematics and science in the senior years of high school and potential entrants to tertiary studies in science, mathematics and related courses.

The issue of teacher shortages is discussed further in chapter 6.

University entrants and graduates

Lack of well-qualified school leavers entering university science courses?

The decline in the proportion of year final year high school students studying science and the shortage of suitably qualified teachers has led to concerns that there will be a lack of well qualified school leavers to enter science and mathematics courses at university.

In any case, it appears that well qualified school leavers are more attracted to other university courses given the relative levels of demand for these courses. In 2005, according to the Australian Vice-Chancellors' Committee (AVCC), all eligible applicants for university science courses received an offer in contrast to other courses (see table L.1).

Table L.1 **Applicants and offers for selected university courses, 2005**

Field of education	*Eligible applicants*	*Offers*	*Percentage not receiving an offer*
Agriculture	4 161	4 304	0%
Architecture	6 733	4 620	31%
Management and commerce	35 282	29 606	16%
Education	25 308	18 648	26%
Engineering	12 162	10 933	10%
Dental studies	1 776	795	55%
Medical studies	8 316	2 320	72%
Nursing	16 675	10 959	20%
Law	12 372	7 917	36%
Veterinary studies	1 929	479	75%
Natural and physical sciences	15 003	16 519	0%
Information technology	6 810	6 392	6%

Source: AVCC (2005).

Those students performing well in science and mathematics at high school tend not to be attracted to science courses at university, but rather to other more vocationally orientated careers for reasons which, according to DEST (2003b and sub. 87), may include family or peer group influences, lack of quality career advice, the attractiveness of other career paths and student perceptions of career and lifestyle values available from other courses. Indeed, the perception of many students is that other courses provide direct entry to professions that are better paid and more secure (Australian Science Teachers Association 2005).

As the demand for science courses is not as strong as for other courses such as veterinary science, dentistry and law and there is a larger number of undergraduate places available, the tertiary entrance score to study science at university is lower than these courses. For example, in 2006 the tertiary entrance score for admission to undertake a bachelor of science at the University of Melbourne or Sydney University was just over 80 in comparison to law and veterinary science undergraduate courses where the scores were in the high 90s (VTAC 2006, UAC 2006 website). While this does not mean that only lesser qualified students or those with lower tertiary entrance scores will enrol in science courses, it does mean that science does not have the same status as those courses where entry is restricted to the 'top scoring' school leavers.

The lower admission requirements give a misleading impression of the average effective quality of those pursuing a career in science. The actual tertiary entrance scores for many school leavers studying science, particularly in the Go8 universities, are not all that 'low'. For example, in 2005 the median tertiary entrance score of students commencing undergraduate study in the natural and physical sciences was 97 at the University of Melbourne, 92 at the University of Sydney, 95 at the University of Adelaide 95 and 92 at the University of Western Australia (information provided by DEST Higher Education Statistics).

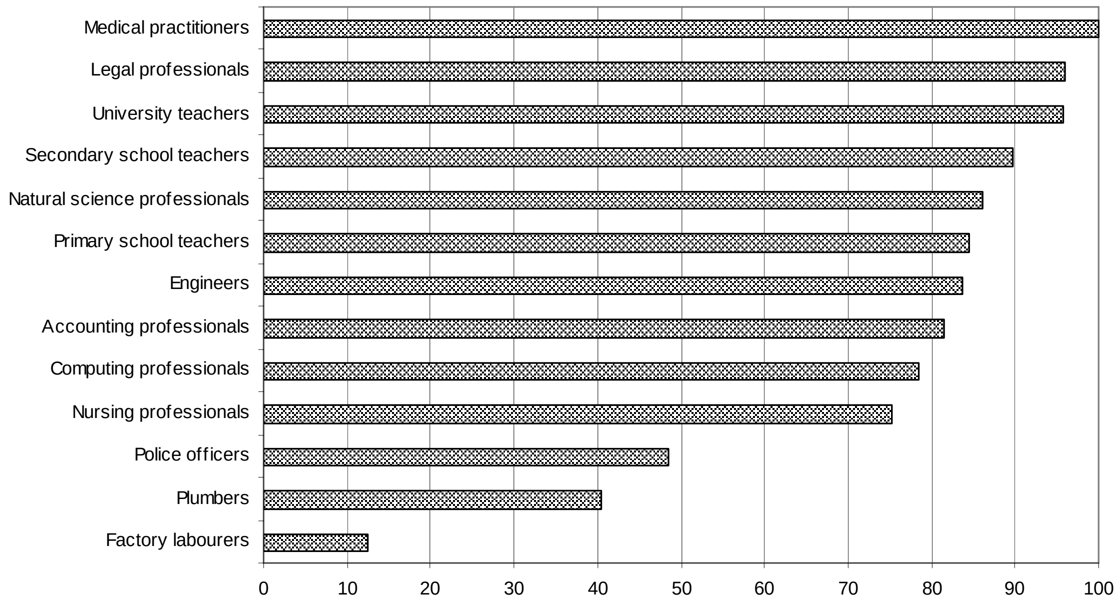
Furthermore, a post-graduate qualification is often required for a professional career in science and the main selection process occurs following completion of the undergraduate degree as only the most able students proceed to post-graduate study. The National Health and Medical Research Council (NHMRC) (2005c) noted that the entry into post-graduate training reflected the selection of the 'best of the best'.

Moreover, the status of scientists appears to be quite good. In comparing the socioeconomic status of various occupations, science professionals rank quite high, although behind medical and legal professionals and university teachers. Interestingly, secondary school teachers are ranked above engineers, science professionals and computing professionals (see figure L.1).

Graduate numbers have been increasing in most areas

Despite being relatively less popular than some other university courses, in the period between 1990 and 2000 there was a substantial increase in the number of Australian citizens graduating in science, computer science and engineering. The number of Australian science and engineering graduates nearly doubled and the number of computer science graduates tripled (see table L.2). However, with the large increase in overall graduates over this period, the number of science and engineering graduates appears to have remained fairly static as a proportion of all graduates.

Figure L.1 **Socioeconomic status of selected occupations and professions — ANU4 scale[a]**



[a] The ANU4 scale links education, occupation and income to provide a 0 to 100 scale of socioeconomic status coded to the ABS's occupational classification system, ASCO.

Data source: Jones and McMillan (2001).

Table L.2 **Award course completions by Australian citizen students in selected fields of study, 1990 to 2000**

Field of study	*1990*	*2000*	*Percentage change 1990 to 2000*
General science	3 395	5 162	49
Life sciences	2 374	6 513	174
Mathematics	477	649	36
Physical sciences	876	1 457	66
Total science	**7 122**	**13 781**	**93**
Engineering	3 071	5 898	92
Computer science	1 701	5 149	202
Total	**11 894**	**24 828**	**109**

Source: Information supplied by DEST, University Statistics Unit.

In 2000, a different classification system to allocate fields of study was introduced. This created a break in the data, requiring any time series to be presented on a pre- and post 2000 basis. Using the changed classifications, there appears to have been a change to the previous trend.

Since 2001, there has been a very slight increase in the number of Australian citizens graduating in science and a slight decrease in engineering. By specific field of study, there have been large decreases in earth sciences and natural and physical science graduates. In physics and astronomy and those fields of study classified as other natural physical sciences, the trend of increased graduations by Australian citizens has continued along with slight increases in mathematical sciences and biological sciences (see table L.3).

Table L.3 **Award course completions by Australian citizen students in selected areas of study, 2001 to 2004**

Detailed area of study	*2001*	*2004*	*Percentage change 2001 to 2004*
Natural and physical sciences (general)	2 687	2 128	-20
Mathematical sciences	591	603	2
Physics and astronomy	254	326	28
Chemical sciences	495	485	-2
Earth sciences	787	456	-42
Biological sciences	3 313	3 532	7
Other natural and physical sciences	4 344	5 278	21
Total sciences	**12 471**	**12 808**	**3**
Computer science	2 011	2 136	6
Engineering	5 415	5 104	-6
Total	**19 897**	**20 048**	**1**

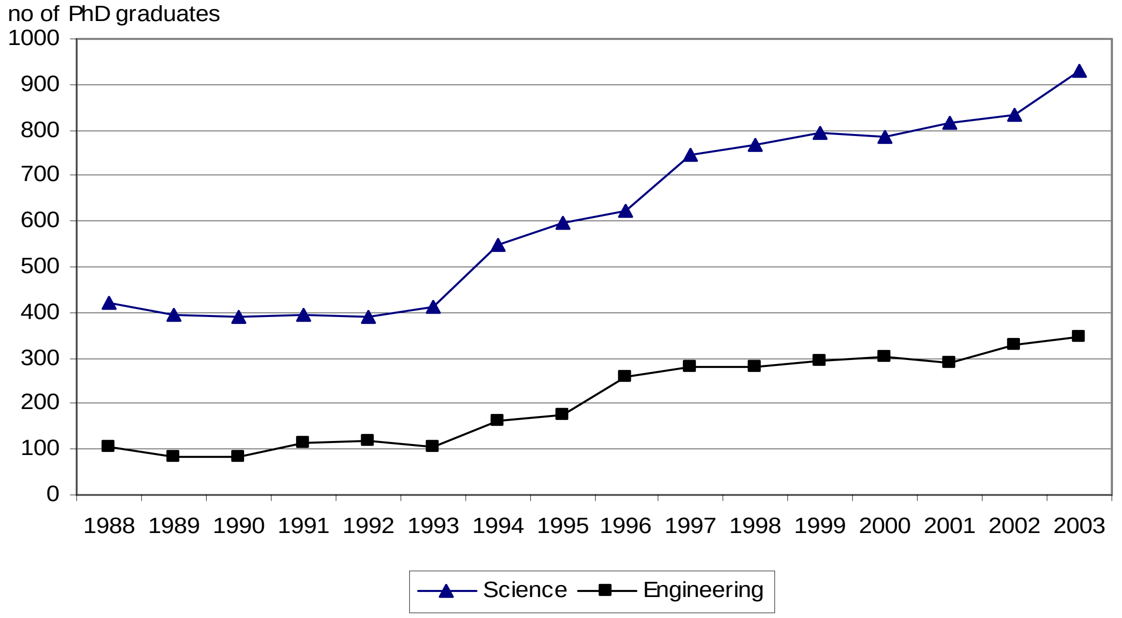
Source: Information supplied by DEST University Statistics Unit.

PhD graduates have increased

The number of PhD students is an important input into Australia’s science and innovation system, not only from the research undertaken by PhD students, but also from the ongoing research focus of PhD graduates. The number of Australian PhD graduates in science and engineering has increased significantly. For example, the number of PhD graduates in science more than doubled between 1988 and 2003 from 425 to over 900. Engineering PhD graduates more than tripled over the same period from 104 to 345 (see figure L.2). However, as a proportion of total Australian PhDs awarded, science and engineering PhD graduates declined from 50 per cent to 35 per cent over the same period (DEST, 2005a).

The larger number of science PhDs relative to engineering PhDs most likely reflects the greater research focus of science compared to the more occupational focus of engineering. To be considered a ‘scientist’ often involves further post graduate education unlike engineering where the undergraduate education provides the entry to the engineering profession.

Figure L.2 **Australian PhD graduates in science and engineering, 1988 to 2003**



Data source: DEST (2005a).

Australia has experienced a brain gain rather than a brain drain

There have been ongoing concerns that Australia has been experiencing a 'brain drain' as skilled professionals, in particular scientists and engineers, move offshore.

However, the academic studies and inquiries generated by these concerns have all shown that Australia has actually experienced a brain gain, as any loss of skilled residents has been more than offset by gains from immigration.

For example, research undertaken for the Department of Immigration and Multicultural Affairs into the movement of skilled workers to and from Australia found that any net loss of skilled residents during the latter half of the 1990s was more than offset for almost every occupation by gains in immigration (Birrell, Dobson, Rapson and Smith 2005). The recent Senate Inquiry, *They Still Call Australia Home: Inquiry into Australian Expatriates* in 2005 similarly concluded that Australia had been experiencing a net gain in skilled workers, as did work on the Australian diaspora by Hugo et al. (2003).

More recent analysis of immigration data through to 2003-04, as with other studies, found that while Australia was losing skilled residents to overseas locations, these losses were exceeded by gains from immigration. It went on to conclude that it was Australia's relative lifestyle advantages — these cover a multitude of dimensions including a pleasant climate, political and social stability, a relatively crime and pollution free urban environment, good housing and other urban amenities and the availability of good quality and low cost education for children — that enabled it to keep the majority of its skilled workforce content to remain in Australia and provided a major attraction to skilled migrants. Moreover, Australia would continue to experience a net gain in skilled workers because of these advantages (Birrell, Rapson and Smith 2005).

More specifically, Australia experienced a net gain in nearly all science occupations and larger net gains in computing professionals and engineers in every year between 1996-97 and 2004-05 (see table L.4).

On a trend basis, the net gains for the science occupations declined overall — although at an occupational level there were increases in geologists and geophysicists, life scientists and medical scientists — and there were increases for engineers, computing professionals and to a lesser extent for mathematicians over this period.

Table L.4 **Net movement of skilled settlers, residents and long-term visitors by selected occupations, 1996-97 to 2004-05**

Occupation	*96-97*	*97-98*	*98-99*	*99-00*	*00-01*	*01-02*	*02-03*	*03-04*	*04-05*
Chemists	174	64	144	164	151	128	102	70	125
Geologists and geophysicists	132	135	146	260	127	64	136	103	234
Life scientists	100	218	112	106	186	168	221	230	189
Environmental and agricultural scientists	228	138	257	264	98	79	75	51	25
Medical scientists	69	46	73	117	193	167	205	233	246
Other science professionals	143	-184	-87	-177	-206	-312	-96	-26	-35
Total science	**846**	**417**	**645**	**734**	**549**	**294**	**643**	**661**	**784**
Engineers	1 177	1 388	1 478	1 684	1 753	1 588	1 709	1 852	1 781
Computing professionals	1 044	1 125	1 399	2 287	4 057	5 063	4 689	5 890	5 692
Mathematicians statisticians and actuaries	60	57	65	58	37	2	61	76	65
Total	**3 127**	**2 987**	**3 587**	**4 763**	**6 396**	**6 947**	**7 102**	**9 614**	**8 322**

Source: Birrell, Rapson and Smith (2006).

Quality issues surrounding the gains

While Australia has experienced a net inflow of skilled migrants, it is unclear as to the quality component of these incoming and outgoing flows and whether or not those immigrating are adequate substitutes for those emigrating. The quality of human capital encompasses potentially measurable features such as experience, qualifications and achievement levels in courses, but it also includes intangible less measurable facets, like motivation, creativity and inherent ability. Unfortunately, it is only possible to gauge with ease selected aspects of tangible and intangible quality.

To this end, Birrell et al. (2004) assessed whether Australia was losing its most highly educated workers by examining the movements of people who had gained their PhD between 1996 and 2001. They found that, contrary to expectations, the very small loss of Australian residents who had gained their PhD in this period was greatly exceeded by the inflow of migrant PhDs and Australian residents returning with PhDs obtained overseas.

A further way of attempting to gauge the substitutability of skilled immigrants is to compare the productivity of immigrants with comparable Australian-born workers using earnings as a measure of their relative productivity. Analysis undertaken by the Productivity Commission (2006) into the economic impacts of migration and population growth found that immigrants from English speaking backgrounds earned slightly more than comparable Australian-born workers[1]. The similar outcomes in earnings between skilled immigrants and comparable Australian-born workers could also mean that the relatively more productive workers have departed Australia in response to the higher incomes available in some other countries. Of course, in any qualitative comparison there needs to be recognition of the selection bias in these flows as those emigrating from Australia, as is the case for those migrating to Australia, are likely to be more highly motivated and risk taking than those that remain.

Nevertheless, English language ability appears to be a key indicator as to the substitutability of skilled migrants for Australian emigrants across all occupations.

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[1] Similarly, analysis on the earnings of immigrants in Canada and New Zealand found that those from English speaking backgrounds achieved fairly similar earnings or experienced only a relatively small difference in initial earnings from native born residents in similar occupations (Glass and Kin Choy 2001, Tockarick 1999).

Do Australians return home?

A critical issue is whether or not those skilled Australians emigrating return to Australia as those who do are likely to return with increased skills and knowledge which would be of benefit to Australia.

The majority of skilled emigrants return to Australia. The overall rate of return of skilled Australian residents, who indicated that they were leaving permanently or on a long term basis, was around 75 per cent (when returns two years after departure were compared). For those moving to the United Kingdom the rate of return was around 85 per cent (Birrell et al. 2004).

There are a range of reasons as to why expatriates did or did not return to Australia according to a survey of Australian expatriates undertaken by Hugo et al. (2003). The major reasons for return were lifestyle and family related, in contrast to work related reasons for leaving. It found that as expatriates aged they were less likely to return, those in the United States and Canada were less likely to return while those in Asia were generally more likely to return. A further factor was the nationality of the spouse, as those with Australian born spouses were more likely to return than those with non-Australian born spouses.

In any case, Australia has benefited from emigration given that the vast majority of its skilled emigrants return home with additional skills and experience.

Australia's science and innovation workforce has been growing

Although there are concerns surrounding high school enrolments in science and mathematics and the quality of students entering university science courses, the actual increase in graduate numbers and skilled migration has produced a net result of a growing science and innovation workforce in Australia. Indeed, the science and innovation workforce has been growing faster than the overall workforce over the past decade, although the experience for particular occupations has been diverse. For example:

- there was strong growth in the employment of computing professionals, engineers and for science professionals as a whole;
- across the science occupations, the number of chemists and geologists and geophysicists in full-time employment increased by over 50 per cent and by nearly 90 per cent for environment and agricultural science professionals;
- in the case of physical scientists, life scientists and mathematicians the increases in employment have been slight; and

- apart from mechanical, production and plant engineers, most engineering occupations have experienced a substantial growth in employment in the past decade (see tables L.5 and L.6).

Table L.5 **Science and related professionals employed full time by occupation, 1996 to 2006**

ASCO Occupation and code	*August 1996*	*February 2001*	*February 2006*	*Change 1996 to 2006*	*Share of the science workforce*
	'000	'000	'000	%	%
Chemists (2111)	5.9	4.4	9.0	52	15.5
Geologists and geophysicists (2112)	4.5	7.1	7.0	55	13.0
Life scientists[a] (2113)	4.6	8.0	4.8	0.4	8.4
Environmental and agricultural science professionals (2114)	11.0	14.4	20.7	88	36.1
Medical scientists (2115)	9.1	13.6	11.5	26	19.4
Other natural and physical scientists[b] (2119)	4.0	5.5	4.5	12	7.6
Total scientists	**39.1**	**53.0**	**57.5**	**47**	**100**
Mathematicians, statisticians and actuaries (2993)	5.4	5.6	5.6	4	
Computing professionals (2231)	93.9	151.6	143.3	52	
Scientists, mathematicians, statisticians and actuaries and computing professionals	**138.4**	**210.2**	**206.4**	**49**	

a Includes anatomists or physiologists, botanists, zoologists, biochemists, marine biologists and life scientists nec. **b** Includes physicists, meteorologists, metallurgists and natural and physical sciences nec.

Source: ABS (*Employed person by occupation, unit group, sex, state, status in employment,* Labour force estimates provided to the PC).

While there has been a smooth upward trend in employment growth for science professionals and engineers in total over this period, at an occupational level employment growth has generally been much more volatile.

By 2006, there were over 57 000 scientists, more than 5000 mathematicians, 143 000 computing professionals and 101 000 engineers employed on a full-time basis in Australia, accounting for around 3 per cent of Australia's total workforce (tables L.5 and L.6). In addition, there was a significant workforce providing administrative, technical and other support to those pursuing scientific knowledge and undertaking research and development type activities. For example, just over a third of CSIRO's staff were involved in providing technical, administrative and other support to CSIRO researchers (CSIRO 2005a).

Of the scientists, the majority were environmental and agricultural science professionals and of the engineers, more than half were civil engineers and electrical and electronic engineers (see table L.5 and L.6).

Table L.6 **Engineering professionals employed full-time by occupation, 1996 to 2006**

ASCO Occupation and code	*August 1996*	*February 2001*	*February 2006*	*Change 1996 to 2006*	*Share of engineering workforce 2006*
	’000	’000	’000	%	%
Civil engineers (2124)	18.5	25.5	30.6	65	30.1
Electrical and electronic engineers (2125)	17.1	24.5	26.9	57	26.4
Mechanical, production and plant engineers (2126)	21.1	18.9	17.1	-19	16.6
Mining and materials engineers (2127)	4.4	4.0	5.7	29	5.7
Other building and professional engineering professionals (2129)	9.5	12.2	14.3	50	14.2
Engineering technologists (2128)	0.2	0.6	0.5	150	0.5
Building and engineering professionals — nfd		1.9	6.5	na	6.5
Total	**70.8**	**87.6**	**101.6**	**43**	**100**

Source: ABS (*Employed person by occupation, unit group, sex, state, status in employment,* Labour force estimates provided to the PC).

As noted in chapter 6, the age structure of the science and engineering workforce closely resembles that of the wider workforce and, in line with the workforce generally, is expected to age in the coming years. The impact of ageing on the productivity of scientists has been subject to numerous studies which have suggested that their productivity declines as they age (see box L.1). If correct, this would imply that more scientists than would otherwise be the case would be required to achieve the same ‘volume’ of work. The issue of workforce ageing, in particular the academic workforce, is discussed further in chapter 6.

Box L.1 **Ageing and the productivity of scientists**

> A person who has not made his great contribution to science before the age of thirty will never do so.
>
> Albert Einstein (quoted in Kanzawa 2003)

Science is often considered to be a young person's game given the age at which Newtown, Einstein and Darwin made their most significant scientific achievements.

The relationship between the age of scientists and their performance has been subject to various studies. Work undertaken in the early 1950s by Lehman (1953) used a statistical analysis of entries in the history of science of individuals who had made outstanding contributions and the age at which this occurred. It concluded that superior creativity rises to a maximum, usually in an individual's thirties, and then falls off slowly.

Further work in the late 1970s and early 1980s, such as Cole (1979), using bibliometric data to assess quantity and quality of work, found that performance was not negatively related to age.

These findings produced a flurry of economic literature using a lifecycle framework to investigate the relationship between ageing and the productivity of scientists (Bhattacharya and Smyth 2003) which have all suggested that the productivity of the scientist declines with age.

For example, Levin and Stephan (1991) used a longitudinal survey of United States scientists, the United States survey of doctorate recipients, and the Science Citation Index to examine the relationship between ageing and productivity. The major finding was that scientists became less productive as they age. This ageing effect was found to be attributed to age per se and not to the possibility that, for some reason older scientists in the sample had different attributes, values or access to different resources from the younger members of the sample. More tentatively, the study also found that the latest educated are not necessarily the best educated. Except for geology, the more recent 'vintages' were found to be no more productive than earlier vintages.

The relationship between ageing and productivity appears to be similar for scientists outside the United States. Work undertaken on the age and productivity of Norwegian scientists (Kyvic 1990) found that publishing activity reached a peak for scientists aged in their late forties and declined rapidly from then on while in the humanities publishing peaked for those in their late 50s early 60s. Similarly, McDowell (1982) found that productivity peaked relatively early for academics in the physical sciences and much later in the case of academics in the humanities. The explanation put forward was that in the sciences new methods and equipment were continuously being introduced which advantaged younger researchers, whereas in the social sciences and humanities the basic knowledge underpinning research occurs at a slower pace.

In addition, older scientists in academia are more likely to be involved in managerial and administrative type roles and have less time for research. Any good idea is likely to be passed over to graduate students and younger researchers. A further factor in the United States, according to Thompson (2003), is that the tenure system provides incentives for younger researchers to be more productive and search for significant discovery in the pursuit of a tenured position and then enables them to 'rest on their laurels' after achieving tenure.

L.2 Demand issues

The demand for scientists, engineers and computing professionals is determined by a range of factors including the rate of economic growth, technological advance, the level of research and development being undertaken and government priorities in research and development. Just as the supply of various disciplines and occupations within these professions varies, so does the demand for their skills. Workers in each occupation face a specific market for their skills and while one occupation may be in high demand there may be shortages at the same time in another occupation (Borthwick and Murphy 1996).

At present, there appears to be strong demand for most types of scientists, engineers and computing professionals in Australia and, as noted above, employment has been increasing. Projections of future demand and supply undertaken as part of the Audit of Science, Engineering and Technology Skills (DEST 2006c) through to 2012-13 suggested that domestic sources and skilled migration would be adequate to meet Australia’s demand for science, engineering and technology skills. However, it warned that being based on historical data, such assumptions may not reflect potential or planned developments in the resources sector, infrastructure development and renewal or defence material needs (DEST 2006c).

The important issue is whether the system will be able to adjust to meet any shortages now and in the future. In well functioning labour markets, shortages are reflected in higher incomes. Provided that price signals in the form of higher incomes and earnings are able to reflect any such shortages, additional skilled migration and new entrants will be attracted into the sector. Shortages are only likely to become problematic when labour market arrangements fail to deliver higher incomes and earnings to reflect such a situation.

Employment prospects are good

Employment prospects are good for science and engineering professionals. The Audit of Science, Engineering and Technology Skills found that an overall tight labour market and the strong growth in the resources sector, defence needs and infrastructure development had led to shortages and recruitment difficulties in respect of certain skills. In particular, employers were facing considerable difficulty in recruiting engineers and to a lesser extent in certain science fields, such as chemistry and earth sciences. In the finance sector, as in other industries, there were difficulties in recruiting individuals with high level mathematical and statistical skills (DEST 2006c).

Recruitment difficulties do not necessarily indicate a shortage. According to Wooden et al. (2004), having only a small field of applications for a position, implies that the market is close to a state of balance whereas having no applications indicates a shortage.

Nevertheless, in the case of engineers, these shortages or recruitment difficulties have been reflected in the rapid growth in salaries for both graduate and experienced engineers and identified by the Department of Employment and Workplace Relations (DEWR) in their compilation of the Migrant Occupations in Demand List (MODL) and the DEWR skills in demand list (DIMA 2006, DEWR 2006b). The occupations on the MODL and the DEWR skills in demand list are discussed below.

Unemployment rates for scientists and engineers are very low. For example, in 2004 unemployment rates for medical scientists, geologists, geophysicists, environmental scientists, agricultural scientists and chemists were around 2 per cent and for life scientists, metallurgists and physicists less than 2 per cent. For engineers, unemployment rates ranged from just over 2 per cent for chemical and industrial engineers to less than 1 per cent for mining engineers (Data provided by DEWR).

Graduates are an important source of new ideas and knowledge for innovating businesses. According to the ABS Innovation Survey (ABS 2006d), for innovating businesses, the most common method of acquiring new knowledge or abilities from the higher education sector was through the employment of graduates. Employment prospects are also good for graduates from most science and engineering disciplines. The graduate destination survey, which surveys bachelor degree graduates four months following graduation found that the proportion of graduates in full-time employment ranged from over 87 per cent for geology graduates, 85 per cent for mathematics graduates and nearly 84 per cent for chemistry graduates to 73 per cent for physics graduates (see table L.7).

For engineering, 100 per cent of mining engineering graduates and 95 per cent of civil engineering graduates were in full-time employment compared to 83 per cent of chemical engineering graduates (see table L.7).

Importantly, these surveys are conducted only four months following graduation and do not indicate whether or not the graduates are in employment related to their qualifications. Also, many science graduates undertake further study. The graduate destination survey indicated that apart from geology, science graduates are more likely to be involved in further full-time study than graduates from other courses.

Table L.7 **Bachelor degree graduates in full-time employment by field of education 2006[a]**

Field of education	*Percentage in full-time employment*
Sciences, mathematics and computer science	
Life sciences	74.2
Chemistry	83.7
Physics	73.3
Geology	87.7
Mathematics	85.7
Computer science	78.8
Economics	87.1
Engineering	
Aeronautical engineering	88.4
Chemical engineering	83.2
Civil engineering	95.4
Electrical engineering	92.0
Electronic and computer engineering	86.4
Mechanical engineering	89.9
Mining engineering	100.0
Other engineering	92.5
All graduates	**82.4**

a Based on a survey of 2005 graduates four months after graduation.

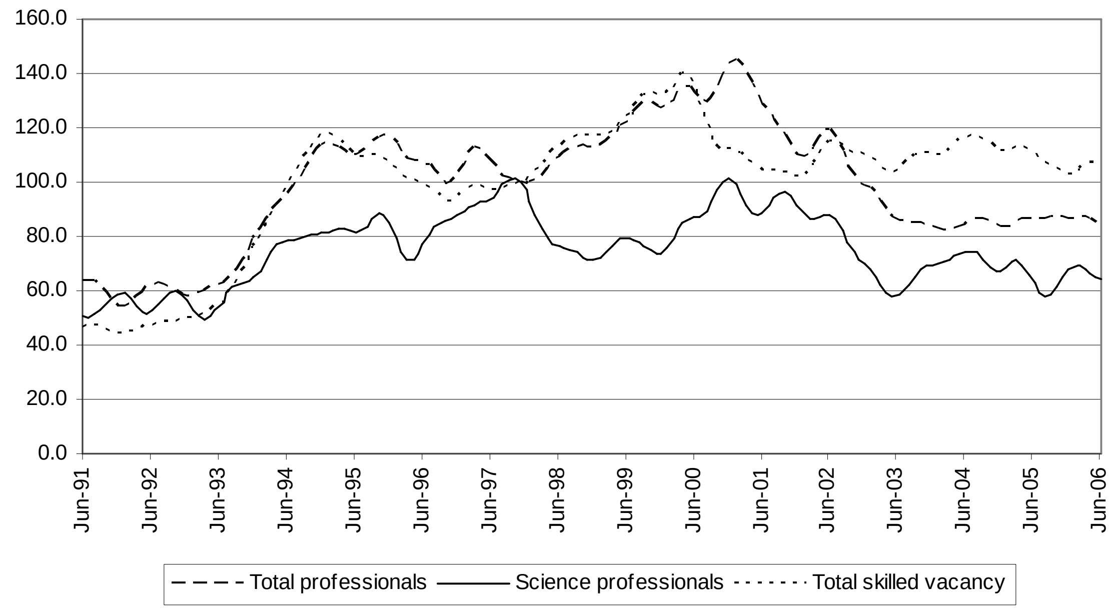
Source: Graduate Careers Australia (2006b).

Employment outcomes for science graduates improve over time. Surveys undertaken further out from graduation, such as the survey commissioned by the Australian Council of Deans of Science (ACDS) in 2001 which investigated the employment profiles of graduates three, five and ten years post initial graduation, provide a better indication of the longer term career paths of science graduates. The survey found that most graduates were employed in a science and related field (75 per cent) and over half of those surveyed had undertaken further formal study in either a science or non-science area.

In addition, up to 80 per cent of respondents indicated that their undergraduate science degree was directly or indirectly related to their current or most recent employment. According to the survey, those not employed in a science and related fields appeared to be employed in managerial and professional employment outside science and technology. The survey found that over time many science graduates move into professional and managerial positions to further their careers, so that by the seventh year since graduation the number of graduates in technical positions had declined. Similarly, the DEST (2006c) *Audit of Science, Engineering and Technology Skills* found that the proportion of those not working in their field increased over time post qualification.

Demand for science professionals generally reflects the demand for other professionals and skilled workers. The DEWR skilled vacancies index shows that vacancies for science professionals have generally followed the trend of overall skilled vacancies and vacancies for all professionals since 2000, although very recently there has been a slight downward trend in the vacancies for science professionals (see figure L.3).

Figure L.3 **Skilled vacancy index, June 1991 to June 2006**



Data source: DEWR (2006a).

A further indication of demand is the Migration Occupations in Demand List (MODL) which lists those occupations and specialisations identified by DEWR as being in ongoing national shortage. This list is updated twice a year to reflect ongoing and emerging shortages and enables the targeting of these skills via the Government's skilled migration program. In addition, the DEWR skills in demand list identifies skill shortages and recruitment difficulties by occupation on a State and Territory basis.

Civil, chemical, electrical, mechanical, mining and petroleum engineers and a number of computing professionals specialising in specific areas were on the MODL for September 2006. Nearly all engineering occupations were listed in at least one jurisdiction and civil, electrical, and mechanical engineers in nearly every jurisdiction in the DEWR skills in demand list (DIMA 2006, DEWR 2006b).

There were no science occupations on the MODL, although geologists were included on the DEWR skills in demand list. That list also identified shortages of mathematics and physics teachers in Victoria and recruitment difficulties in respect of science and mathematics teachers in nearly all other jurisdictions (DIMA 2006, DEWR 2006b).

The adequacy of the size of the workforce and the issue of shortages are discussed further in chapter 6.

M Does public support elicit additional R&D?

M.1 Introduction

A recurrent theme in this report is that public funding does not necessarily translate to new dollars of R&D — the issue of additionality (box M.1). This is critical to the issue of impacts since it is only R&D *induced by policy* that can potentially produce any economic, social or environmental impacts. To understand the nature of the issue, policy relevant impacts are:

$$\text{Policy Impact} = SUBSIDY \times (1 + v) + \Delta\, Privately\text{-}financed\ R\&D \times (1 + r) \qquad \{1\}$$

where *SUBSIDY* is total government support, Δ*Privately-financed R&D* is the change in the value of business-financed R&D as a result of government-financed R&D (negative if there is some crowding out and positive if there is some crowding in); and v and r are the average spillover rates of return respectively of the two forms of R&D.[1] These spillover rates could be the same as each other. But they could also be different from each other because governments may, on the one hand, target projects with a premium spillover rate of return or, on the other, have poor selection methods that result in projects of low social worth.

We can represent the change in privately-funded R&D as a constant fraction of supported R&D $\Delta\, Privately\text{-}financed\ R\&D = \alpha \times SUBSIDY$ and v as an excess return, $v = r + \rho$ where ρ is the premium rate of return. In that case:

$$\begin{aligned}\text{Policy Impact} &= SUBSIDY\ \{(1 + r)(1 + \alpha) + \rho\} \\ &= SUBSIDY\ \{(1 + r) \times additionality + \rho\}\end{aligned} \qquad \{2\}$$

[1] Private rates of return are ignored in this analysis, with the simplifying assumption that supported projects displace private investments (not necessarily R&D investments) that have the same marginal private rate of return.

Box M.1 **What does additionality mean?**

Additionality has been defined in several ways and can occur at several levels, which can sometimes be the source of semantic confusion.

At one level, additionality has been referred to the extent to which R&D *eligible* for at least partial public support is truly additional. For example, if businesses receive tax concessional treatment for R&D of around $6 billion, but only $400 million is actually elicited by the measure, then additionality is around 7 per cent. This was used by Lattimore (1996).

At a higher level, Streicher et al. (2004) refer to additionality as 'leverage', measured as the ratio of the change in privately-funded R&D to the subsidy level (α in {2} above). Leverage is positive if a subsidy induces complementary private R&D ('crowding in'), -1 if there is complete crowding out and between -1 and 0 if there is partial crowding out.

Probably the clearest definition of additionality is the ratio of total new R&D stimulated by a measure to its subsidy cost (as used by the CIE 2003b in its review of the Australian R&D Tax Concession). This is (1+α) in {3}. This is also referred to in the literature as the 'bang for a buck' (Lattimore 1996), and in some cases as the benefit-cost ratio (Hall and van Reenan 2000), though the latter term may be misleading since the ratio is not a conventional benefit-cost ratio. In the example of the tax concession above, the subsidy rate from the government's perspective is around 7.5 per cent,[2] so the extension of concessional treatment to $6 billion of R&D amounts to total support of around $450 million. If this support elicits $400 million of additional R&D, then the 'bang for a buck' is about 90 cents, or 'additionality' of 90 per cent. Crowding out in that case would be 10 cents in the dollar.

where:

$$Additionality = (1+\alpha) = \frac{(SUBSIDY + \Delta\, Privately\text{-}financed\ R\&D)}{SUBSIDY} = \frac{\text{net new R \& D undertaken by the firm}}{\text{SUBSIDY}} \qquad \{3\}$$

For generic business programs, such as the R&D Tax Concession, businesses, not government, choose the R&D projects, so that $\rho=0$. In that case, it is clear that, as

2 For the firm, the after-tax subsidy rate is probably the better measure. For a firm with no R&D tax concession, but immediate expensing, the after tax cost of undertaking R&D is, for every dollar of R&D, (1-τ*1.00) where τ is the corporate tax rate. (This ignores some of the complexities of the real tax system, such as treatment of physical capital used for R&D purposes). At τ=0.30, the after tax costs is therefore 1-0.3=0.7. If there is a tax concession of 125 percent, the cost is 1-0.3*1.25= 0.625. With the concession, the cost has therefore fallen by 10.7 per cent, which is the subsidy rate to the firm. The different subsidy rates for government and firms reflect the different bases on which they are calculated. The subsidy *amounts* are the same.

well as the spillover rate, the rate of additionality is the determinant of the policy impact. Were additionality to be zero (complete crowding out), then policy impacts would also be zero. The spillovers on supported R&D may exist, but since the R&D would have happened anyway, so would the spillovers, with no net policy impact.

For any additionality rate greater than zero, there are at least some policy impacts. Were additionality to be greater than one (supported R&D is then a complement to private sector R&D), then the policy impact arises not only because of the benefits directly associated with value of government spending, but also stimulates additional private sector spending.

It is important to distinguish three types of support when gauging the economy-wide responsiveness of R&D to government support of R&D:

1. Government generic support measures for business R&D that allow the businesses to choose the R&D projects and that work by lowering the after-tax cost of investments in R&D (such as the R&D Tax Concession).

2. Government business R&D grants that are capped and use merit-based selection of R&D projects (such as the *Commercial Ready* program).

3. Government-funded R&D in universities and public sector research agencies.[3]

M.2 The first mechanism — lowering the price of business R&D investments

The first alters the tax cost and, therefore the price of business R&D investments, and can therefore be expected to elicit a normal demand response to lowered prices. In that instance, the effects of subsidies acting through (1) can be inferred from firms' own price elasticity of demand for R&D,[4] as well as event studies and survey methods. Tax price elasticities refer to the same concept as the own price elasticity,

[3] A fourth category might be R&D funded by government, but contracted to private firms. This is more common in defence contracts, particularly in the United States. It is a relatively minor area of public spending in Australia and is not covered here, except where it is relevant to understanding the international literature.

[4] This is the proportional increase in R&D spending associated with a proportional decrease in the price of R&D inputs. If a 1 per cent decrease in the price of R&D inputs generates an additional 1 per cent in R&D, the elasticity would be unity. The additionality rate associated with a given elasticity depends on the nature of the tax system. This reflects the fact that, as noted earlier, the subsidy *rate* for government and firms are different because the bases are different. The firm responds to its reduction in its after tax effective cost of capital, not to the gross subsidy rate.

but assess the responsiveness of R&D to measures that work specifically through the tax system.

The results of international studies are not precise. Looking across the international literature, Griffith et al. (2004) concluded that own price elasticities of R&D were in the range of 0.3 to 2.0. Table M.1 summarises some of the elasticity measures based on recent reviews and other papers, which confirms the imprecision among different studies.

The ultimate effect is determined by long-run elasticities, which tend to be considerably higher than short-run elasticities. This reflects the fact that it takes firms time to gear up and adjust to the presence of subsidies. This is particularly relevant to assessing whether new government policies have impacts over the short run. For example, Bloom et al. (2001) use panel data to find that long-run price elasticities are around 1.1, compared with a short-run elasticity of only 0.16. The average of the (higher) elasticities in table M.1 suggests an average of just below one.

It is conceivable that some types of businesses are more or less responsive to subsidies than these estimates. For example, Parisi and Sembenelli (2001) used a censor panel-data regression model with random effects to a balanced panel of over 700 Italian firms over the 1992–1997 period incorporating a sizeable number of unlisted small and medium sized firms. The paper estimated an elasticity in the range of 1.5 to 1.77. In periods of recession it found evidence that the elasticity is greater (2.01) than in expansion (0.87).

Lattimore (1996) investigates the BIE's 1993 survey data and finds that firms with less than 20 employees had bangs for a buck around 50 percentage points higher than the average.[5] Firms with a limited R&D focus, on the other hand, had bangs for a buck about 30 percentage points lower than the average. This suggests that eligibility criteria for participation in programs can have a marked effect on additionality, and therefore their impacts.

The actual level of *new* R&D stimulated by subsidies per dollar of revenue lost — the additionality parameter in equation {2} above — depends on the design of R&D incentive mechanisms. Depending on the effectiveness with which they target marginal R&D investments, the use of incremental R&D incentives can considerably lower the cost to revenue for the same price effect of the subsidy (Russo 2004; Bloom at al. 2001, p. 4). As a consequence, for a given price elasticity of demand, the associated additionality can be much higher if more marginal investments are subsidised.

[5] At the 150 per cent concessional rate applying at the time.

Table M.1 **Studies of price elasticities and additionality rates**[a]

Country	*Additionality* Low	High	Mean	*Author*	*Elasticity*	*Source*
US	..	..	<1	Collins 1983	..	Hall & van Reenan
US	0.3	0.6	0.45	Mansfield 1986	0.35	Hall & van Reenan
US	..	..	1.74	Berger 1993	1-1.5	Hall & van Reenan
US	..	..	1.3	Bailey & Lawrence 1987,1992	0.75	Hall & van Reenan
US	..	..	2.00	Hall 1993	1.00-1.50	Hall & van Reenan
US	0.29	0.35	0.32	McHutchen 1993	0.28-10.7	Hall & van Reenan
US	1.3	2	1.65	Hines 1993	1.2-1.60	Hall & van Reenan
US	0.95	1	0.98	Nadiri & Mamuneas 1996	0.95-1.00	Hall & van Reenan
US	0.35	0.93	0.64	Cordes 1989	..	Sawyer
Canada	..	..	0.60	McFetridge & Warda 1983	0.60	Hall & van Reenan
Canada	0.38	0.67	0.53	Mansfield & Switzer 1985	0.04-0.18	Hall & van Reenan
Canada	0.83	1.73	1.28	Bernstein 1986	0.13	Hall & van Reenan
Canada	..	..	..	Bernstein 1998	0.14-0.30	Hall & van Reenan
Canada	..	..	0.98	Dagenais et al. 1998	0.40	Hall & van Reenan
Canada	..	..	1.38	Department of Finance Canada and Revenue Canada 1998	..	Sawyer
Sweden	0.3	0.4	0.35	Mansfield 1986	..	Hall & van Reenan
G7 & Australia	..	..	..	Bloom et al. 1999	0.16-1.10	Hall & van Reenan
France	..	..	..	Asmussen & Berriot 1993	0.26	Hall & van Reenan
France	..	..	3.16	Mulkay & Mairesse 2003	..	Sawyer
Italy	..	..	..	Parisi & Sembenelli 2001	1.50-1.77	Parisi & Sembenelli
Australia	0.6	1.0	0.8	BIE 1993	..	BIE
Australia	0.5	0.9	0.7	CIE 2003	..	CIE
Australia			2.64	BIE 1994[b]	..	BIE
Australia	1.7	1.8	1.75	Price Waterhouse & AIRG 1996[c]	..	Lattimore
Average[d]	**0.58**	**0.96**	**0.77/1.18**	**..**	**0.82**	**..**
Median[e]	**0.44**	**0.92**	**0.67/0.98**[f]		**0.68**	

[a] .. means not available. [b] Relates to tax loss trading provisions under the Syndicated R&D program and so is an unusual measure compared with standard tax-based measures. [c] This relates to the apparent bang for a buck from shifting the R&D Tax Concession from 125 per cent to 150 per cent. The survey was based on strategically chosen respondents, which might introduce bias. [d] The averages for the additionality rates ignores the Price Waterhouse/AIRG study, because of concerns about bias. The first figure of the average of the mean is over the same sample from which the high and low estimates are drawn, and the second over the full sample (still excluding the Price Waterhouse/AIRG study). The average shown for the price elasticity is of the high value (usually the long-run value), but excluding the extreme value of McHutchen. [e] The median value is the middle value. The samples selected for the calculations follow the same convention as in (d).

Sources: Hall and van Reenan (2000); Sawyer (2004); Parisi and Sembenelli (2001), BIE (1993); BIE (1994); CIE (2003b); Lattimore (1996).

For example, Bloom et al. (2001) find that standard R&D tax concessions that allow concessional treatment of every dollar of business R&D have additionality rates of 83 cents per dollar, which climbs to as high as $2.94 for some kinds of incremental R&D credits. This is the major motivation for re-balancing of the Australian R&D Tax Concession sought by the Commission (chapter 10).

The evidence on additionality rates for tax concessions — incremental and otherwise — reveals rates that vary significantly (table M.1). Measures of central tendency (the mean and the median) suggest that rates are probably between 70 cents and $1.20. Accordingly, for every dollar of revenue forgone by government, private R&D investment rises by between 70 cents and $1.20 — so that crowding out is between 30 cents in the dollar and minus 20 cents (crowding in). The Australian evidence on orthodox tax concessions to date (BIE 1993 and CIE 2003b) suggests rates more towards the lower end of this range, perhaps because of the continued importance of a non-incremental component of the tax concession.

A technical challenge affecting some of these studies is re-labelling of business costs. Firms face an incentive to re-categorise other business expenses as R&D to attract concessional treatment. For example, this was a problem in Australia in the mid-1990s, when pilot plants and feedstock that were essentially unrelated to R&D were sought as deductions under the tax concession. These loopholes were subsequently closed, but various studies that consider how R&D changes as the user costs alter with concessional tax treatment may be biased upward because of the presence of similar re-labelling phenomena.

An additional issue, raised by the IPA (sub. 30) is that of the marginal burden of taxation. Subsidies of any kind[6] must be financed through taxes. Those taxes impose distortions on private consumption, work and investment decisions, whose costs are implicit in the 'marginal excess burden' (MEB) of taxation. The IPA raised this burden as a curb on additionality. It could be conceived of in this way, or equally it could be accounted for as a separate cost — as we do in chapter 10 in cost-benefit analysis of business programs (and in the chapter 4 case studies). Either way, it provides a constraint on the impacts of publicly funded support for R&D that should not be omitted. There are various estimates of the cost — some very high. A recent review is provided by Robson (2005), who suggests an MEB rate somewhere between 20 and perhaps 30 cents for every dollar. In this report, we have assumed a cost of around 20 per cent of the magnitude of public funding for R&D. The implication of this is that when governments take one dollar of income from a taxpayer, they must earn *at least* 20 per cent on that dollar to make Australians even marginally better off.

[6] Including those that fund competitive grants or R&D undertaken directly by government and universities, as discussed in the next sections.

M.3 The second mechanism — competitive grants

An alternative business subsidisation measure (2) is based on merit-based assessment, usually by experts, of alternative business bids for grants. These grants usually stipulate a maximum grant per firm and overall finance for the grant program is also often capped. Subsidy rates are often much higher than generic tax concession or credit arrangements. In theory, such programs allow the potential to:

- select projects with higher spillover rates — to the extent that these can be judged ex ante; and
- to finance projects that would not otherwise have been undertaken. This can be accentuated for smaller firms facing finance constraints, since the grant can be big enough to act as a de facto form of independent finance. It may also have additional 'halo' effects in such instances, signalling to private financiers that the firm is competent, stimulating external finance for R&D.

But they also pose potential problems for additionality that stem from the way they are designed.

To understand the main potential problem with grants, it is useful to consider a situation in which they were uncapped and freely available (except that they required 50 per cent matching or some similar amount, as in *Commercial Ready*). In that case instance, grants would be like a generous tax concession, and would generate a bang for a buck determined by the price elasticity of demand. Of course, they would support many R&D investments that were going to proceed anyway. But at the margin they would always increase additional R&D by some amount because they would have lowered the price of R&D.

But they are not generally like this, and certainly not in Australia. Grant measures are usually capped and are awarded subject to the discretion of a committee. There is, therefore, no general price elasticity effect on the demand for R&D since any single firm's opportunities for accessing grants will often be limited by a scarce supply of projects that are likely to meet the eligibility conditions. The problem with this is that there need be no marginal effect as in the case when they are capped. This is because of the strategic incentives firms face and the profound information asymmetries that exist between firms and merit committees.

Firms would prefer to receive subsidies for non-marginal investments because these offer the highest private returns and can save shareholders' funds.[7] Consequently,

[7] Incentive compatible mechanisms that provide for contingent repayment of grants, as in Israel (Lach 2002), probably address this limitation because they reduce the risk of selection biases that are the threat to additionality.

firms have strategic incentives to put forward projects that they would have done otherwise. This may be a viable strategy for two reasons:

- the selection committees on panels providing grants cannot tell easily which projects are truly additional; and
- selectors may wish to choose firms that are likely to be commercially successful to avoid the impression that they are wasting public funds on very risky projects. They may then pick projects with the greatest private returns, which are those that are more likely to proceed anyway.

Accordingly, among possible applicants, those firms with non-marginal investments that otherwise appear to meet the eligibility criteria for a grant have the strongest interest in applying and good prospects of being selected, suggesting risks of selection biases that act against additionality (Lach 2002, p. 371; Klette et al. 2000; Wallsten, 2000).

On a more positive note, the size of grants is often high enough that they could sometimes realistically deal with financing constraints facing firms. This could elevate additionality rates above those predicted by looking only at investment price elasticities (small changes in prices may have little effect on demand for a financially-constrained firm, so elasticities appear lower than they would be were the firm unconstrained).

As a result, for competitive capped grant arrangements — and unlike general tax-based subsidies — levels of additionality cannot be inferred from the price elasticity of demand. The issue of additionality then must be determined empirically from studies of particular grant programs, since it could be very high or very poor, regardless of price elasticities.

Such studies need to take account of the presence of selection biases, although, as noted by Klette et al. (2000), many have not done so. More recent studies (box M.2) have usually applied methods that (attempt to) deal with this problem.

Box M.2 Recent studies of the effects of grants on private firms show crowding 'in'

Aerts and Czarnitzki (2004) found large crowding in effects in Belgium using a matching model that attempted to control for selection effects.

Ali-Yrkkö (2005) undertook a study of Finnish companies that also attempted to control for such biases, as well as usefully summarising the existing literature that also attempts to control for selection bias. Ali-Yrkkö found large additionality rates of around 2.0. This implies that if a government provides $1 of grant, the firm adds its own $1 so that the total firm R&D spending increases by $2. The effects were higher in big firms than small firms. Firms with financial constraints did not appear to have higher additionality than non-constrained firms.

Ebersberger (2005) also considered public funding of innovation in Finland, using the Community Innovation Survey. This thorough study used a variety of methods to control for selection biases and also tested whether the effects of public funds on the value (outputs) of private projects were high or low. The study suggested strong crowding in — though the effects varied depending on the model. However, unlike Ali-Yrkkö, this study finds that effects diminish with firm size. This study goes further than others and tests whether public funding has output additionality (valuable impacts) as well as input additionality. The results were positive, suggesting good value associated with the projects supported. The largest effects were associated with support of collaborative ventures.

Guellec and Van Pottelsberghe (2001) find additionality rates — of 1.70 — not much different from Ali-Yrkkö, but from a pooled study of 17 countries.

Streicher et al. (2004) also used a method that controlled for selection biases and found a somewhat smaller response of 1.40 Euros of R&D per 1 Euro of subsidy in a fixed effects panel study of Austrian firms. This study found additionality rates were higher for very small and large firms over intermediate sized businesses.

An evaluation of a German R&D subsidy program for innovative expenditure in the services sector that provided subsidies of up to 50 per cent of firms' expenditure found that a 1 DM of public subsidy produced DM 1.37 of R&D expenditure, which declined to DM 1.26 in the second year (Czarnitzki and Fier 2001).

A review (Lach 2002) of the effectiveness of an Israeli matching grant program at the firm level found that an extra dollar of subsidy generated extremely large long-run increases in R&D spending by small firms (though short- run negative effects), but had significant displacement effects on larger firms, which dominated the program. Overall, the effect was that an extra dollar of subsidy generated additional R&D spending of 1.23 cents (that is, crowding in of about 23 cents per dollar of subsidy).

Busom (1999) found in a Spanish study additionality rates of around 1.20 (that is, crowding in of privately financed R&D of 20 cents per dollar of subsidy).

Falk (2004) finds evidence of additionality in Austria, but small aggregate effects due to the small scale of the interventions compared with private activity. Some of the effects of programs could not be adequately assessed.

These studies above are typical of the general, but not universal, finding in the European literature that grants/loans and other direct government assistance to R&D

induce additional (complementary) R&D. The additionality of competitive grants is significantly better than that of R&D Tax measures, though the range of impacts is large without a clear reason for the differences.

This uncertainty grows if we move across the Atlantic. David, Hall and Toole (1999) and Streicher et al. (2004) observe that the European and Unites States literature are at odds. In reviewing the available firm level studies they find while European studies were more likely to find additionality rates of above unity (or some crowding in), US studies tended to find low additionality (significant crowding out). For example, Streicher et al. (2004) cite the study of Wallsten (2000) of the often praised Small Business Innovation Research (SBIR) program. This was found to have only resulted in 18 cents of new R&D per dollar of subsidy (that is, privately-*funded* R&D actually fell by 82 cents for every dollar of subsidy). The reason given for this is that the program gave support for commercially oriented R&D projects that were so inherently successful that they were likely to succeed anyway. David, Hall and Toole (1999) give a more comprehensive listing of US (and other) studies preceding 1999.

Fosfuri et al. (2006) has been one of the few studies to empirically assess when crowding out or in might occur. Using data from the Spanish Community Innovation Survey for 2000 and 2002, they found that in sectors where appropriability was high, public support policy was unable to stimulate additional private expenses in R&D. When legal protection was effective firms were found to use public support to partially substitute private funds, but not to undertake projects that would be unprofitable without the grant. This echoes Wallsten's results, warning against providing grants to R&D projects that have strong commercial prospects whose benefits can be principally retained by the firm. It is notable that in the Australian *Commercial Ready* program, applicants must demonstrate the strong commercial potential of their projects and normally that they will, if successful, own any IP resulting from the project. However, it is unclear whether this exposes this program to the problems that beset the US SBIR program.

The overall international evidence favours the view that, notwithstanding the risks for additionality posed by strategic incentives, they tend to have high additionality rates. These usually exceed tax measures. There is, however, an apparent gulf between US and European evidence. There is also a concern, not present in non-merit based programs, that selection biases may have affected the results. Most of the approaches taken to deal with these biases have been based on econometric methods that rely on assumptions that may not be warranted. Other methods for dealing with the biases, and why they might tell a different story, are discussed below.

The Australian evidence

In an Australian context, there have been several assessments of the additionality of competitive grants. Several studies are described in chapter 10 that suggest that many projects receiving grants would have still proceeded, but these studies did not report the bang for a buck. The Productivity Commission's review (PC 2003a, p. 5.29) of the Australian Pharmaceutical Industry Investment Program represents one of the few formal studies to control for selection bias in a competitive grant program. It found a high additionality rate between 1.25 to 3.65. The global nature of the industry and the program design is likely to have been instrumental in this high impact. The Productivity Commission (PC 2002a) also examined the Automotive Competitiveness and Investment Scheme (ACIS), which provided competitive grants to that industry alone. The Commission judged that the circumstances of the industry and the large nature of subsidy were likely to have led to some effects. However, no numerical estimates were made.

Allen Consulting (2000) reviewed the R&D Strategic Assistance for Research and Development (R&D Start) program. They based their assessment of additionality on survey questions posed to beneficiaries. This did not reveal a single additionality measure, but did suggest reasonable inducement:

- 3 per cent of firms said there had been no impact on new R&D;
- 8 per cent said the impact was low;
- 26 per cent said the impact was moderate;
- 42 per cent said the impact was high; and
- 20 per cent said the impact was very high.

However, direct questions posed to self-interested beneficiaries, without appropriate controls, are methodologically suspect.

Other evidence on additionality is circumstantial. The IR&D Board regularly publishes technical failure rates for its grant programs. In its 2005-06 annual report, the Board (2006) noted that of the 121 *R&D Start* projects completed in 2005-06 86 percent were considered to be technically successful (that is, with results being commercialised or expected to be commercialised in the near future) and four percent had technically failed. This was consistent with other projects over the life of the program. The report did not indicate outcomes for the other 10 per cent of projects. A four per cent failure rate appears very low, especially when defined in terms of commercialisation. Prima facie, such low risk projects could be expected to be more readily financed without public support than risky projects, raising questions about their additionality.

The most thorough investigation of a grant program (the now lasped R&D Start program) in an Australian context has been undertaken by the CIE (2003d,e). The broader issues posed by this study have been raised in chapter 10, but here it is worth spelling out in detail some of its findings for additionality as well as some of the key problems in estimating policy parameters precisely. The CIE took two broad approaches to additionality:

- One was based on subjective questions, backed by evidence about whether, given the private commercial returns of the subsidised projects, the assisted projects were really likely to have gone ahead without support.
- The second approach was to establish a control group of rejected applicants as to follow their R&D over time compared with those firms that received grants (the 'treatment' group).

The first suggested that about a third of the firms would have gone ahead with the projects without a subsidy. About 50 per cent of firms implied that they would not have gone ahead without the grant and the remaining 15 per cent did not answer on this issue. On average, recipients suggested that in the absence of funding the scope of their projects would have declined by about one third due to a lowered probability of success and delays to time of completion. On average, recipients indicated very high private returns, a proposition that is not consistent with high additionality unless there are severe capital market failures (CIE 2003e, p. xv–xvi). The CIE estimated additionality rates between 20 and 80 percent, assuming no capital market failures (which are lower than for the R&D Tax Concession).

The second approach — only reported in the initial report issued by the CIE (2003d) — suggested an additionality rate that was close to zero.

Both findings are damaging to any cost-benefit analysis of this grant program, but particularly the latter. However, in the final report the control group approach was rejected as invalid because two anonymous reviewers considered that it was flawed. This issue is centrally important because it highlights the difficulties in constructing such control groups that could be used in future Australian evaluations. It is also relevant to the Commission's assessment in chapter 10 of the *Commercial Ready* program and our interpretation of the CIE's evaluation(s).

Control groups present difficult challenges

When trying to assess the effects of a program on some 'treatment' group (the term used widely in program evaluations of all kinds, not just in the clinical field) there is an implicit or explicit counterfactual of what would have happened to the treatment group had no treatment been provided. The difference, if observable, is the effect of the treatment. This is the desired estimate of additionality. Of course, it is not possible to simultaneously observe the effect of the treatment on the treated (group A) and what would happen to them had they not received the treatment. Instead, the effect of a treatment on A is compared with the effect of no treatment on B, with B chosen to be as close as possible to A in their characteristics.

One of the biggest problems in evaluating business programs is choosing a group B that minimises selection bias. This can occur because of two distinct factors, firms *choose* to participate and selection committees *choose* the most 'beautiful' in terms of their merit criteria.

Selection bias type I

Firms that apply for a grant can be different in many ways from those that do not — applicants are different from the general population of firms. (Busom 1999 has shown this clearly for a sample of grant applicants in a Spanish context.) Some of the differences are observable, such as their size. But some of their differences are not easily observable, such as their forecasts for growth, likelihood of getting finance for new projects, the marginal returns on new projects, the drive of their management teams, and their attitudes to compliance costs or working with government.

Since firms anticipate that the grant selection committee will apply the eligibility and merit criteria set down by the program, this also substantially affects the nature of those that apply. Firms that fail the size or financial criteria will not generally apply. Applying firms also have to believe that they have a fair chance[8] of convincing the committee on the other, more subjective, criteria such as large project benefits and an inability to fund projects otherwise, regardless of whether, in fact, they genuinely do meet these criteria. It is this gulf between the appearance of compliance with these criteria and actual compliance that additionality tests aim to divulge.

When these hard-to-observe traits of applicants compared with non-applicants can affect the variable that the treatment is intending to affect then selection bias is present, and it is not possible to easily construct a control group matched to observables from the general population of firms.

[8] There would be few flippant applications because the compliance costs of applying for grants is relatively high.

Selection bias type II

The second strand of selection bias can sometimes arise from choices made by the committee, which eliminate some statutorily ineligible firms and then sort the remaining candidates on their apparent merit. Some applicant firms will be mistakenly rejected or accepted by any grant committee (that is, they inevitably will make errors, more so on some criteria than others). However, it can reasonably be assumed that, on average, successful and unsuccessful applicants differ from each other in some respects. These differences, may (or may not) be correlated with the additionality of the program. Accordingly, there is a second *potential* source of selection bias associated with committee choices.

Dealing with selection bias

There are a variety of approaches that are used to combat selection bias, some involving careful ex ante design of control groups, such as the use of identical twins in educational program designs, or the 'gold standard' — full experimental designs. The former is not viable in a business evaluation setting and the latter presents challenges for a fully rolled-out program. In the case of a grant program, such as *R&D Start* or *Commercial Ready*, such a randomisation approach would involve a two stage process. In the first, the grant agency would seek applications and then rank and select the best applicants. In the second stage, it would have a lucky dip among the best ranked group, assigning some firms a grant and refusing others. The refused firms would constitute a good control. However, every firm in the control group would still have to bear compliance costs, as would the grant giving body, increasing the costs of the program. Also it may not be appropriate to reject candidates of high merit. That could forgo a highly valuable technology as well as being problematic on political grounds. However, the gold standard approach may be applicable to pilot programs for which the demands for funds by ranked applicants significantly exceed the available resources.

In the case of the evaluation of *R&D Start* by the CIE such a randomisation approach was not, in any case, a feasible option. No experiment had been done by DITR. Once in an ex post setting, the only option was the creation of 'pseudo' control groups through econometric modelling and/or less ideal comparison groups. To do nothing on the basis of the limitations of such approaches would, in effect, relinquish the possibility of an evaluation at all.

CIE chose a control group based on those firms that applied for the grant, but that were rejected by the grant committee. The advantage of this control group is that these firms are more likely to have shared the general non-observable characteristics of the treatment group, which is the main source of bias in control-treatment comparisons of this kind (eliminating any selection bias type I).

The main disadvantage of this group is that they were rejected by the merit committee on various grounds, and the reasons for rejection may be correlated with their subsequent R&D performance (selection bias type II). One of the particular risks is that the criteria for eligibility indicate that the firm must show the need for funding. Clearly, if many of the control group firms were rejected on this basis *and* that the committee was, on average, able to discriminate on this issue — by no means an easy ask — then it would give a negative bias to the measure of additionality. On the other hand, the eligibility criteria also emphasise demonstrated commercial viability, the high quality of the R&D project, and the availability of own complementary business funding for the projects. This tends to suggest firms in the rejected group may often have had lower inherent capabilities for executing their R&D (biasing additionality estimates the other way). Given these offsetting risks, the problems with the control group results may be less adverse than initially considered by the reviewers of CIE's methodology.

The reviewers themselves argued that the control group was inadmissible on other, broader, grounds. One reviewer claimed that the appropriate control should be drawn from the target population that did not apply (group C) rather than rejected applicants (group B). It was claimed that biases would arise if B were different from C. That, taken literally, is not the right control group, since the goal is to assess treatment effects on the relevant population, not all members of the broader population from which the treated are drawn. For example, it would be misleading to assess the effect of a cancer drug on all people, rather than the people suffering the particular form of cancer.

The other reviewer also noted that the control should be drawn from the general population of firms, but only those that would meet the eligibility criteria, which is a reasonable restriction. However, they noted that this would be costly. If this strategy were literally adopted this is correct — it would involve firms putting in detailed applications and going through the same processes as the treated. Indeed it is hard to see such a method ever being realistically applied. Other than the pragmatic difficulty of this approach, it suffers from a conceptual limitation. The control group identified by this method could differ significantly from the treatment group in that they have not actually applied for a grant, and are therefore evidently different in some characteristics from applicants. For example, the commercial aggressiveness of the management teams of non-applicant, but eligible firms, may be lower (or higher) than the treatment group, something that may well affect their capacity for carrying through an R&D project.[9]

So the alternative controls suggested by the reviewers also have pragmatic and conceptual limitations. The Commission's overall view is that the reviewers may have been correct to question the validity of the control group, but not on the grounds claimed by them. However, it is difficult to establish completely valid control groups, unless a full experimental approach is adopted, which involves its own costs and pragmatic difficulties. So the question when assessing evidence from 'pseudo' control groups is how likely, given their nature, they are to be biased and in which direction. In the Commission's view, the results found using CIE's (2003e, p. 99) apparently 'failed' control group approach still constitute evidence of the potential for low additionality in Australia's premier business grant program.

Options for the future

There are several possibilities for future evaluations of competitive grants, loans or any innovation program that uses selection processes based on merit. Jaffe (2002) discusses several of the econometric approaches, but many have onerous data requirements and are, in any case, not necessarily robust. The gold standard of randomisation, while useful in social and educational programs, is probably not feasible for any business grant program that imposes significant compliance and administrative costs on firms and committees. An exception is pilot programs, where their use should be considered.

Two other options may be more attractive for future program evaluations:

- Use those firms that are rejected as a control group, but limit the group to those firms that were eligible but did not get a grant on the basis of their lower ranking compared with rival applicants. It would then be desirable to use their ranking as a further control for their differences with the treatment group. Jaffe (2002) describes this 'regression-discontinuity' approach and how to implement it.
- Alternatively, a model could use CIE's control group, but attempt to take into account the effect of the reason for rejection in modelling additionality and therefore to control for this independently. For instance, results for firms rejected on the basis of their likelihood of proceeding anyway would be compared statistically with those rejected on other grounds, as well as with the treatment group.

[9] There are econometric approaches for creating virtual control groups that are 'like' successful applicants, such as propensity scoring, though these can still fail to pick up differences in non-observables that influence the dependent variable.

Summing up the additionality of competitive grants

It is hard to characterise the varying results that have emerged from the literature evaluating additionality of direct R&D subsidy measures, such as grants and loans. The European evidence (the bulk of the international evidence) appears generally favourable to high additionality rates, but the actual magnitudes of rates are still variable. The US evidence is not as favourable. The variations probably reflect the variety of eligibility, selection and other administrative arrangements underpinning the various grant arrangements and the significant variations in the methodologies and scope of the evaluations that have been conducted to date.

As noted above in the case of the CIE evaluation, apparently small details in the methodology used to derive additionality estimates may matter significantly. These have been unearthed for that study, but are unknown for the others. It would be useful to understand the sources of the variety of additionality outcomes found in the international literature. Given the large value of subsidies provided around the world on grant programs, there would be potential value in a detailed collaborative exercise in evaluation among governments (or through the OECD) to learn from their various grant programs and to exploit their differences in understanding policy directions. For example, how does any restriction on firm size or R&D amounts affect outcomes? Do loan schemes have different results than outright grants and why? How do evaluation methods affect measured additionality rates? Do additionality rates vary with the failure rates of the projects and their appropriability conditions? Such a collaborative exercise may be able to pool the results of existing and prospective evaluations in a meta analysis, rather than represent a single large-scale evaluation.

A second lesson from the literature on competitive grants is how to properly construct control groups. The Commission suggests two approaches, described in greater detail above, that should be implemented in future evaluations of innovation programs that use merit selection committees.

In contrast to a general finding of crowding 'in' found in the bulk of international studies, the most rigorous and recent Australian evidence for the major grant program (*R&D Start*, now part of *Commercial Ready*) raises the risk that it may have low additionality rates (or significant crowding 'out'). That evidence suggests that the grants may actually attract firms that intend to undertake their R&D anyway. This has potentially significant implications for the design of *Commercial Ready* (chapter 10).

M.4 The third mechanism — publicly undertaken R&D

While public funding support offered through competitive grants and the R&D Tax Concession amount to some billions of dollars over any five year period, the total quantum provided to higher education and public sector research agencies is several times bigger. Accordingly, the most critical question regarding crowding out relates to funding of public R&D institutions.

There has been considerable concern that public support for R&D conducted outside business might crowd out business R&D, most strikingly argued by Kealey (1996, 1998) and the IPA (sub. 139). In principle, this could occur through several mechanisms, though in fact, it is not clear that either seems likely to hold in the long run in Australia. Many participants representing entities receiving public funds argued that crowding out did not occur and that indeed, sometimes public funding support for publicly conducted R&D may sometimes be complementary to private sector R&D (ARC sub. 73; AVCC sub. 60; Medical Research Institute sub. 41; and Research Australia sub. 33). Which story is true will depend on whether the circumstances for crowding out are likely and, ultimately, on what the evidence suggests.

The R&D type is substitutable

The type of R&D undertaken outside business might be relatively substitutable with that which might otherwise be undertaken by businesses. For example, PSRAs and universities may undertake R&D into mining or manufacturing technologies that are directly applicable to these sectors.

However, much of the R&D undertaken in higher education institutions and PSRAs in Australia is undertaken in basic research and non-commercial applied fields (such as environmental research) that have little immediate application to business-oriented problems. The former type of research activities can build up general capabilities for R&D in business and on *a priori* grounds could be expected to be complementary to private R&D activities.

Data from the ABS on spending by socio-economic objective substantiate the importance of non-business-oriented R&D activities for higher education (appendix G), revealing that only around 30 per cent of their activities are in market-oriented areas. It is considerably higher in PSRAs at about 54 per cent.

These estimates cannot, however, be used as reliable measures of crowding out since the fact that research has a potential use in markets does not mean that it would otherwise be undertaken in businesses. Research of this kind may:

- reflect the complementarities between specialist skills within these institutions and market applications. It could not be effectively undertaken in businesses lacking the complementary skills;
- be of the strategic basic kind that has *potential* future business uses, but is still too uncertain and far from commercial development to be undertaken within businesses; and
- be of the generic kind that can be cheaply imitated by many businesses and so suffers from standard appropriability problems for individual businesses (chapter 3). A significant share of agricultural research undertaken within CSIRO fits into this category.

Resource constraints

There are finite specialist resources — particularly talented scientists — available for R&D, so their use in one application may deny their use elsewhere. Where this resource constraint binds, additional public spending on R&D will tend to raise scientists' wages, rather than scientific activity per se. Any increase in wages of specialist R&D labour inputs raises the costs of business R&D investment since such labour inputs are the most important component of R&D. This prompts the conventional negative effects on investment. There is empirical evidence of the importance of this phenomenon overseas (Goolsbee 1998 for the United States and for some sectors, Marey 2002 in the Netherlands).

The phenomenon observed by Goolsbee should apply, regardless of whether the public funding is to public agencies or to private firms. Ebersberger (2005) finds evidence for Finland (and cites other evidence along these lines too) that in this context, there is no wage-mediated crowding out.

Moreover, some aspects of Australian circumstances should be distinguished from other countries, particularly the United States. First, Australian PSRAs and higher education institutions tend to employ those specialist labour inputs where labour constraints are least — scientists not engineers. It could be that part of the reason defence-related R&D spending by government has apparently bigger crowding out effects than other R&D spending (as discussed later) is that defence-related spending tends to use more engineering skills. Second, Australia is a small open economy that has, so far, been able to attract many professionals from overseas without having to offer large wage premia. The United States could not do the same because of its scale relative to global science and technology resources.

A more general observation is that resource constraints of this kind are much greater over the short-run than the long-run.[10] Long-run labour supply elasticities for specific occupations are higher than short-run ones, as students shift between subjects in response to future incomes and as net migration inflows increase.

In any case, even if there is ultimately some binding limit to the availability of scientific resources, the experiences of those other countries where scientists per capita ratios are much higher than Australia suggests that it has not been reached here yet.

The econometric evidence

The empirical evidence on this issue is incomplete. This is because, as noted by Guellec and van Pottelsberghe (2001, p. 5), most studies of crowding out have concentrated on (1) and (2): fiscal subsidies and government grants to, or contracts with business. Where studies have been more general than this, they have not distinguished public support given *to* business from publicly supported R&D undertaken within universities and PSRAs. For example, the definitive summary of the crowding out literature area so far is David, Hall and Toole (1999)[11], which considers the overall links between public spending and business spending. They undertook a survey of 33 empirical studies at different levels of aggregation undertaken since the early 1960s to evaluate the evidence of whether public R&D support as a whole was complementary or additional to private R&D spending or crowded it out. Their overall conclusion was equivocal:

> The findings overall are ambivalent and the existing literature as a whole is subject to the criticism that the nature of the 'experiment(s)' that the investigators envisage is not adequately specified.

This important study is an influential one. For example, it was cited by the IPA (sub. 30) and Davidson (2006) in drawing attention to the questionable impacts of government spending on R&D.

However, several observations should be made about the study, which are important for its interpretation:

- the presence of some crowding out was more prevalent for those studies carried out at the firm level than for those undertaken at the industry and higher levels of aggregation;

10 Though David and Hall (2000) posit some theoretical, rather subtle, mechanisms in which long run crowding out could be worse, due to dynamic quality effects, they do not seriously consider these a risk.

11 And complementary econometric meta analysis undertaken by Garcia-Quevedo (2003).

- some crowding out was a common feature of studies based on the United States, but an uncommon characteristic of others, a feature that could be ascribed to the peculiarly dominant influence of defence spending in the United States;
- quite different types of funding modalities and R&D types are categorised together making it harder to determine its relevance to the particular questions relating to spending within PSRAs and higher education institutions;
- crowding out is not interesting as a dichotomous variable. For example, were government spending of one dollar in a PSRA to reduce business funded R&D by 10 cents, then crowding out is said to be occurring. However, if the marginal excess burden of taxation is, say, 20 cents in the dollar, the spillover rate to achieve a net social benefit from spending in the PSRA is anything greater than 22.2 per cent (a relatively small rate).[12] In contrast, suppose that government spending of one dollar in a PSRA were to *increase* business spending by 10 cents (*complementarity*). In that instance, the spillover rate to achieve a net social benefit from spending in the PSRA is anything greater than 18 per cent — hardly much different from the outcome with some crowding out. So the lower the crowding out the better, but some crowding out per se is not that damaging to R&D policy.

Guellec and Van Pottelsberghe (2001)[13] present the results of econometric analysis that provides an explicit separation of crowding out effects by type of funding support. The study used a 3SLS panel data design based on a 17 country panel of OECD members. It controlled for business cycle, country and time dummies among other things.

The long-term results (table M.2) suggest that a 10 per cent increase in government funding through fiscal measures (B) reduces business own funded R&D by around 3 per cent.[14] Business grants (RG) have small complementarities. Every dollar of government R&D spending within government (GOVERD) crowds out 38 cents of business R&D spending (an economy-wide net bang for a buck of 62 cents) and support through higher education (HE) has neither complementary or crowding out effects (an economy-wide net bang for a buck of one dollar).

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[12] Calculated as spillover rate >= MEB/(Bang for a buck).

[13] Also summarised and interpreted in Van Pottelsberghe (2005).

[14] In the study by Guellec and Van Pottelsberghe (2001) — unlike those described above for fiscal measures — the bang for a buck cannot be directly inferred because the fiscal measure is the Warda B index.

Table M.2 **Long-run effect of government R&D spending on business funded and performed R&D**

By type of government spending, OECD countries[a]

Model and result	*λ*	*B*	*RG*	*GOVERD*	*HE*
Simple model					
Short run elasticity[b]	0.083	-0.281	0.072	-0.063	0
Long run elasticity[c]	nr	-0.306	0.079	-0.069	0
Marginal effect on RP[d]	nr	nc	0.70	-0.38	0
Economy-wide effect on R&D[e]	**nr**	**nc**	**1.70**	**0.62**	**1**
Defence effect adjustment					
Short run elasticity[b]	0.098	-0.29	0.07	0	0
Long run elasticity[c]	..	-0.32	0.076	0	0
Marginal effect on RP[d]	.	nc	0.67	0	0
Economy-wide effect on R&D[e]	**..**	**nc**	**1.67**	**1**	**1**

[a] The model estimated was:

$$\Delta RP_{it} = \lambda \Delta RP_{it-1} + \beta_1 \Delta VA_{it} + \beta_2 \Delta RG_{it} + \beta_3 \Delta B_{it} + \beta_4 \Delta GOV_{it} + \beta_5 \Delta HE_{it} + \tau_{it} + \mu_{it}$$

where RP is business-funded and performed R&D (that is, excludes the value of R&D funded by government but performed in the business sector), VA is business sector value added, RG is government grant funding of R&D implemented in business, B is the B-index (fiscal generosity for R&D), GOV is government intramural R&D expenditure, HE is higher education R&D outlays, τ are time dummies, μ is a residual, i denotes countries, t is years, β are short-term effects, [β/(1-λ)] are long-term effects and Δ is the 1st logarithmic difference operator. Variations in the specification took account of the role of defence-related R&D spending by government. All results are averages over time and countries. [b] The short run elasticity is the β value for the regression shown above or $B_X = (\partial RP/\partial X) \times (X/RP)$ for the Xth type of government spending on R&D. [c] The long run elasticity is calculated as β/(1–λ). [d] The marginal effect on business funded and conducted R&D of the Xth government funded form of R&D is $\rho_X = (\partial RP/\partial X) = \beta_X \times (RP/X)$. This is the *business* R&D bang for a buck of government spending. [e] The economy-wide effect is the sum of the subsidy value and the marginal effect on business, so it is (1+ ρ_X). nc means not calculated due to the unavailability of RP/X data. nr means not relevant.

Source: Guellec and Van Pottelsberghe (2001) and Commission calculations.

The finding for government's own R&D spending (GOVERD, but not HERD) would, if it were valid, seriously bring into question the impacts associated with that spending. However, as in previous analyses that have probed this question, Guellec and Van Pottelsberghe (2001) note that government spending on defence-related R&D (concentrated in three countries, the United States, France and the United Kingdom) distort the findings. If the adverse impacts of defence spending are accounted for, the crowding out effects associated with government own R&D spending disappear. Australia undertakes relatively little defence-related R&D so the defence-adjusted model appears more appropriate.

Ebersberger (2005) summarises some of the other studies at the aggregate level that have assessed crowding out effects of GOVERD and HERD, and generally these support either no crowding out or crowding in.

Some studies have also been undertaken on crowding out at a disaggregated level. For example, a recent industry-specific case in the canola industry in Canada revealed interesting complementarities and substitution effects by the type of R&D (Gray et al. 2006). The study found that private sector R&D by firms tended to crowd out that of other private firms, but that public expenditure on basic and applied tended to crowd in private expenditure.

Accordingly, the evidence for crowding out of private funded R&D by publicly funded *civilian* government and university research is weak. The conclusions drawn by the IPA and Kealey are not well founded. In the former case, they are drawn selectively from the literature on this issue and cite results that principally do not relate to GOVERD or HERD (as compared with public support of R&D more generally). The flaw in Kealey's (1996) empirical analysis is that the correlations presented are not the ones relevant for gauging the question, and can be consistent with no crowding out (box M.3). More sophisticated methods that focus on the relevant empirical issue, and that control for other variables generally find no evidence of crowding out.

M.5 Summary

When considering the question of additionality, it is important to distinguish three types of publicly supported R&D: that mediated through tax measures; competitive grants to businesses; and through spending in public research agencies and universities. In many discussions of the risks of crowding out, the three modalities are conflated, with the potential for misdiagnosis of the true effects.

The broad conclusions from this strand of work are that:

- tax measures for business R&D have been intensively analysed, though only recently has analysis attempted to empirically differentiate the degree of additionality associated with different designs of scheme. The evidence suggests that it is likely that every dollar of public support generates somewhat less than a dollar of new business R&D, though this may well rise above one dollar for well-designed incremental schemes;

Box M.3 **Is over-crowding out a risk?**

Kealey (1996) proposes three laws of scientific research that culminate in the claim that public support for R&D 'over crowds out' private R&D. That is, a dollar spent on R&D by government, decreases business R&D by more than one dollar. The primary evidence supporting over crowding out is a scatter plot and a bivariate regression that shows a positive relationship between the percentage of GDP spent on civil R&D and the ratio of private R&D (BERD) to government funded civil R&D ($R\&D^{pub}$). On face value, this suggests that countries with more 'nationalised' R&D industries discourage overall R&D spending. However, the problem with this statistical evidence is that the relationship could easily be true in circumstances where no crowding out actually occurs (and, accordingly, constitutes a weak empirical approach).

This is because the ratio of business to government funded R&D does not give reliable information about the degree of government involvement in R&D. By definition this ratio will be largely determined by the amount spent on business R&D (BERD), which is, in turn, strongly influenced by industrial structure and other factors independent from government (appendix C).

As an illustration of the problem, in the absence of any crowding out effect, apparent crowding out would be inferred by Kealey's method in the case where all countries shared the same $R\&D^{pub}$ to GDP ratio, but had a random distribution of BERD to GDP expenditures. It can be shown that, in the absence of crowding out effects, the sign of the cross-sectional relationship between total civil R&D to GDP and BERD to $R\&D^{pub}$ is dependent on the cross-country averages of these variables and the relative variances across countries in these variables. For existing empirical data, this will inevitably reveal a positive relationship using Kealey's suggested econometric specification, spuriously suggesting crowding out.

More direct measures of the relationship between BERD and $R\&D^{pub}$ are more likely to reveal the true risk of crowding out, ideally performed using panel data. The existing evidence that has used this more appropriate methodology has not found crowding out of BERD by government funded civil R&D.

- competitive grants could theoretically lead to high or low additionality rates. Less adequate designs risk lower additionality than tax concessions because they can elicit perverse strategic responses by firms. On the other hand, if firms are highly finance-constrained or merit committees can discriminate between marginal and inframarginal investments then additionality rates can be high. The bulk of international evidence (mainly of European origin) suggests that competitive grants to business have additionality rates above one dollar per dollar of revenue lost (that is they crowd 'in' private funding of R&D). The US evidence suggests much lower rates and the most rigorous Australian evidence to date also suggests this may apply to the lapsed *R&D Start* program. Given its re-badging as *Commercial Ready*, there is a risk that low additionality rates are present for that program.

- There appears to be little crowding out (or for that matter, consistent evidence of complementarities[15]) between government-funded R&D support for its own R&D activities in PSRAs and higher education institutions and business-performed and financed R&D.

[15] Complementarities may take many years to materialise, so their absence should not be regarded as definitive evidence against their existence. On the other hand, it is unlikely that long-run crowding out is greater than short-run crowding out, so the same bias is probably not present.

N Intellectual property system

Intellectual property (IP) consists of the ideas generated by the mind or intellect. Unlike normal property, the idea itself is intangible embodying the thoughts and knowledge created by a person.

IP rights confer ownership to the creator of the IP, akin to a farmer having ownership of his crop. They include patents, trade marks, copyright and designs. Each of these mechanisms gives exclusive, albeit limited, property rights over IP. As with any property rights, IP rights can be bought and sold in the market, their price reflecting the value of what is embodied in the property.

In making IP excludable, IP rights increase the incentives for businesses to invest in innovation and commercialisation. However, because IP rights confer an ability on holders to exclude others from making, using or selling the IP, there is a risk that they may be cast too restrictively so as to confer undue monopoly power. This could, for example, manifest in holders extracting excessive licensing royalties or placing unnecessary restrictions on knowledge dissemination with further knock on effects for the rest of the innovation system.

This appendix gives a brief snapshot of the current IP system in Australia — the institutional setting and legal environment within which IP rights operate and are administered. Two key facets of the IP system considered are:

- patents — a key form of IP rights; and
- domestic and international regulatory and support agencies.

Other IP-related issues dealt elsewhere in this report are the potential for IP rights to impede the operation of the innovation system (chapter 5), the management of IP in universities and public sector research agencies (chapter 7), and the use of patent data as indicators of innovation system performance (appendix J).

N.1 Patents

Patents give protection over 'any device, substance, method or process, which is new, inventive and useful' and are used by private firms and public research agencies alike (IP Australia 2007a).

Standard and innovation patents

There are standard and innovation patents (covered under the *Patents Act 1990*). The main points of difference between these two types of patents are the level of inventiveness needed to gain certification and the maximum level of protection. The innovation patent, replacing the petty patent from 2001, requires a lower level of inventiveness and is aimed at protecting innovations which are not greatly different from existing technologies, but still have a significant commercial value. In line with the lower inventive threshold, the innovation patent is cheaper to obtain, requires less certification testing and has a faster approval process. However, it is also shorter and gives a lower level of protection compared to the standard patent (table N.1).

Table N.1 **Standard versus innovation patents, as at 1 February 2007**

	Standard patent	*Innovation patent*
Maximum duration (years)	20	8
Application cost[a] ($)	770	440
Maintenance cost[b] ($)	7830	900
Inventiveness or innovativeness test	A new invention not obvious to an expert in that field	A substantial contribution to the working of an invention
Main industry users	Life science and ICT industries	Consumer goods, mining and transport industries

a All patent fees are to change from 1 March 2007. Assumes online application, no Australian intellectual property examination report (for standard patents) and no third party requests (for innovation patents). **b** Assumes fees paid for maximum life of patent. A standard patent can be extended past 20 years for $1200 per year.

Source: IP Australia (2007a).

Application process

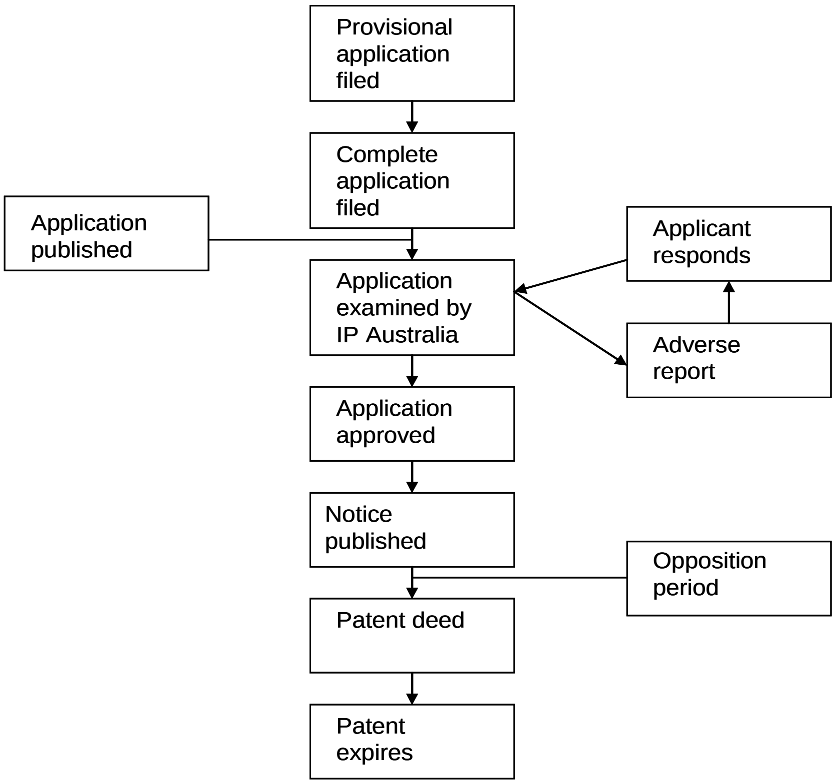
The basic process for attaining standard patent approval is shown in figure N.1. Upon issuance, patents are enforceable after grant[1]. The optional provisional application (which attracts an additional fee) gives the inventor a twelve month window to file the complete application. This application facilitates the granting of a priority date without fulfilling all the requirements of the complete application in the short term. The earlier priority date means that the information can be publicly disclosed sooner and still defendable for infringements. In addition to priority dates, Australia offers academics a 12 month grace period between disclosure of research and filing of patent application. This aims to address the problem, common to

1 Certain rights accrue from the priority date — the first date the patent application is filed. However, once the patent is granted, it can be enforced back to the publication of the patent application.

academia, of researchers disclosing information without knowledge of its potential. Annual patent fees are only payable from the fifth annniversary of filing the patent application (regardless of whether the application is accepted).

Applying for a patent is a complex process. As such, many creators of IP utilise advisory services, such as technology transfer offices or patent attorneys, to assist in the application process and, ultimately, give them a greater chance of attaining patent approval.

Figure N.1 **Standard patent approval process, Australia**



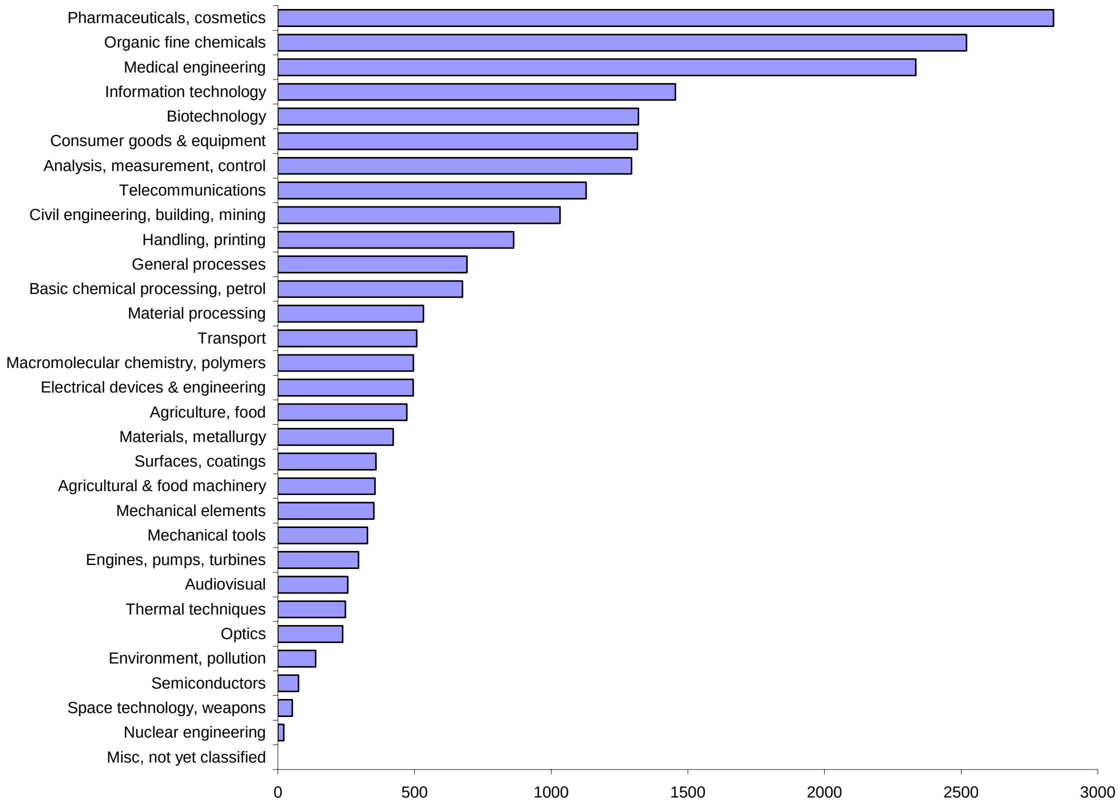
Source: IP Australia (2007a).

Patent usage

Industry usage of standard patents varies (figure N.2), with the pharmaceuticals and cosmetic industry having the highest number of standard patent applications and the nuclear engineering industry the lowest. This variation in industry usage reflects Australia's industry structure.

In the public research sector, universities are by far the largest users of IP (table N.2). This is mostly attributable to their dominance in public research.

Figure N.2 **Standard patent applications[a] by industry group, 2005**



a Patent applications consists of non PCT (Patent Cooperation Treaty) applications filed in Australia from domestic and foreign sources and PCT applications entering the national phase.

Data source: IP Australia (2007b).

Table N.2 **Standard patents issued for Australian publicly funded research, 2002**

	Universities	*CSIRO*	*CRCs*	*Medical research institutes*	*Other public sector research agencies*	*Total*
International patents[a]	123	148	26	15	7	319
Australian patents	72	27	35	9	3	146
Total	195	175	61	24	10	465
(%)	(41.9)	(37.6)	(13.1)	(5.2)	(2.2)	(100)

a Patents issued to domestic agency in other countries.

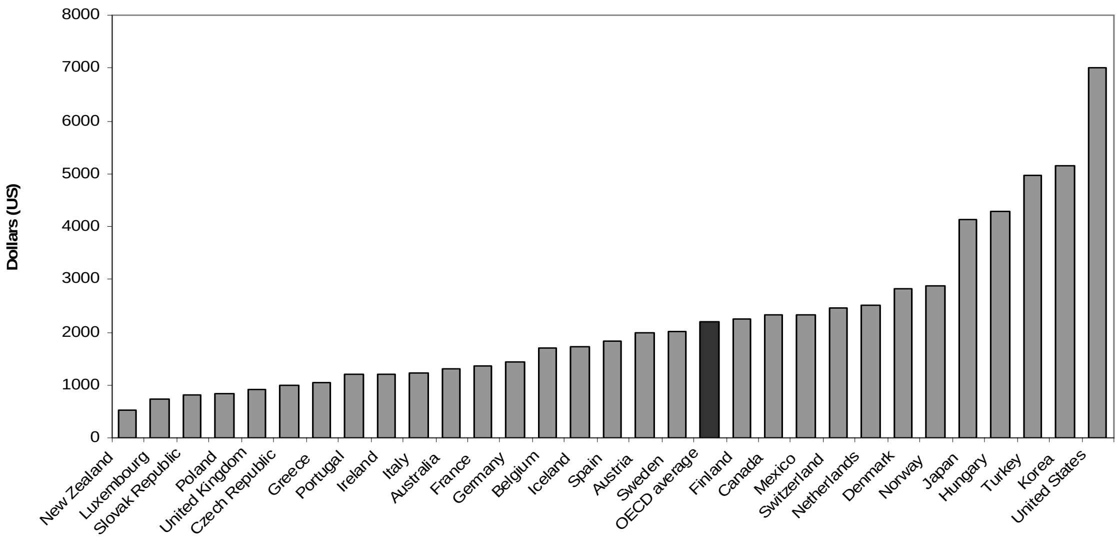
Source: DEST (2004d).

Patent application costs

As outlined in table N.1, there are certain costs associated with applying for a patent. These include both the official application fees and, quite often, patent attorney fees. Although fees vary greatly between countries, Australian fees, at $US1320 are below the OECD average of $US2200 (figure N.3). Patent attorney fees are estimated at between $5000 and $8000 per application, varying with complexity of the innovation (IP Australia 2007a).

Figure N.3 **Standard patent fees, OECD countries**

Fees[a] as at September 2005, patent grants for 2004



[a] Total fees, assuming annual fees paid for 8 years and using September 2005 exchange rate of 0.76

Data source: IP Australia, unpublished data.

The international patent system

A standard patent application only affords protection against competitors in the original country of application. Hence, IP rights must be applied for in every country the product is to be marketed for protection to be comprehensive. The main (and, often, most cost effective) avenue for gaining cross-jurisdictional protection is through the Patent Cooperation Treaty (PCT).

The PCT came into effect in 1978 and currently has 128 member states. Basically, the PCT gives innovators the option to patent in other countries where they believe there will be a market for their product. This option does not guarantee approval in each country, there being no such thing as an 'international patent'. Hence, the innovator must still pursue patent applications in individual jurisdictions separately.

So, while the complexity of multiple patent applications remains, the advantage of PCT applications is that they allow the innovator to obtain a priority date in each country that is a member of the PCT. The applicant is then able to perform additional market research to ascertain in which countries their product will be marketable and proceed with the normal patent application process in those countries (called the national phase). Given that patent applications are a costly process, the opportunity to conduct market research could result in significant long run cost savings. However, these costs savings must be weighed against the initial higher fee for PCT patent applications.

N.2 Institutions

The IP system is administered and supported by several domestic and international institutions.

Domestic institutions

There are a number of public and private institutions that implement and support the IP system. These generally fall into the categories, or are a combination, of regulatory, research, advisory or public or private sector support.

IP Australia

IP Australia is an independent agency of the Department of Industry, Tourism and Resources and is the central regulatory and administering body for IP in Australia. Its primary function is administering Australian IP.[2].Within this, and its other auxiliary roles, IP Australia processes IP claims, collects IP application and maintenance fees, maintains the Australian IP register, provides information, liaises with international bodies and undertakes policy research and analysis.

Technology transfer offices

The commercialisation and technology transfer offices of universities and public sector research agencies offer advisory services and expertise to the research community within these institutions. While the specific service charter may vary from office to office, they generally bridge 'the gap between basic research performance in universities and the development of new products and processes in

[2] Copyright and circuit layout rights are administered by the Attorney General's Department and plant breeders' rights are administered by IP Australia.

industry' (Uniquest 2006). Other aspects of their operation include liaising with business to sell patents, forming start up companies and encouraging business engagement of research services. These agencies are becoming increasingly common as commercialisation strategies are employed to ensure research output utilisation.

There are many examples of technology transfer offices in universities (table N.3). Over all technology transfer offices, there were 194 full-time equivalent staff, 462 patent applications filed and 225 licences executed in 2002 (DEST 2004d). The most notable of these is Uniquest, which oversees the IP portfolio of the University of Queensland and, recently also, the University of Wollongong (box N.1).

Table N.3 **Selection of university technology transfer offices**

Technology transfer office	*University*
Uniquest	University of Queensland
Melbourne Ventures	University of Melbourne
Research and Development Office	James Cook University
Flinders Technologies	Flinders University
Monash Commercial	Monash University
Access Macquarie	Macquarie University
ANU Enterprise	Australian National University

Box N.1 **Uniquest**

A subsidiary of the University of Queensland, Uniquest began operation in 1983, initially focusing on licensing of technologies to third parties. The operations of Uniquest expanded into the formation of start up companies and spin offs with the help of a $5 million investment from the University of Queensland in 1995. Uniquest now offers its services to the University of Wollongong. Uniquest's experience and size of operations has allowed it to fine tune the commercialisation process.

Uniquest's method of granting licenses to private industry involves three options:

- finding a suitable existing domestic company; or
- finding a suitable existing foreign company; or
- forming a new company

The company has been involved in the establishment of 54 start up companies (46 still active) and, in 2004, filed 34 patent applications, negotiated 28 licence deals and contracted 39 R&D projects. The company generated a net profit of $3.45 million.

Source: Uniquest (2004).

Other institutions

Other institutions playing a role in the IP system include the Advisory Council on Intellectual Property, the Intellectual Property Research (IPRIA) of Australia and, previously, the Intellectual Property and Competition Review Committee (IPCRC).

The Advisory Council on Intellectual Property and the IPRIA both undertake research on a wide range of topics in the field of IP.

- The Advisory Council is an independent body appointed by the Australian Government to advise the Minister for Industry, Tourism and Resources on intellectual property matters and the strategic administration of IP Australia. It has performed a number of reviews on certain aspects of the IP system, resulting in policy changes. For example, the replacement of the petty patent with the innovation patent was due to recommendations in the Advisory Council's report *Review of the Petty Patent System* (ACIP 1995).
- The IPRIA is a national centre for multi-disciplinary research on the law, economics and management of IP. It is based at the University of Melbourne and is run jointly by the Faculty of Law, the Faculty of Economics and Commerce, and the Melbourne Business School. It focuses on making contributions to the general understanding of the optimal settings for IP policy and how these interact with levels of innovation.

The IPCRC was established by the Australian Government to review the impact of IP policy on competition. The resulting report, *Review of Intellectual Property Legislation Under the Competition Principles Agreement* (IPCRC 2000), gave a raft of recommendations that have resulted in changes to IP and competition policy including, for example, repealing parallel importation bans.

Another agency involved in the IP system, is the Australian Institute of Commercialisation. Its role, however, is one of monitoring IP-related issues in relation to commercialisation.

International institutions

Two main bodies that assist in harmonising the interaction of individual countries are the World Intellectual Property Organization (WIPO) and the World Trade Organization (WTO).

WIPO

The WIPO is the primary, international IP body whose focus is the facilitation of IP rights that transcend national borders. It is one of 16 specialised units under the United Nations system. It administers 23 international treaties (including the PCT), that are applicable to its 183 member states. The Organisation originated from the bureaus established to administer the Paris and Berne Conventions. The former Convention, dating from 1883 was designed to protect industrial property (patents, trade marks and designs) over international borders. The latter Convention, established in 1886, performed the same task for copyright.

WTO

The protections afforded under international treaties (administered under the WIPO) became increasingly insufficient with increased international trade. Specifically, there was little incentive for nations importing technology and entertainment to adhere to international agreements, as in the absence of such constraints, they were able to access to cheap imitations. The main industries susceptible to such threats are those with little know-how required for reproduction, including pharmaceuticals and chemicals, publications, entertainment and certain technologies vulnerable to reverse engineering.

These factors considered, the WTO (then the General Agreement on Tariffs and Trade) introduced the Agreement on Trade Related Aspects of Intellectual Property (TRIPS) in 1994. The TRIPS Agreement extends the treaty-based protections of the WIPO, making IP laws stronger and with greater penalties for breaches. Specific changes enacted under the TRIPS Agreement include the extension of patent life to 20 years, extension of copyright protection to 50 years after the death of the author, 'compulsory licensing'[3] and enforcement provisions (for example, trade sanctions).

The main change affecting Australia was the extension of maximum patent life from 16 to 20 years. All other Australian IP laws met the minimum TRIPS standard. Because the TRIPS Agreement was introduced to mitigate IP infringements, it has mainly benefited developed countries, arguably at the expense of developing nations. This is most commonly highlighted using the example of restrictive access to patented pharmaceutical products in developing countries (for example, AIDS drugs in Africa). To address such problems compulsory licensing, least developed country exemptions and other flexibility provisions were included in the TRIPS Agreement.

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[3] 'Compulsory licences' are given out by the government in the event that the actual patent holder abuses their rights, for example by not supplying to the domestic market. Hence the licence is sold to a competitor, allowing it to produce the good under certain conditions.

O Research infrastructure expenditure

Table O.1 **Key research infrastructure, capital works and equipment programs, 2005-06[a]**

Program (administering agency)		*$m*
Australian Government		
Medical Research Infrastructure Projects (DHA)		215.0[b]
Research Infrastructure Block Grants (DEST)		199.9
Systemic Infrastructure Initiative (DEST)[c]		61.4
Capital Works for John Curtin School of Medical Research (DEST)		50.0
Major National Research Facilities Programme (DEST)[c]		42.3
National Competitive Grants – Linkage Infrastructure (Equipment and Facilities) (ARC)		35.8
Health and Medical Research — Overhead Infrastructure Support (DHA)		27.0
Independent Research Institutes Infrastructure Support Scheme (NHMRC)		21.9
National Collaborative Research Infrastructure Strategy (DEST)		13.2[d]
Equipment Grants (NHMRC)		8.6
Enabling Grants (NHMRC)		8.0
Building Information Technology Strengths — Advanced Networks Programme (DCITA)		7.0
Commonwealth Environment Research Facilities (DEH)		4.8
Capital Works for Medical Institutes (DHA)		2.0[b]
Special Facilities (NHMRC)		0.2
States[e]		
NSW	Infrastructure Grants Program[f]	15.6
	Capacity Building Infrastructure Grants Program[f]	3.0
	Other (health) infrastructure funding[f]	2.2
Vic	Health Futures: The Victorian Life Sciences Statement	68.0
	Science, Technology and Innovation Initiative — Infrastructure Grants Program	49.8
	Australian Synchrotron	40.6
	Operational Infrastructure Support for Medical Research Institutes	26.4
Qld	Smart State Research Facilities Fund[g]	23.7
	Queensland Brain Institute[h]	10.0
WA	WA Major Research Facility Program	5.1
	Centres of Excellence in Science and Innovation Program	8.8
	Medical and Health Research Infrastructure Fund	5.0
	New Independent Researcher Infrastructure Support	0.0[i]
	Other infrastructure funding	1.0
SA	Research Grant (health and medical projects)	6.0
	Premier's Science and Research Fund	3.0[j]
	Commercial Infrastructure Grant and Research Infrastructure Fund	0.6
Total		**965.9**

[a] This table does not cover expenditures by public sector research agencies and universities under block funding arrangements. [b] Nil expenditure is estimated for 2006-07. [c] This program will be replaced by the National Collaborative Research Infrastructure Strategy. [d] Budget estimate for 2006-07 is $98.2 million. [e] Spending on research infrastructure in Tasmania, the Northern Territory and the ACT is not significant. [f] From 2006-07, the Medical Research Support Program has replaced these programs. [g] This program has been replaced by the Innovation Building Fund which will allocate spending of $128 million over four years. [h] One-off expenditure. [i] Expenditure was $80 000. [j] Program funds both infrastructure and research.

Sources: Australian Government (2006a, 2006d); State Government personal communications.

P *Privacy Act 1988*

P.1 Introduction

The Australian Government's Privacy Act, first introduced in 1988, is intended to protect the personal information of individuals and give them greater control over how that information is collected, used and disclosed. It sets out privacy principles that Commonwealth and ACT public sector agencies, private sector organisations and individuals must observe in collecting, storing, using and disclosing personal information. It also gives individuals rights to access and correct their own personal information. The Act was extended to cover private sector organisations in 2001.

There are two sets of privacy principles in the Act. The *information privacy principles* cover the collection, storage and security, use, disclosure and access to 'personal information' held by Commonwealth and ACT public sector agencies. The *national privacy principles* set out how private sector organisations across Australia should collect, use and disclose personal information, maintain data quality, keep personal information secure, maintain openness, allow for access and correction of personal information, use identifiers, allow anonymity, conduct trans-border data flows and collect sensitive information. Private sector organisations include all health services holding 'health information' such as private hospitals and health practitioners.

P.2 Provisions applying to health information and medical research

As the Office of the Privacy Commissioner noted, there is a 'social interest' in enabling medical researchers to have access to health information in certain circumstances. Accordingly:

> … while health information is afforded extra protection, the Privacy Act recognises the desirability of medical research by providing mechanisms that allow health information to be collected, used and disclosed for medical purposes, including in some circumstances, without the consent of the individual. (sub. 63, p. 3)

Privacy principles

Allowing for variations in wording, the basic effect of the privacy principles in the Act is that, unless a limited range of circumstances applies, personal or health information cannot be collected, used or disclosed for the purpose of research without consent.

The information privacy principles do not permit public sector agencies to use or disclose in identifiable form records of personal information for research and statistical purposes, unless specifically authorised or required by another law, or the individual has consented to the use or disclosure.

The national privacy principles do not permit private sector organisations to use, disclose or collect information required for research (including compilation or analysis of statistics) relevant to public health or public safety, or the management, funding or monitoring of a health service, unless consent is impracticable and de-identification of information will not achieve the purpose of the activity.

Guidelines

In accordance with the Act, guidelines have been developed by the NHMRC, and approved by the Privacy Commissioner, to enable the use of personal or health information in the conduct of specific activities (including research of various types) without consent following an assessment by a human research ethics committee that the research and other activities are, on balance, substantially in the public interest and outweigh concerns about privacy protection (NHMRC 2000, 2001).

- Guidelines under section 95 (public sector agencies) address aspects of the collection, use and disclosure of health information in medical research.
- Guidelines under section 95A (private sector organisations) address research relevant to public health and public safety, compilation or analysis of statistics relevant to public health and public safety, and the management, funding or monitoring of a health service.

Compliance with the guidelines is reported annually to the NHMRC through its Australian Health Ethics Committee. In turn, the NHMRC reports this information to the Office of the Federal Privacy Commissioner.

P.3 Recent reviews

The Act has been subject to several reviews in recent years including by: the Senate Legal and Constitutional References Committee (SLCRC 2005) on, among other things, the overall effectiveness of the Act as a means by which to protect the privacy of Australians; the Office of the Privacy Commissioner (OPC 2005) on the private sector provisions; and by the Australian Law Reform Commission and the NHMRC's Australian Health Ethics Committee on the protection of human genetic information (ALRC and NHMRC 2003).

The main recommendation of both the Senate Legal and Constitutional References Committee and the Office of the Privacy Commissioner was a wider review of Australia's privacy laws. The Australian Government has already acted to address this recommendation by requiring the Australian Law Reform Commission to undertake a wide-ranging review of the Act into the extent to which it provides an effective framework for the protection of privacy (ALRC 2006). This review is expected to be completed in March 2008.

The three reviews' key recommendations relating to national consistency, health information and medical research are contained in table P.1.

Table P.1 **Key recommendations on national consistency, health information and research**

Review	*Recommendations*
OPC (2005)	**National consistency**
Rec. 3	The Australian Government should consider asking the Council of Australian Governments (COAG) to endorse national consistency in all privacy related legislation.
Rec. 4	The Australian Government should consider setting in place mechanisms to address inconsistencies that have come about, or will come about, as a result of exemptions in the Privacy Act … .
Rec. 5	The Australian Government should consider commissioning a systematic examination of both the [information privacy principles] and the [national privacy principles] with a view to developing a single set of principles that would apply to both Australian Government agencies and private sector organisations. … .
	Health consistency
Rec. 12	The Office urges the National Health Ministers' Council to finalise the National Health Privacy Code. This should include agreement by all jurisdictions on the contents of the code and on its consistent implementation in each jurisdiction.
Rec. 13	The Australian Government should consider adopting the National Health Privacy Codes as a schedule to the Privacy Act. This would recognise the Australian Government's part in the consistent enabling of the code. Should agreement not be reached by all jurisdictions about implementing the Code, the Australian Government should still consider adopting the code as a schedule to the Act to provide greater consistency of regulation for the handling of health information by Australian Government agencies and the private sector.

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Table P.1 **(continued)**

Review	*Recommendations*
Rec. 13	The Australian Government should consider adopting the National Health Privacy Codes as a schedule to the Privacy Act. This would recognise the Australian Government's part in the consistent enabling of the code. Should agreement not be reached by all jurisdictions about implementing the Code, the Australian Government should still consider adopting the code as a schedule to the Act to provide greater consistency of regulation for the handling of health information by Australian Government agencies and the private sector.
	Research
Rec. 60	As part of a broader inquiry into the Privacy Act, the Australian Government should consider: • How to achieve greater consistency in regulating research activities under the Privacy Act • Whether regulatory reform is needed to address the issue of de-identification in the context of research and the handling of health information • Where the balance lies between the public interest in comprehensive research that provides overall benefits to the community, and the public interest in protecting individuals' privacy (including individuals having choices about the use of their information for such research purposes) • Whether there is a need to amend [national privacy principle] 2 to permit the use and disclosure of personal information for research that does not involve health information • Undertaking further research and education work with the broader community to ensure that the balance between research and privacy accords with what the community expects and understands. The Office will work with the NHMRC to simplify the reporting process for human research ethics committees under the section 95A guidelines.
SLCRC (2005)	**Consistency**
Rec. 3	The committee recommends that the review by the ALRC, as proposed …, examines measures to reduce inconsistency across Commonwealth, state and territory laws relating to, or impacting upon, privacy.
Rec. 4	The committee recommends the development of a single set of privacy principles to replace both the national privacy principles and information privacy principles, in order to achieve consistency of privacy regulation between the private and public sectors. These principles could be developed as part of the review by the ALRC, as proposed …
	Health information and medical research
Rec. 18	The Committee recommends that the Australian Government, as part of a wider review of the Privacy Act, determine, with appropriate consultation and public debate, what is the appropriate balance between facilitating medical research for public benefit and individual privacy and the right of consent.
ALRC and NHMRC (2003)	**Information and health privacy law**
Rec. 7-1	As a matter of high priority, the Commonwealth, States and Territories should pursue the harmonisation of information and health privacy legislation as it relates to human genetic information. This would be achieved most effectively by developing nationally consistent rules for handling all health information.

Q Privacy legislation

The following table covers Australian Government as well as State and Territory legislation or, if that does not exist, administrative requirements directly governing the privacy of personal information. There are also privacy, confidentiality and secrecy provisions in other legislation — such as freedom of information legislation, telecommunications interception and spent convictions legislation — as well as privacy/confidentiality obligations under the common law and industry codes. These latter type of provisions are not included.

Jurisdiction	*Public sector - generally*	*Public sector - health*	*Private sector - generally*	*Private sector - health*
Commonwealth	Privacy Act (Cth)	Privacy Act (Cth)	Privacy Act (Cth)	Privacy Act (Cth)
New South Wales	*Privacy and Personal Information Protection Act 1998*	*Health Records and Information Privacy Act 2002*	Privacy Act (Cth)	*Privacy Act (Cth) Health Records Information Privacy Act 2002*
Victoria	*Information Privacy Act 2000* (except health information)	*Health Records Act 2001*	Privacy Act (Cth)	Privacy Act (Cth) *Health Records Act 2001*
Queensland	No privacy laws but Information Standards 2001, No. 42	No privacy laws but Information Standards 2001, No. 42A (Queensland Health)	Privacy Act (Cth)	Privacy Act (Cth)
South Australia	No privacy laws but Information Privacy Principles (reissued 1992)	No privacy laws but Information Privacy Principles (reissued 1992) and Code of Fair Information Practice	Privacy Act (Cth)	Privacy Act (Cth)
Western Australia	No privacy laws[a]	No privacy laws[a]	Privacy Act (Cth)	Privacy Act (Cth) Confidentiality of Health Information Committee

(Continued next page)

Jurisdiction	*Public sector - generally*	*Public sector - health*	*Private sector - generally*	*Private sector - health*
Tasmania	*Personal Information Protection Act 2004*	*Personal Information Protection Act 2004*	Privacy Act (Cth)	Privacy Act (Cth)
Northern Territory	*Information Act 2002*	*Information Act 2002* Health Information Privacy Code of Conduct	Privacy Act (Cth)	Privacy Act (Cth) Health Information Privacy Code of Conduct
Australian Capital Territory	Privacy Act (Cth)	*Health Records (Privacy and Access) Act 1997*	Privacy Act (Cth)	Privacy Act (Cth) *Health Records (Privacy and Access) Act 1997*

a Although there are no privacy-specific legislative or administrative arrangements in Western Australia, various privacy, confidentiality and secrecy provisions exist in the *Freedom of Information Act 1992*, *State Records Act 2000*, *Spent Convictions Act 1988* and other Acts.

Sources: ALRC (2006); OPC (2006); Thomson (2004).

R Business innovation determinants

This appendix analyses influences on product innovation, process innovation, non-technological innovation and the acquisition of advanced manufacturing technologies by Australian manufacturing businesses.

R.1 Background to the data

The data sources are the two ABS innovation surveys of manufacturing businesses covering the periods July 1991 to June 1994 and July 1994 to June 1997. The unit record data from these surveys were supplemented with basic sales, employment and capital stock unit record information from other ABS collections.

Table R.1 provides basic information on the datasets. Regressions were based on business units surveyed in both innovation surveys (the 'overlap' dataset). Businesses with fewer than 10 employees were excluded as only a small percentage of these businesses were included in both survey samples.

The overlap dataset consists of 1048 responding businesses with 10 or more employees of which 762 businesses self-identify as technological innovators (defined below).

Table R.1 **Datasets used in the analysis**

File	*Period*	*Number of responding businesses (all)*	*Number of responding businesses (10 or more employed)*	*Technological innovators (10 or more employed)*
1st Innovation Survey	1991-94	3 813	2 553	1 630
2nd Innovation Survey	1994-97	4 690	3 279	2 009
Overlap	1991-97	1 101	1 048	762

Source: Datasets constructed by the ABS for the Commission.

The overlap dataset is skewed towards larger businesses. The number of responding businesses included in both surveys as a percentage of all businesses that responded to each individual survey is substantially higher for larger firm sizes (column 3 of table R.2).

Table R.2 **Characteristics of responding businesses (RB) in the overlap dataset versus the full samples of the two innovation surveys**

Dataset	*Stratification*	*RB included in both surveys as % of all RB*	*Technological innovators as % of RB - full sample*	*Technological innovators as % of RB - overlap*
1993-94 - By employment	0 to 4	3.2	25.4	26.1
	5 to 9	4.7	29.8	26.9
	10 to 49	21.6	46.5	55.0
	50 to 99	39.7	62.7	62.5
	100 to 499	58.0	76.9	78.9
	500 or more	65.4	86.5	90.2
	Total	*29.2*	*51.8*	*71.7*
1996-97- By employment	0 to 4	2.7	21.4	12.5
	5 to 9	4.9	29.7	26.9
	10 to 49	13.1	47.7	52.0
	50 to 99	31.5	65.1	71.8
	100 to 499	52.4	72.3	74.3
	500 or more	65.7	89.2	90.9
	Total	*23.5*	*50.2*	*70.1*
1993-94 By sub-division[a]	21	39.3	56.9	70.8
	22	26.9	46.7	69.9
	23	26.8	30.0	50.7
	24	25.1	47.9	55.8
	25	43.6	69.1	81.1
	26	25.9	50.2	76.3
	27	27.9	50.9	75.3
	28	34.9	62.5	75.7
	29	12.0	39.7	68.9
1996-97 By sub-division[a]	21	36.4	61.0	71.3
	22	34.8	47.9	68.9
	23	14.0	32.9	55.7
	24	27.6	45.1	60.2
	25	25.2	64.6	78.6
	26	34.1	56.3	73.1
	27	20.9	47.1	71.1
	28	19.1	52.0	72.6
	29	15.8	34.2	60.0

a Manufacturing sub-divisions are: Food, Beverage & Tobacco (21); Textile, Clothing, Footwear & Leather (22); Wood & Paper Product (23); Printing, Publishing & Recorded Media (24); Petroleum, Coal, Chemical & Associated Product (25); Non-metallic Mineral Product (26); Metal Product (27); Machinery & Equipment (28); and Other Manufacturing (29).

Source: ABS unpublished data.

The percentage of firms defined as technological innovators in the overlap dataset is substantially higher than in either of the full 1993-94 or 1996-97 samples. The propensity to be a technological innovator is positively correlated with firm size. Comparison by employment size indicates that 70.1 per cent of businesses in the overlap dataset were technological innovators versus 50.2 per cent for the full 1996-97 sample. The proportion of businesses that are technological innovators in the overlap dataset is higher for each manufacturing sub-division.

The technological acquisition and innovation indexes

Influences on the innovation performance and technological acquisitions of Australian businesses during 1994-95 to 1996-97 were analysed using four indexes constructed from responses to the second innovation survey:

- an indicator of product innovation intensity;
- process innovation;
- the breadth or intensity of advanced manufacturing technologies 'in-use' (while seeking to hold firm size constant); and
- non-technological innovation.

A business was defined to be a technological product and/or process innovator (TPP innovator) if the business provided a 'yes' response to any one of questions 8, 9 or 10 (table R.3). The data were used to construct the innovation indexes IP2, I2A and I2C described in table R.4.

Detailed information on the use of advanced manufacturing technologies (AMTs) was collected. Businesses were asked to provide information on thirty technologies under five categories:

- design and engineering (for example, CAD/CAM and rapid tooling);
- fabrication, machining and assembly (for example, computer numeric controllers and robots);
- automated material handling;
- automated inspection and testing equipment; and
- communications and control (for example, LANs, and EDI).

Table R.3	**TPP innovation measures from the second innovation survey**		
Survey question		*Period*	*Data*
Q8	Did the business evaluate, develop or produce any *new* products that could be identified as potential, abandoned or implemented innovations?	1994-95 to 1996-97	Binary response = yes/no, for each of potential, abandoned and implemented
Q9	Did the business evaluate, develop or produce any *changed* products that could be identified as potential, abandoned or implemented innovations?	1994-95 to 1996-97	Binary response = yes/no, for each of potential, abandoned and implemented
Q10	Did the business evaluate, develop or produce any new or changed processes that could be identified as potential, abandoned or implemented innovations?	1994-95 to 1996-97	Binary response = yes/no, for each of potential, abandoned and implemented

Source: ABS 'Innovation in Industry' manufacturing survey forms (1993-94 and 1996-97).

For each technology, businesses were asked to indicate whether the technology was 'in use', 'being installed', and/or 'planned to be installed within two years'. The index is a simple sum of the number of AMTs 'in-use' (TI2). A high index score indicates that a firm uses a greater number of different types of technologies. It is intended that the index provide an indicator of the 'vintage' of a firm's capital stock. The non-technological innovation index (NT2) is based on whether the business restructured or reorganised its physical layout, management structure or workgroups.

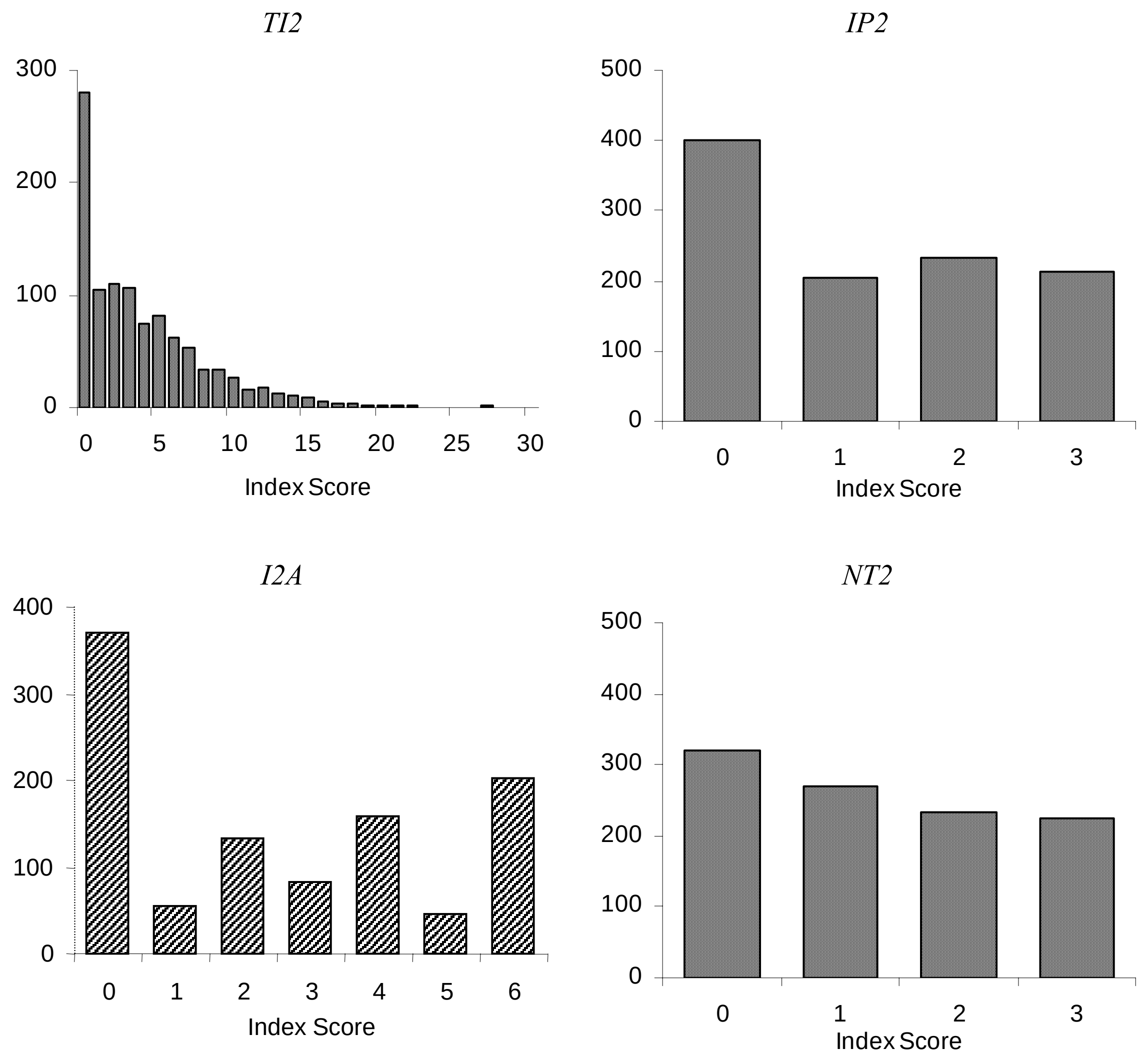
Table R.4 **Definition of dependent variables**

Description		*Data – survey question*	*Range*
Incidence of 'in use' advanced manufacturing technologies	TI2	Q61: index = 1 point for each technology 'in use'. Technology groups included are: design and engineering (CAD/CAM, rapid tooling, etc.); fabrication, machining and assembly (Computer numeric controllers, robots etc.); automated material handling; automated inspection and testing equipment; and communications and control (LANs, EDI,etc).	(0 – 30)
Process innovation	IP2	Q10: no process innovations (= 0), then 1 point for each of potential, abandoned and/or implemented process innovations	(0 – 3)
New and changed product innovations	I2A	Count of Q8_1 to Q9_3 including potential, abandoned and implemented new and changed products	(0 – 6)
Implemented product innovations	I2C	Q8 and Q9: no implemented product innovations (= 0), implemented changed product (= 1), implemented new product (= 2), implemented changed and new product (= 3)	(0 - 3)
Non-technological innovation	NT2	Q12: 1 point for each of restructured or reorganised physical layout, management structure or workgroups	(0 – 3)

The number of firms with ten or more employees in each category is shown for the TI2, IP2, I2A and NT2 indexes in figure R.1. Each distribution sums to 1048 firms.

Figure R.1 **Frequency distributions for the innovation indexes**

Number of firms with ten or more employees



Data sources: ABS unpublished data; Commission estimates.

Explanatory variables

The surveys collected a large range of business characteristics information that could be used to investigate influences on decisions to acquire AMTs, and the TPP and non-technological innovation performance of businesses. 'Performance' refers to the firm's ordering or ranking on the index and not the efficiency with which it achieves innovations.

Table R.5 provides background information on the explanatory variables used in the regressions under the following headings[1]:

- opportunities to innovate;
- incentives to innovate;
- domestic linkages;
- international linkages;
- strategic and identification, organisational and learning capabilities; and
- resources to innovate and other firm characteristics.

R.2 Estimation strategy

The models were estimated as ordered probit models with the five indexes on the left-hand-side of the regressions. The ordered probit model takes the general form $y^* = \beta' x + \varepsilon$, where y^* is unobserved, x is a vector of explanatory variables, β represents the corresponding vector of coefficients to be estimated, and ε represents unobservable factors.

The mapping from y^* to y is captured by a non-linear function. For a model with five response categories, Y is observed as follows:

$y = 0$ if $y^* < \tau 1$ or

$y = 1$ if $\tau 1 \le y^* < \tau 2$ or

$y = 2$ if $\tau 2 \le y^* < \tau 3$ or

$y = 3$ if $\tau 3 \le y^* < \tau 4$ or

$y = 4$ if $y^* \ge \tau 4$.

[1] There are a number of groupings that could be employed to help organise the large quantity of innovation survey data. Cabagnols and Le Bas (2002) use six lines of inquiry: characteristics of a firm's demand (price elasticity, level, evolution and homogeneity); conditions for appropriation of innovation benefits; sources of technological knowledge; market structures (concentration level, intensity of technological competition); characteristics of the firm (size, market share, diversification level); and firm strategy (towards quality, marketing and so on).

Table R.5 **Definition of the explanatory variables**

'IS1' denotes the data are from the first innovation survey

Description	*Mnemonic*	*Data – survey question*	*Unit/ range*
Opportunities to innovate			
Technological opportunities	tech_opp	Q8 - Q10: proportion of firms identified as technological product and/or process innovators by 2-digit ANZSIC	Per cent
Incentives to innovate			
Presence of dominant businesses	conc	Q18: potential market dominated by established businesses as reason for not starting innovation projects ('n.a.'/'not important' = 0 and 'crucial' = 2)	(0 – 2)
Market power	mkt_pwr	Q5: if ind_conc = 0, then mkt_pwr = 0. Q6: Whether the business is one of the dominant players. If Q6 = 'Yes', then mkt_pwr = 2, otherwise mkt_pwr = 1	(0 – 2)
Domestic linkages			
Knowledge and abilities acquisition methods utilised	know_acq	Q31: count of knowledge acquisition methods utilised (for example, obtained rights of invention from other businesses, contracted out R&D, take-over of another business, and used consultants)	(0 – 11)
Methods used to transfer or sell knowledge and abilities	tech_trf	Q32: count of knowledge transfer methods utilised (for example, transferred skill staff within business, offered invention rights to other businesses, performed R&D for others)	(0 – 11)
Current period acquisition of external technologies	acq_int2	Q50 expenditure on acquisition of external technologies (patents, trademarks and licences) as a per cent of total sales during 1996-97	Per cent
Prior-period acquisition of external technologies	acq_int1	IS1 Q24: expenditure on acquisition of external technologies as per cent of total sales during 1993-94	Per cent
International linkages			
Degree of foreign ownership	foreign	Q4: per cent of foreign ownership in company equity	Per cent
Export intensity of the firm	exp_int	Q7: per cent of the firm's product that entered export markets	Per cent

(continued on next page)

Table R.5 **(continued)**

Description	*Mnemonic*	*Data – survey question*	*Unit/ range*
Strategic, identification capabilities			
Importance of organisational and production flexibility to firm strategy	stg_flex	Q62: importance of flexibility in new product development and production as a reason for acquiring AMTs (‘n.a.’ or ‘not important’ = 0 and ’crucial’ = 4)	(0 – 3)
Time/quality based strategy	time_stg	Q25: strategy in undertaking business innovative activity - importance of improving the quality or speed of service (‘n.a.’ = 0 and ‘crucial’ = 3)	(0 – 3)
Customer focus at the forefront of strategy	cust_fcs	Q25: importance of increasing ability to be responsive to customers	(0 – 3)
Strategic integration with suppliers: importance of suppliers as source of ideas and information for innovation projects	supp_ing	Q36 – count of suppliers of raw materials, components or parts and equipment as a source of ideas and information for initial idea, throughout the project and technical information or advice)	(0 – 8)
Strategy of total quality control - feedback, evaluation and revision	qltyctrl	Q26 – count of regularly revised and evaluated customer requirements, customer satisfaction, supplier agreements, business practices, business strategy, business culture and other	(0 – 6)
Organisational capabilities			
Cross-unit information and knowledge flows: degree of organisational and systems integration	ideas_i	Q36: count of internal sources of ideas and information used in innovation projects for initial idea, throughout the project and technical information or advice	(0 – 14)
Learning capabilities			
R&D intensity	r&d_int2	Q50: R&D expenditure as a percentage of total sales during 1996-97	Per cent
Prior-period R&D intensity	r&d_int1	IS1 Q24: R&D expenditure as a percentage of total sales during 1993-94	Per cent
Experience - years established	age_firm	Q1: number of years the firm has been established	Integer
Experience in present range of activities	age_mkt	Q2: number of years the firm has been undertaking its present range of activities	Integer
Resources to innovate and other firm characteristics			
Insufficient retained earnings as barrier to starting innovation projects	r_e	Q18: importance of insufficient retained earnings for firms that had innovative activity that did not proceed beyond the evaluation or feasibility stage (‘n.a.’=0, ‘not important’=1, ‘important’=2, ‘crucial’=3)	(0 – 3)
Control for size of firm	size_emp	Number (’000) employed	Integer

where τ_1 to τ_4 represent various thresholds that, along with the regression coefficients β_i, are estimated from the data. The intuition is that whenever the actual *y* is above the threshold value τ4, then *y* will be ranked in the highest value of the index, and so on.

Under the assumption that *y* is normally distributed, it is possible to compute the probabilities with which, for a given set of characteristics, the firm will report the observed *y* in each of the above categories.

$$prob[y=0] = \Phi(\tau 1 - \beta`x)$$

$$prob[y=1] = \Phi(\tau 1 - \beta`x) - \Phi(- \beta`x)$$

$$prob[y=2] = \Phi(\tau 2 - \beta`x) - \Phi(\tau 1 - \beta`x)$$

$$prob[y=3] = \Phi(\tau 3 - \beta`x) - \Phi(\tau 2 - \beta`x)$$

$$prob[y=4] = 1 - \Phi(\tau 4 - \beta`x)$$

where Φ is the cumulative distribution function for the standard normal distribution.

The regression coefficients and values of the explanatory variables can be used to compute marginal effects. The marginal effect is often computed to give an interpretation like, 'A one unit increase in the variable x is associated with a z per cent change in the probability of observing the firm in the top category of the index'.

The marginal effects in this appendix are calculated differently. The marginal effect from equation (1) is the expected number of response categories shifted by a one unit increase in an explanatory variable.

$$\frac{\partial E(y_i)}{\partial x_i} = -\sum_{j=1}^{J-1} \frac{\partial F_\varepsilon(\tau_j - S)}{\partial x_i}$$

$$= \beta_i \times \sum_{j=1}^{J-1} f_\varepsilon(\tau_j - S) \qquad (1)$$

where y_i is the marginal effect of explanatory variable x_i, f_ε is the standard normal distribution used in the probit model, j is the number of cut or threshold points, $S = \sum S_i$, and $S_i = \bar{x}_i \beta_i$ which is the product of the mean of each explanatory variable x_i and its estimated regression coefficient β_i.

R.3 Regression results

Regression results in table R.6 are based on the overlap dataset with marginal effects calculated as per equation (1) (the regression coefficient estimates are provided in table R.8). Non-innovators are excluded from the regressions as the surveys were structured to 'skip' non-innovators past many of the business characteristics questions. This means that the results below should be interpreted as applying to businesses who self-identify as technological innovators, and not the broader population of businesses, or the propensity to innovate.[2]

After controlling for the effect of the size of the business (size_emp) and whether the business is in a low or high innovating industry, the main results were:

- the number of methods used to acquire knowledge and abilities, which could help the business undertake innovative activity, is positive and highly significant in all models;
  - for product innovations (I2A), a one unit increase in the knowledge acquisition index is associated with a probability of being observed 0.2 response categories higher on the index;
- R&D intensity is positively associated with both product innovation and the acquisition of AMTs, but not process or non-technological innovation. Prior-period intensity appears to drive the results, which, at least for product innovation, could be consistent with a gestation lag of two to three years:
  - for product innovations (I2A), a one unit increase in R&D intensity (for example, an increase from 0.5 per cent of sales to 1.5 per cent of sales) is associated with a probability of being observed 0.07 units higher on the index;
- businesses with higher AMT scores also tended to have higher process innovation and non-technological innovation scores, providing evidence of a positive relationship between embodied technological knowledge and the organisation of economic activity;

[2] The models were not specified with a 2-stage selection equation, which is sometimes used when analysing innovation survey data to support inferences about the broader population of firms when analysis is based on a sub-set of firms (see Crepon et al. (1998), Mairesse and Mohnen (2004), Therrien and Chang (2003), or, for an Australian application, Brunker and Salma (2006)). This issue of scope can arise for two related reasons: innovation surveys usually collect a reduced information set for non-innovators; and multiple equation models are utilised to, in part, address the possible 'simultaneity of R&D'. This can result in a sample of firms being used in some part of the model that is not randomly drawn from the larger population of firms.

Table R.6 **Average change in response categories [a]**

Evaluated at sample means. Probability > Chi2 in brackets.

Model:	*TI2*	*IP2*	*I2A*	*I2C*	*NT2*
TI2		0.029 ***			0.043 ***
		(0.006)			(0.001)
tech_opp	7.385 ***	0.196	6.400 ***	2.455 ***	-0.847
	(0.003)	(0.757)	(0.001)	(0.000)	(0.176)
size_emp	1.067 ***	0.231 ***	0.556 ***	0.241 ***	0.105 *
	(0.001)	(0.001)	(0.001)	(0.004)	(0.077)
conc	-0.297	-0.061	0.187 *	0.119 **	0.023
	(0.172)	(0.284)	(0.086)	(0.050)	(0.685)
mkt_pwr	0.311 **	0.009	0.022	0.039	-0.007
	(0.038)	(0.820)	(0.770)	(0.327)	(0.849)
know_acq	0.209 ***	0.100 ***	0.202 ***	0.072 ***	0.043 **
	(0.003)	(0.001)	(0.001)	(0.001)	(0.016)
tech_trf	0.312 ***				0.062 ***
	(0.001)				(0.010)
acq_int2	0.000				
	(0.297)				
acq_int1	0.196				
	(0.263)				
foreign	0.760 ***				0.029
	(0.001)				(0.487)
coop_ovr	0.149				
	(0.529)				
exp_int		0.002	-0.005	-0.005 ***	
		(0.195)	(0.108)	(0.005)	
r&d_int2	0.000	0.000	0.000	0.000	
	(0.882)	(0.431)	(0.159)	(0.103)	
r&d_int1	0.113 **	-0.005	0.071 ***	0.050 ***	
	(0.015)	(0.716)	(0.009)	(0.007)	
age_firm	0.025 ***	-0.001	0.008 **	0.002	
	(0.001)	(0.598)	(0.023)	(0.292)	
age_mkt	-0.021 ***	0.001	-0.005	-0.001	
	(0.009)	(0.593)	(0.179)	(0.722)	
r_e		-0.013	0.112	0.018	
		(0.745)	(0.132)	(0.658)	
stg_flex	0.473 ***	0.001			
	(0.001)	(0.971)			
time_stg	0.933 ***	0.030			
	(0.001)	(0.452)			
ideas_i	0.085 ***				
	(0.007)				
cust_fcs			0.181 *	0.100 *	
			(0.065)	(0.060)	
time_stg				0.000	
				(0.998)	
supp_ing				0.059 ***	
				(0.007)	
qltyctrl					0.118 ***
					(0.001)

(Continued on next page)

Table R.6 **(continued)**

Model:	*TI2*	*IP2*	*I2A*	*I2C*	*NT2*
Test statistics					
Response levels	23	4	7	4	4
Observations	594	741	741	741	741
AIC	2875	1896	2563	1444	1940
SC	3046	1975	2646	1523	1995
-2LogL	2797	1862	2527	1410	1916
R-Square	0.400	0.149	0.194	0.145	0.167
Max rescaled R-Square	0.402	0.160	0.199	0.166	0.178

* denotes significance greater than 10 per cent. ** significance greater than 5 per cent. *** significance greater than 1 per cent. [a] Marginal effects as per equation 1.

Source: Commission estimates based on unpublished ABS data.

- retained earnings as a barrier to starting innovation projects was not significant in predicting technological (product or process) or non-technological innovation:
  - insufficient retained earnings also did not explain technological innovation performance on models based on the full second innovation survey, suggesting that the bias towards larger firms in the overlap dataset is not driving the result;
  - however, as noted above, the results should be interpreted as applying to firms self-identifying as TPP innovators and not the broader population of firms. It is possible that 'insufficient retained earnings' may be a more significant barrier to starting innovation projects for those firms classified as non-innovators;
- the importance of flexibility and time-based strategies, and higher degrees of foreign ownership, were strongly positively associated with the acquisition of AMTs; and
- differences in export intensity did not predict rankings on the ordered AMT index or the innovation indexes.

A range of other explanatory variables were tested in the models under various specifications and were not significant (table R.7).

The model results have several policy implications for this study. First, they substantiate the point emphasised in chapter 1 that it is important not to see R&D intensities as an indicator for all types of innovation. Second, the results suggest that R&D is just one way of absorbing external knowledge and that acquisition of advanced technologies also appears to be important (appendix D). Third, it is at least suggestive that finance barriers to R&D investment, and the constraints on investment imposed by insufficient retained earnings highlighted by some formal models and empirical work, may be less binding than thought (chapter 3). Finally, domestically-oriented firms do not appear to be intrinsically less innovative (after accounting for other factors) than those with an export orientation, weakening the commonly-stated view that export-oriented firms should be special targets for innovation policy.

Table R.7 **Explanatory variables that were insignificant**

All indicators based on questions from the second innovation survey

Description	*Mnemonic*	*Data – survey question*	*Unit/range*
Operating environment			
Degree of regulatory uncertainty in the firm's environment	reg_unc	Q18: importance of government standards and regulations for not starting innovation projects	(0 – 3)
Domestic linkages			
Horizontal technological collaboration	coop_dom	Variety of cooperative innovative activities with domestic partners. If Q37 = 'No', then coop_dom = 0, otherwise coop_dom = sum of variety of domestic arrangements from Q38	(0 – 8)
Variety of external sources of ideas and information	Ideas_e	Q36: count of domestic external sources, excluding suppliers and technologies as this information is used separately. 1 point for each source for initial idea, throughout the project and technical information or advice	(0 – 81)
Technology markets	tech_mkt	Q36: Patents, licenses and technical know-how as important sources of ideas and information used in innovation projects	(0 – 2)
International linkages			
Overseas parent company	ovrs_par	Q36: overseas parent company as an important source of ideas and information used in innovation projects (initial idea, throughout the project, technical information or advice)	(0 – 3)
International horizontal technological collaboration	coop_ovr	Variety of cooperative innovative activities with overseas partners. If Q37 = 'No', then coop_ovrs = 0, otherwise coop_ovrs = sum of variety of overseas arrangements from Q38	(0 – 8)
Overseas innovation expenditure	ie_ovrs	Q51: proportion of total innovation expenditure undertaken overseas	Per cent

(continued on next page)

Table R.7 **(continued)**

Description	*Mnemonic*	*Data – survey question*	*Unit/range*
Organisational capabilities			
Degree of devolution of innovation project decision making	hierarch	Q27: for new projects and for ongoing projects. Hierarchy = 1 (parent company, company board, managing director)	(0 – 1)
Cross-unit information and knowledge flows: degree of organisational and systems integration	ideas_i	Q36: index of internal sources as important sources of ideas and information with sources being management, production staff, technical staff, R&D staff and marketing staff. Source is for initial idea, throughout the project and technical information or advice (a higher index value indicates greater importance)	(0 – 15)
Learning ability			
Intensity of formal training activities	train_int	Q50: expenditure on training and further education as a percentage of total sales	Per cent
Intensity of other innovation expenditures	oi_int	Q50: innovation expenditure as a percentage of total sales less R&D and training and further education expenditures	Per cent
Resources to innovate and other firm characteristics			
Lack of appropriate sources of finance	finance	Q18: importance of appropriate sources of finance as barrier to starting innovation projects (not applicable = 0 and crucial = 4)	(0 – 3)
Non-linear firm size effect	$size\_emp^2$	Square of number of employed	Integer

Table R.8 **Regression coefficients, Pri > Chi^2 in brackets** [a]

Model:	*TI2*	*IP2*	*I2A*	*I2C*	*NT2*
TI2		0.032 (0.006)			0.048 (0.001)
tech_opp	2.258 (0.003)	0.220 (0.757)	3.661 (0.001)	3.019 (0.000)	0.948 (0.176)
size_emp	0.326 (0.001)	0.259 (0.001)	0.318 (0.001)	0.297 (0.004)	0.118 (0.077)
conc	-0.091 (0.172)	-0.069 (0.284)	0.107 (0.086)	0.147 (0.050)	0.025 (0.685)
mkt_pwr	0.095 (0.038)	0.010 (0.820)	0.012 (0.770)	0.049 (0.327)	-0.008 (0.849)
know_acq	0.064 (0.003)	0.111 (0.001)	0.115 (0.001)	0.089 (0.001)	0.048 (0.016)
tech_trf	0.096 (0.001)				0.069 (0.010)
acq_int2	0.000 (0.297)				
acq_int1	0.060 (0.263)				
foreign	0.232 (0.001)				0.032 (0.487)
coop_ovr	0.046 (0.529)				
exp_int		0.002 (0.195)	-0.003 (0.108)	-0.006 (0.005)	
r&d_int2	0.000 (0.882)	0.000 (0.431)	0.000 (0.159)	0.000 (0.103)	
r&d_int1	0.034 (0.015)	-0.005 (0.716)	0.041 (0.009)	0.061 (0.007)	
age_firm	0.008 (0.001)	-0.001 (0.598)	0.005 (0.023)	0.003 (0.292)	
age_mkt	-0.006 (0.009)	0.001 (0.593)	-0.003 (0.179)	-0.001 (0.722)	
r_e		-0.014 (0.745)	0.064 (0.132)	0.022 (0.658)	
stg_flex	0.145 (0.001)	0.002 (0.971)			
time_stg	0.285 (0.001)	0.033 (0.452)			
ideas_i	0.026 (0.007)				
cust_fcs			0.104 (0.065)	0.123 (0.060)	
time_stg				0.000 (0.998)	
supp_ing				0.073 (0.007)	
qltyctrl					0.132 (0.001)

S R&D expenditure by State and Territory

This appendix examines R&D expenditure on a State and Territory basis and its focus by jurisdiction, highlighting some of the similarities and differences underpinning this. It then provides a snapshot of the scientific publications output by State and Territory.

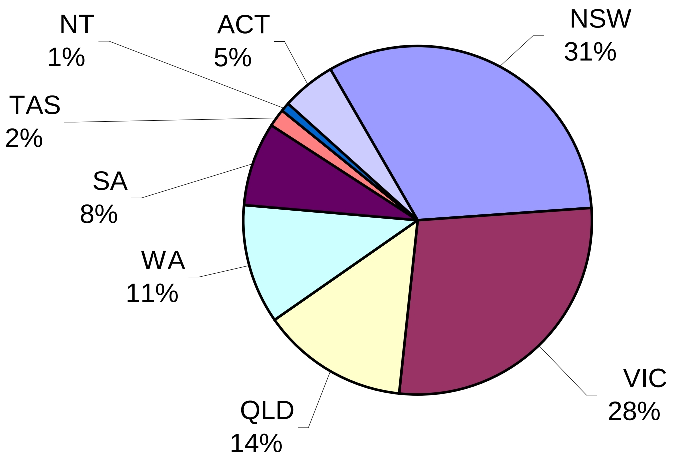
To date, extensive work has not been undertaken regarding Australia's involvement in R&D on a State and Territory basis. However, this is an area where further work could usefully be undertaken given the important role States and Territories play in relation to science and innovation, the increasing number of State and Territory Government programs in this area and the interest in differences across Australian jurisdictions.

Indeed, a number of State and Territory Governments in their submissions on the draft report called for further examination of the innovation system as a whole and not just the impact of publicly supported science and innovation — which is the focus of this study (Victorian Government sub. DR211 and Tasmanian Department of Economic Development sub. DR 181).

S.1 Level of R&D expenditure

The differences across the States and Territories in terms of Australia's gross expenditure on R&D (GERD) reflects differences in the size and structure of their economies and population, industry composition, natural endowments, research infrastructure and their research strengths in particular areas. As expected, R&D expenditure is concentrated in New South Wales and Victoria, with these jurisdictions accounting for around 60 per cent of all R&D expenditure in 2004-5 (see figure S.1).

Figure S.1 **Share of GERD by State and Territory, 2004-05**



Data source: Data derived from ABS (2006c).

However, the picture changes after adjusting for population size and the size of the economy. On a per capita basis, R&D expenditure in the ACT significantly exceeded all other jurisdictions, whereas New South Wales was towards the middle and Queensland had the lowest per capita expenditure (see table S.1).

After adjusting for the size of each State and Territory's economy — by using expenditure on R&D as a percentage of its gross state product (GSP) — there were three distinct groupings, apart from the ACT which was significantly above the other jurisdictions. At the top was South Australia and Victoria then Western Australia, Tasmania and New South Wales followed by and Queensland and the Northern Territory (see table S.1).

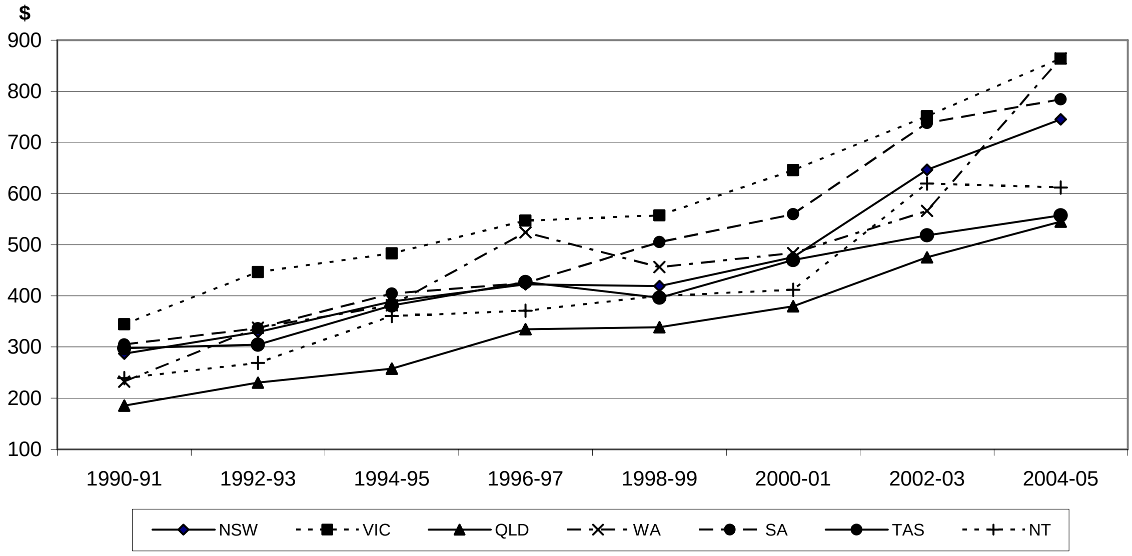
Table S.1 **Expenditure on R&D by State and Territory, 2004-05**

State and Territory	*Per capita*	*State and Territory*	*As a percentage of GSP*
ACT	$2 388	ACT	4.20
WA	$864	SA	2.03
Vic	$863	Vic	1.95
SA	$784	WA	1.69
NSW	$745	Tas	1.68
NT	$611	NSW	1.65
Tas	$557	Qld	1.34
Qld	$544	NT	1.16

Source: Data derived from ABS (2006c).

Over time, excluding the ACT, per capita R&D spending has remained fairly constant (see figure S.2). The most significant increase in per capita R&D expenditure in the 15 years to 2004-05 occurred in Western Australia.

Figure S.2 **Per capita R&D spending by State and Territory, 1990-91 to 2004-05**[a]



a Excludes ACT.

Data source: Data derived from ABS (2006c).

In regard to changes in R&D spending as a share of GSP over time, some jurisdictions such as Tasmania remained fairly static between 1990-91 and 2004-05 whereas other jurisdictions such as New South Wales and Tasmania increased over the period.

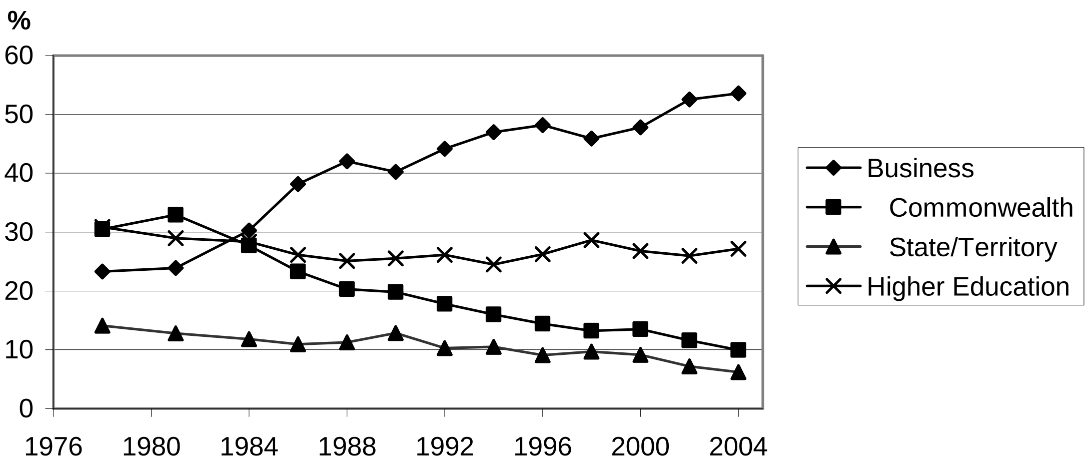
Government R&D expenditure (GOVERD) by State and Territory

Although the Australian Government spends considerably more than the State and Territory Governments on R&D, its level of expenditure has been declining relative to State and Territory Government expenditure, which has remained fairly constant over time.

The Australian Government's expenditure on R&D declined from 0.28 per cent of GDP in 1978-79 to 0.18 per cent in 2004-05, whereas State and Territory Government's expenditure as a share of GDP changed only slightly over this period from 0.13 per cent to 0.11 per cent of GDP (ABS 2006c).

The decline in Australian Government expenditure is reflected in the declining total government share of R&D spending over the last three decades (see figure S.3).

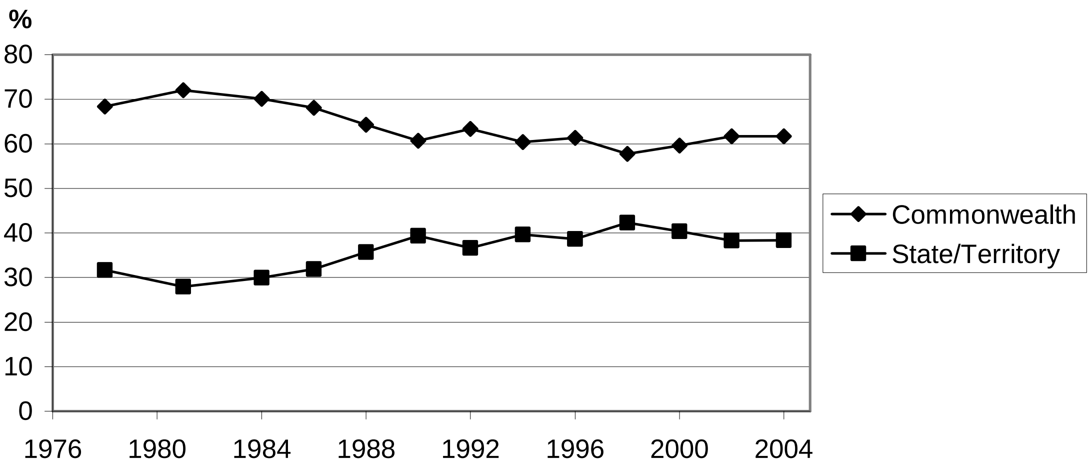
Figure S.3 **Share of GERD by sector, 1978-79 to 2004-05**



Data source: ABS (2006c).

Consequently, the share of State and Territory Government R&D expenditure of total government spending has been increasing. Of the total government expenditure on R&D (GOVERD) of just over $2.5 billion in 2004-05, State and Territory Governments accounted for 38 per cent and the Australian Government 62 per cent compared to 32 per cent and 68 per cent respectively in 1978-79 (see figure S.4).

Figure S.4 **Shares of GOVERD, 1978-79 to 2004-05**

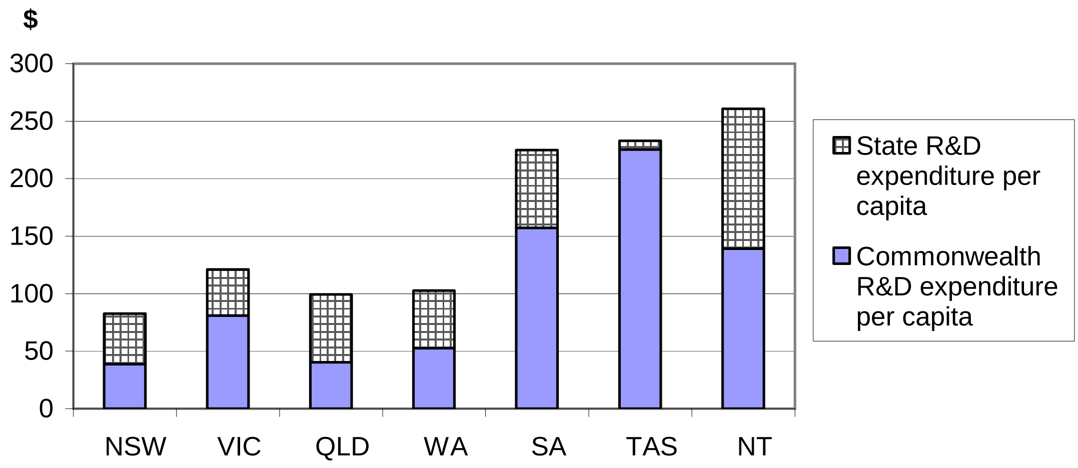


Data source: ABS (2006c).

The level of concentration in government R&D expenditure has also been declining. For example, between 1978-79 and 2004-05, New South Wales and Victoria's share of total government expenditure declined from 57 to 46 per cent and their share of Australian Government expenditure from 59 to 42 per cent (ABS 2006c).

On a per capita basis, Australian Government spending, apart from the ACT, is focused on Tasmania, the Northern Territory and South Australia with the other jurisdictions receiving considerably less (see figure S.5).

Figure S.5 **GOVERD per capita by State and Territory, 2004-05**



[a] Does not include the ACT.

Data source: Data derived from ABS (2006c).

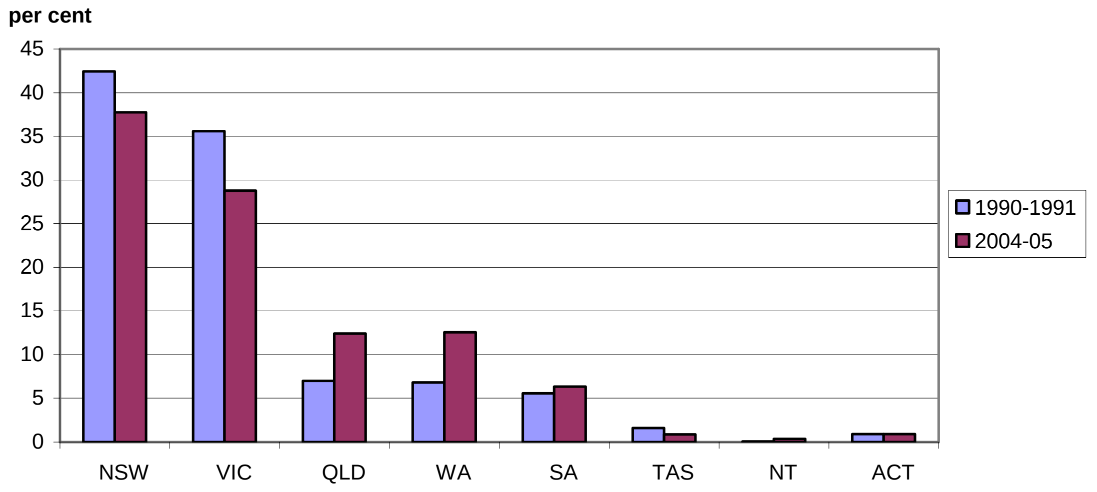
In contrast, there was little variability in State and Territory Government R&D expenditure on a per capita basis across most jurisdictions in 2004-05 apart from the Northern Territory Government which spent more than the other jurisdictions and Tasmania which spent considerably less (see figure S.5).

Business expenditure on R&D (BERD) by State and Territory

The most significant aspect of business expenditure on R&D has been the growth in Queensland and Western Australia's share and the decline in New South Wales and Victoria's share.

Although, business expenditure on R&D remains concentrated in New South Wales and Victoria, their combined share of business expenditure on R&D has declined from around 80 per cent in the mid-1980s to less than 70 per cent in 2004-05, while Queensland and Western Australia's share has increased (see figure S.6).

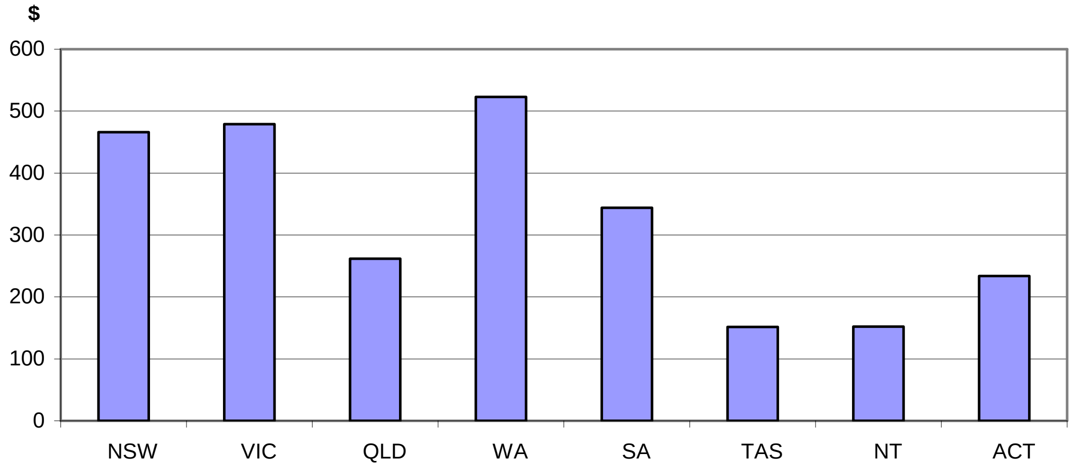
Figure S.6 **Distribution of BERD by State and Territory, 1990-91 and 2004-05 (per cent)**



Data source: Data derived from ABS (2006c).

However, on a per capita basis, Western Australia was the leading jurisdiction in regard to business expenditure in 2004-05 followed by Victoria and New South Wales (see figure S.7). It appears that those jurisdictions with relatively lower per capita business expenditure on R&D had relatively higher Australian Government per capita R&D spending.

Figure S.7 **BERD per capita by State and Territory, 2004-05**

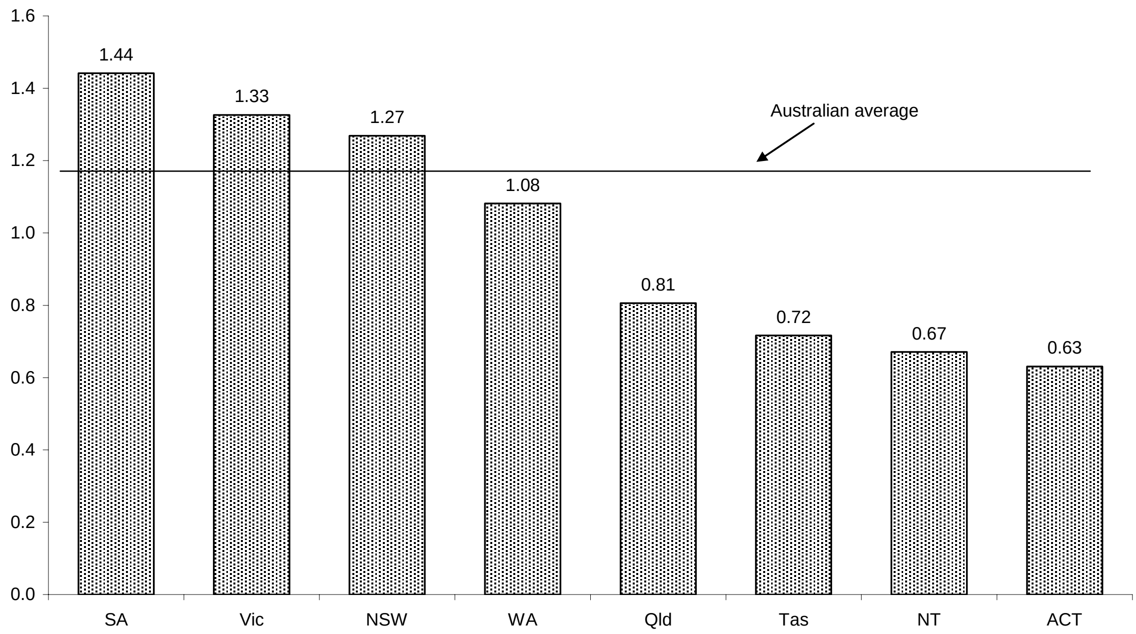


Data source: Data derived from ABS (2006c).

BERD intensity and industry structure

An examination of differences in BERD intensities based on the ratio of BERD spending (current prices) to current price factor incomes[1] revealed some differences across jurisdictions, with South Australian businesses registering BERD intensities around double those of smaller jurisdictions like the ACT, Northern Territory and Tasmania (figure S.8). Similarly, the larger more manufacturing (and business services) oriented states of NSW and Victoria registered considerably higher BERD intensities than the more resource-oriented states of Western Australia and Queensland.

Figure S.8 **State and Territory BERD intensities, 2003-04[a]**



a Latest available BERD data by industry by State and Territory.

Data source: BERD data by State and Territory and industry provided by ABS.

Although industry structure clearly plays a role in these differences it is difficult to determine precisely how much. Applying the same methodology used to investigate the effects of differences in industry structure on BERD intensities across countries sheds some light on the role structural factors play in interjurisdictional differences in BERD intensity (see appendix C and chapter 9).

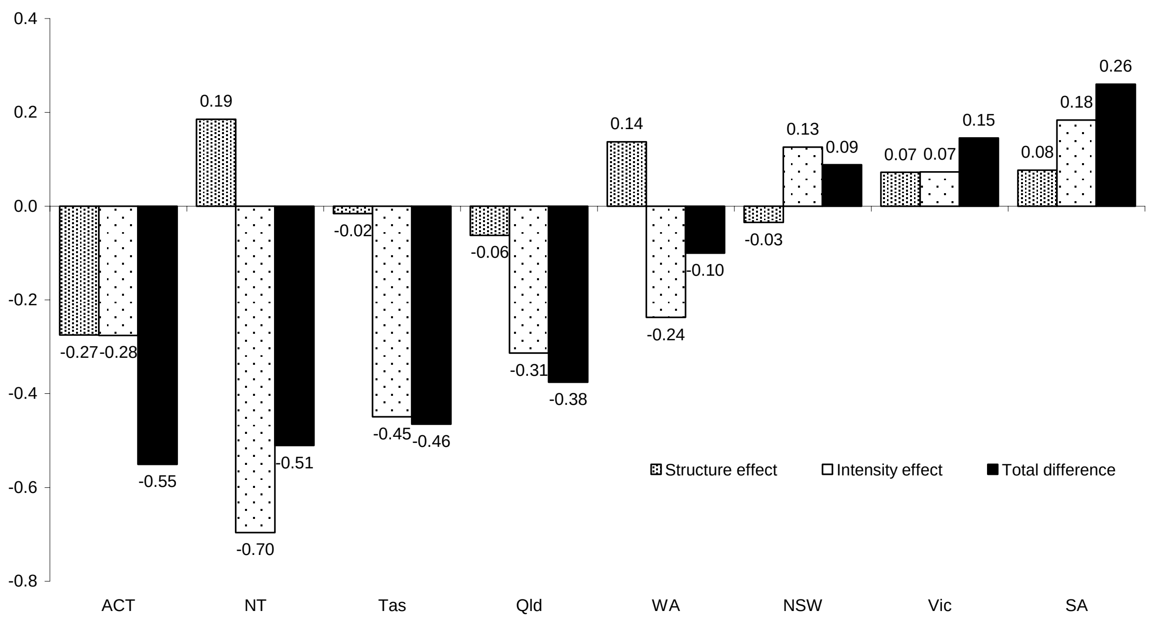
Data provide by the ABS on ANZSIC division level BERD revealed substantial variations in BERD intensities across industries. Overall the industries with the

[1] A measure similar, but not identical, to value-added.

highest BERD intensity were manufacturing (3.6 per cent), mining (2.4 per cent), business services (1.7 per cent), finance and insurance (1.1 per cent) and communication (1.1 per cent). There were, however, substantial variations in industry BERD intensities across jurisdictions.

Results of the decomposition for 2003-04 suggest that differences in industries *between* states explain some of the differences in State and Territory BERD intensities. For example, structural effects contribute to two of the three states with above-average BERD intensity — accounting for around one third of the difference in South Australia and one half of the difference in Victoria (figure S.9). Structural factors also played a positive role in Western Australia and the Northern Territory due to their large mining industries. Structural factors also explain half of the difference between the ACT BERD intensity and the national average. However, in the majority of cases, differences in BERD intensity *within* industries were the driving factor.

Figure S.9 **Decomposition of differences in State and Territory BERD intensities from Australian average, 2003-04**



Data source: BERD estimates provided by ABS, ABS Cat. No 5220.0

Caution is needed in interpreting these results. This analysis is likely to substantially understate the true contribution of structural factors in interjurisdictional differences in BERD intensities. As noted in appendix C, the level of aggregation of data used has a large impact on this type of analysis. As BERD estimates are only available for the manufacturing sector as a whole, the analysis misses the substantial variations within the manufacturing sectors in different states.

Manufacturing employment data confirm that there are substantial differences in the composition of the manufacturing sector in each jurisdiction (ABS 2006c). For example, one-third of the employment in South Australia's manufacturing sector is in the more R&D intensive machinery and equipment industry. This compares to 23 per cent in Western Australia, 22 per cent in Victoria and less than 20 per cent in all other jurisdictions. By contrast, the more resource-intensive metal products and non-metallic mineral product manufacturing industries accounted for one quarter and one fifth of manufacturing employment in Western Australia and Queensland. This compares to 13 and 14 per cent in Victoria and South Australia respectively.

Higher education expenditure on R&D (HERD) by State and Territory

Higher education expenditure on R&D is concentrated in New South Wales and Victoria accounting for around half of this expenditure in 2004-05. These shares have remained fairly constant over time.

On a per capita basis, higher education expenditure is fairly even across jurisdictions. As a percentage of GSP it was also relatively even across jurisdictions in 2004-05, although South Australia was slightly ahead of the other jurisdictions and the Northern Territory expenditure was behind.

S.2 Focus of R&D expenditure

As expected there are variations in the type of R&D being supported across the States and Territories which reflects differences in natural endowments, industry structure, history and differing social and environmental challenges. The socio-economic objectives — defence, economic, social and environmental — being supported by this expenditure provide an indication of the focus of R&D across the States and Territories.

Focus of business expenditure on R&D (BERD)

Unsurprisingly, the bulk of business expenditure on R&D is directed towards supporting economic objectives followed by social and environmental objectives. However, in Western Australia, Queensland, Victoria and New South Wales a larger share of this expenditure is directed towards supporting economic objectives than in South Australia and Tasmania and to a lesser extent again in the two territories.

There are differences between jurisdiction which are worth noting in regard to the type of economic objectives being supported by business expenditure on R&D. In New South Wales, Victoria and South Australia this expenditure was relatively concentrated on supporting manufacturing and information and communication services. In Queensland and Western Australia, the business expenditure was less concentrated, with a focus on manufacturing, energy, information and communication services and minerals (see table S.2).

Interestingly, manufacturing was the major focus of business R&D expenditure in all jurisdictions outside of the Northern Territory and the ACT, with Tasmania having the highest proportion of business R&D expenditure directed towards manufacturing (see table S.2).

Table S.2 **Average proportion of BERD by type of economic objective, 1992-93 to 2002-03**

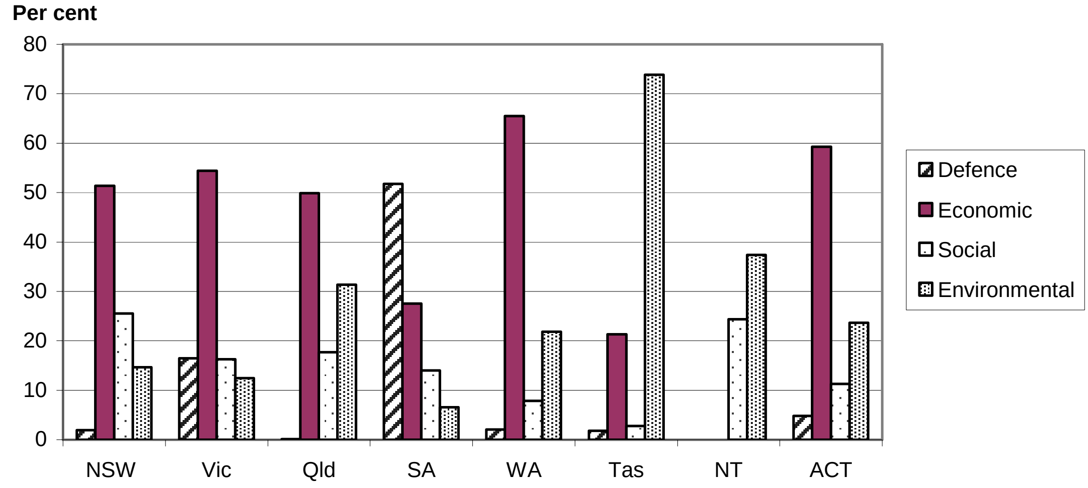
	NSW	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*NT*	*ACT*
Agriculture	1.9	1.3	3.5	1.7	2.6	6.3	0.0	0.7
Minerals	3.6	2.4	12.5	35.9	2.2	2.1	41.9	0.0
Energy	5.7	4.3	13.7	5.8	2.6	0.6	3.1	0.2
Manufacturing	41.0	55.0	39.3	38.9	57.1	62.6	1.2	6.9
Construction	1.9	1.1	1.6	1.9	0.7	0.8	1.0	0.1
Transport	2.3	1.8	2.5	1.5	0.7	1.9	4.4	6.2
Information and communication services	22.1	20.8	13.4	5.2	11.0	1.7	0.0	35.6
Commercial services	10.0	2.9	3.9	1.9	2.2	0.7	0.2	3.3
Economic framework	1.9	0.2	0.1	0.0	0.0	0.0	0.1	0.1

Source: Unpublished ABS data.

Focus of government R&D expenditure (GOVERD)

The largest share of government R&D expenditure was directed towards economic activities in all jurisdictions except for Tasmania and South Australia. In South Australia, defence activities received the largest share of government expenditure on R&D and in Tasmania it was the environment. This reflects major defence projects being undertaken in South Australia and the Antarctic research capacities located in Tasmania (see figure S.10). This does not imply that less per capita is being spent in South Australia and Tasmania on economic activities than in other jurisdictions. Rather this is indicative of the unusually high environmental and defence expenditure in Tasmania and South Australia respectively.

Figure S.10 **Share of GOVERD by socio-economic objective**



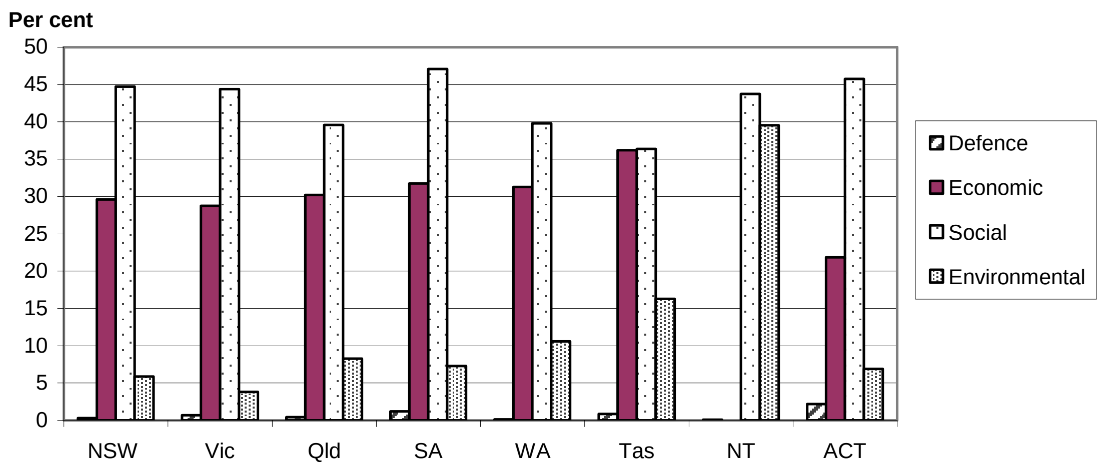
Data source: Unpublished ABS data.

Within the economic category, there was a particular focus on manufacturing and agriculture in New South Wales and Victoria and in Queensland and Western Australia the focus was primarily on agriculture.

Focus of higher education expenditure on R&D (HERD)

The bulk of higher education expenditure on R&D was directed towards social objectives in all jurisdictions followed by economic objectives (see figure S.11).

Figure S.11 **Share of HERD by socioeconomic objective**



Data source: Unpublished ABS data.

By type of social objectives, the largest expenditure was on health, apart from the Northern Territory where it was on education (see table S.3).

Table S.3 **Average proportion of HERD by type of social objective and environmental objective, 1992-93 to 2002-03**

	NSW	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*NT*	*ACT*
Health	20.4	27.6	18.4	20.9	26.8	11.6	5.0	15.5
Education and training	4.6	5.3	5.2	4.6	4.4	6.3	9.9	1.3
Social development and community services	5.7	4.3	5.1	3.1	4.8	6.0	8.6	9.0
Environmental	6.0	4.4	8.1	7.4	9.1	18.4	25.6	6.9

Source: Unpublished ABS data.

Also of note is that Tasmania and the Northern Territory directed a larger share of higher education R&D expenditure towards environmental objectives than the other jurisdictions.

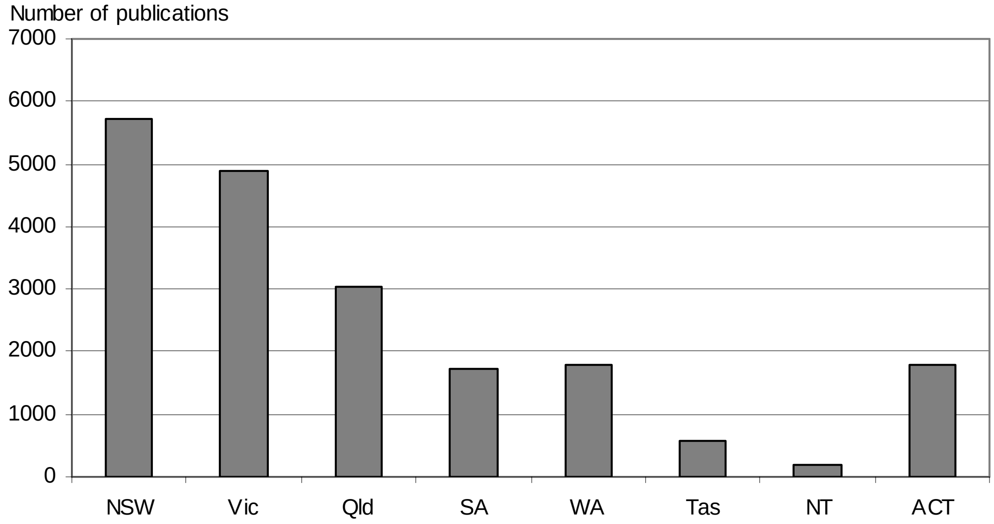
S.3 Publications by State and Territory

In Appendix K, Australia’s scientific performance based on journal output and impact was discussed relative to other countries. The following discussion examines journal output across each State and Territory.

By State and Territory, New South Wales and Victoria accounted for the bulk of the Australian scientific publications that appear on the Science Citation Index (see figure S.12).

By field of science, most publications were produced in New South Wales and Victoria. However, in agriculture, veterinary and environmental sciences, Queensland accounted for the most publications and in the physical sciences the ACT accounted for the second largest number, behind New South Wales and slightly more than Victoria (see table S.4).

Figure S.12 **Scientific publications on the Science Citation Index by State and Territory, 2002[a]**



a The analysis is based on 'whole counting'. Where more than one State or Territory collaborated on a publication, each was given a count of 1 for that publication.

Data source: Technical paper no. 1, PC website (http://www.pc.gov.au/study/science/index.html).

Table S.4 **Publication output by field for each State and Territory, 2002**

Field	*NSW*	*Vic*	*Qld*	*SA*	*WA*	*Tas*	*NT*	*ACT*	*Aust*
Mathematical Sciences	220	127	72	46	68	8		83	583
Physical Sciences	894	451	233	163	94	36	19	457	2109
Chemical Sciences	501	445	268	177	135	44	2	177	1524
Earth Sciences	286	286	201	108	206	145	21	219	1245
Biological Sciences	1133	1023	782	411	410	201	60	460	3864
Information, Computing and Communication Science	86	60	68	21	30	5	1	27	278
Engineering and Technology	820	630	414	162	213	31	9	149	2221
Agricultural, Veterinary and Environmental Sciences	487	410	525	189	289	141	36	194	1885
Medical and Health Sciences	2397	2303	1119	782	714	114	63	279	6857
Science - general	316	349	295	122	144	99	18	89	1250
Total	**5718**	**4899**	**3051**	**1729**	**1779**	**590**	**178**	**1792**	**17269**

a The analysis is based on 'whole counting' where more than one State or Territory collaborated on a publication, each was given a count of 1 for that publication.

Source: Technical paper no. 1, PC website (http://www.pc.gov.au/study/science/index.html).

T R&D support and ‘transformational firms’

This appendix considers the question of whether direct government support for R&D in firms can promote transformation of the Australian economy. After briefly discussing the role of ‘transformational firms’ in structural change, approaches to assessing the impact of direct public support on firm performance are considered. The results of a data matching exercise that tries to identify the overlap between lists of commercially-successful firms and firms that received direct support for R&D through merit-based competitive grant programs over the past decade and a half are also presented. Some broad conclusions are then made as well as some suggestions for further work.

T.1 Public support for R&D and the role of ‘transformational firms’

In response to the debate about the role of industry structure in Australia’s aggregate BERD spending (chapter 9 and appendix C), several participants noted the important role played by large high technology firms such as Nokia in Finland, Ericsson in Sweden or Phillips in Holland. These are sometimes called ‘transformational firms’ — so named because their strong growth can contribute to the transformation of a country’s industry structure. A similar idea underlies ‘platform firms’, as the Australian Business Foundation notes (sub 72, p. 13):

> These platform firms have the capability of capturing and holding the economic ‘value-add’ from their innovative technologies and global brands and bringing a stream of both novel products and entirely new businesses to the market. The existence and success of such enterprises ensures the continued viability and contribution of those industry sectors to their national economies.

Some participants have expressed doubts about Australia’s existing industry structure to deliver continued increases in living standards (see, for example, subs DR159, DR169, DR181 and chapter 9). Others have claimed that Australia has traditionally provided insufficient support for business R&D and that if support had been higher in the past, Australia’s present industry structure would have a larger proportion of high R&D performing firms and industries (appendix C).

Setting aside the question as to the appropriateness of the levels of Australia's public support (discussed in chapters 9 and 10), the fact remains that substantial public funds have already been provided directly to firms to support their R&D activities over the past decade and a half via merit-based competitive grant programs. Under the R&D START, as well as predecessor R&D grant programs, over $1.3 billion in grants and $98 million in loans were issued by the IR&D board between 1990-91 and 2003-04 (constant 2005-06 prices).

According to the IR&D Board (2005), the key eligibility criteria for R&D START were that projects had to have clearly identified commercial potential and that applicants had to demonstrate the projects could not proceed 'satisfactorily' without support. Although the predecessor programs sought to achieve a range of different objectives, the criteria used to assess project eligibility have remained relatively constant (chapter 10). While the promotion of a transformation in Australia's industrial structure towards 'high-technology' firms was not an explicit objective of these programs, an examination of the commercial success of firms that have received public support via R&D grants should shed some light on the extent to which existing expenditures have helped promote the emergence of 'transformational firms'.

One approach that can both highlight and assist in understanding the performance of successful firms that received grant funding is to undertake case studies. Biota, for example, claimed (sub. DR187 pp. 2–3) that the $2.7 million R&D START funding it was awarded in 2003 for lead optimisation and early pre-clinical development of compounds to treat respiratory syncytial virus infections was pivotal in its negotiation of a $US112 million collaboration and licensing agreement. A number of case studies of successful recipient firms are also provided in IR&D board annual reports. Recent examples include Beeline, Easymail, Micro Forte, Micronisers, Muir Engineering and Pathfinder (IR&D Board 2005).

Although case studies can provide much useful information (as discussed in appendix I), they are, by definition, highly selective. A more comprehensive approach is needed. However, to do this effectively requires access to longitudinal firm data. Limitations in data availability, particularly in obtaining access to a lengthy time series, as well as time constraints have meant that this analysis has not been possible for this study. However, ongoing work by the ABS Business Demographics area on developing a consistent time series based on Business Activity Statement data means that initiating such an approach is likely to be feasible in the near future. (This issue is discussed further at the end of the appendix.)

Our approach

For this study a much more modest data matching approach has been adopted in an effort to identify evidence of emerging ‘transformational firms’ that previously received an R&D grant. It is also hoped that this analysis will provide some insight into some of the characteristics of recipient firms, both before and after receipt of a grant.

Clearly there is no need for any comprehensive data matching analysis to determine that Australia has no ‘transformational firms’ of the scale of Nokia or Siemens (DITR sub. 93). Of the top 1250 global R&D performing firms in 2005-06, only three were Australian — Telstra, CSL and Aristocrat Leisure (DTI 2006). However, identifying the emergence of firms at the next tier down — firms that are either large or fast growing relative to other Australian firms — and have previously received grant support requires more systematic analysis.

To undertake this analysis, a unified list of all recipient firms between 1990-91 and 2003-04 was constructed based on published IR&D Board annual reports. Over the period, 4506 separate grant and loan payments worth $1.4 billion (table T.1, constant 2005-06 prices) were paid to an estimated 1655 firms. Since grants comprised the overwhelming majority of this support (93 per cent over the period), the term ‘grant recipients’ is used here to refer to both grant and loan recipients. The average yearly grant size was $260 000 (constant 2005-06 prices) and recipient firms received grant funding for an average of three years. Annual grant sizes have been steadily increasing, up from around $100 000 a year in the early to mid-1990s to around $350 000 over the second half of the period (constant 2005-06 prices).

Firms in this list were then matched against the following:

- Business Review Weekly (BRW) lists of Top-500 public companies, Top-500 private companies and the Fast-100;
- Australian Export Award and Australian Design Awards winners; and
- IPRIA (Intellectual Property Research Institute of Australia) Top-50 Innovation Index and IPRIA Top-50 firms based on R&D spending levels and intensities and patent applications (number and intensity).

The timing of R&D grants were then examined to determine whether matched firms received the grant before, or after, appearing in these lists.

Table T.1 Raw data on R&D grant recipients[a] and various annual lists of firm performance

	Years for which data were available	*Number of observations*	*Number of firms (estimated)*	*Average ABN match score*[b]
R&D grant data				
Grants awarded	1990-91 to 2003-04	4506	1655	98.5
BRW data				
Top-500 public companies	1993 to 2006	7500	1613	98.0
Top-500 private companies	1993 to 2006	7500	1316	97.9
Fast-100	1995 to 2006	1200	743	98.1
Awards data				
Australian Export Awards	1990 to 2005	836	582	98.1
Australian Design Awards	1990 to 2005	335	269	97.7
IPRIA data				
Innovation index	1997-98 to 2005-06	450	179	99.8
R&D spending — absolute amount	1997-98 to 2004-05	400	126	99.9
R&D intensity	1997-98 to 2004-05	400	174	99.8
Patent applications — absolute amount	1997-98 to 2005-06	450	200	99.7
Patent applications — intensity	1997-98 to 2005-06	450	243	99.5

[a] These data include grants made under R&D START as well as a number of predecessor programs including: discretionary grant payments for the years 1990-91 to 1994-95; competitive grant payments for the years 1995-96 to 1997-98; and concessional loans for the years 1994-95 to 2003-04. Grants and loans to universities, research institutes and public agencies including CSIRO divisions have been omitted. [b] Discussed in box T.1.

Source: Box T.1.

Some qualifications

Long time series were chosen for most indicators (of around a decade and a half) in an attempt to allow for the fact that it can take a long time for R&D spending to result in commercial outcomes. But employing such long time frames introduces several complications. Hence, before discussing the results of the data matching exercise some caveats are appropriate.

- *Data entry errors* — much of the data were obtained by scanning or typing in published relevant lists of firm names and years. In total, the raw dataset contained around 25 000 separate lines of data. Despite the care taken to 'clean' the dataset, and attempts to cross check using Australian Business Numbers (ABNs) and other methods (box T.1), it is inevitable that errors in either the spelling or formatting of firm names remain. The most obvious problem stemming from uncorrected differences in spelling is that matches between recipient firms and the performance lists may be missed. A related, but less significant, problem stemming from uncorrected differences in spelling from year to year, is that a single firm will appear as multiple entries and hence overstate the number of firms in each list.

- *Name changes and firm takeover* — one of the key issues with any firm based analysis is the problem of changes in firm names over time. In the years covered in this analysis a number of recipient firms underwent name changes. ABN software helped in the identification of some of these. But it is not possible to determine precisely how many there were. Name changes can affect the results in a number of ways. For example, if a recipient firm achieved strong growth under a different name it may not be picked up with the data matching. Name changes also introduce problems in determining when a firm first received an R&D grant.
- *Grant size* — the amount given to a firm is likely to have a major impact on the success of the funded project. This analysis is unable to account for differences in grant size. In the early period under consideration grant sizes were considerably smaller than the latter years (after R&D START grants commenced). Moreover, grants varied considerably in size depending on the project funded. For example, Biota has consistently listed as a Top-500 public company since 1994 (ranked 486). However as it received a grant for under $4000 in 1992 it is recorded as a company that achieved listing *following* receipt of a grant. Such a small grant is unlikely to have had much impact on its overall growth — particularly relative to the larger grants (discussed above) it received well after it achieved Top-500 status.
- *Start and end periods* — determining whether grants preceeded or followed achievement of Top-500 status, or appearance in other lists, is complicated by the different starting and ending periods for each list (table T.1). A number of companies may well have been among the largest or fastest growing companies before 1993. For example, although United Milk Tasmania ranked as approximately Australia's 100th largest private company in each year from 1993 to 1998, as Top-500 data were not available for this analysis prior to 1993, it is recorded as a firm that first achieved listing *following* the initial receipt of grant funding (it received R&D grants in 1991, 1992 and 1994). Similarly, any firms that received R&D grant funding prior to the 1990-91 and subsequently appeared in a BRW list or won an award will not be captured in the analysis.

While these limitations are unlikely to result in a substantial systematic biases in the dataset, caution is needed in interpreting the results of the data matching. The results presented below represent a fairly rudimentary indicator of the commercial performance of R&D grant recipients and should be treated as approximations rather than precise measures. Further, although information on the timing of the appearance of matching firms in different lists is provided, this does not constitute evidence of causality. Hence, the data and methodology are not appropriate for evaluating the effectiveness of R&D grants programs over the past decade and a half.

Nevertheless, the results should at least provide some indication as to the success of direct R&D support in assisting the development of 'transformational firms'. Moreover, in addition to serving an informational purpose, the results presented below should highlight areas for further work in this area and point to some of the issues that would need to be considered in undertaking such analysis.

T.2 Data matching results

BRW data

Top-500 public companies

The BRW Top-500 public companies list covers companies on the Australian Stock Exchange (ASX) with the largest market capitalisation, ranked according to net profit figures for the most recent half year.[1] When the recipient firms were cross matched with these data it was found that 77 (or 4.7 per cent of) recipient firms were listed in Australia's Top-500 public companies between 1993 and 2006 (table T.2). This amounted to 4.8 per cent of the total number of Top-500 public companies over the period.

Just over half of these, 44 (56 per cent) of the 77 recipient firms, achieved their ranking *prior* to receipt of grant funding. The remaining 34 firms (44 per cent) achieved their ranking following the first year of receipt of grant funding. This figure falls to 14 (18 per cent) for firms that achieved their ranking following the conclusion of funding (figure T.1). However, it is likely that this figure is underestimated to some degree as it is based on the conclusion of *all* R&D grants received by a firm. The dataset did not allow the separate identification of funding for different projects within the one firm.

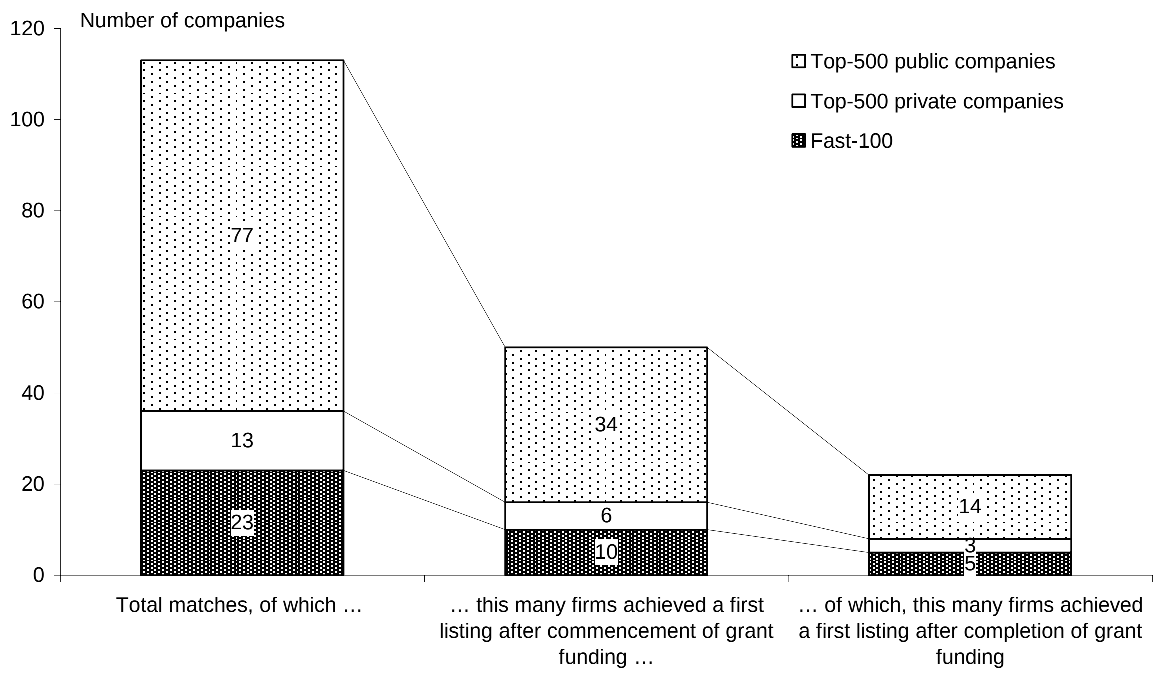
[1] There were 1900 listed companies on the ASX in February 2007. Foreign companies except those based in Papua New Guinea and New Zealand are excluded.

Table T.2 **BRW data matched with R&D grant recipients**
1993 to 2006

	Top-500 public companies	*Top-500 private companies*	*Fast-100*
Total matches (number of firms)	77	13	23
Share of recipients (per cent)	4.7	0.8	1.4
Share of listed firms (per cent)	4.8	1.0	3.1
Average rank	342	230	46
Average number of recipients listed each year	25	7	5
Firms that achieved first listing after *commencement* of grant funding			
(number)	34	6	13
(per cent)	*44*	*46*	*57*
Firms that achieved first listing after *completion* of grant funding			
(number)	14	3	5
(per cent)	*18*	*23*	*29*

Data source: Box T.1.

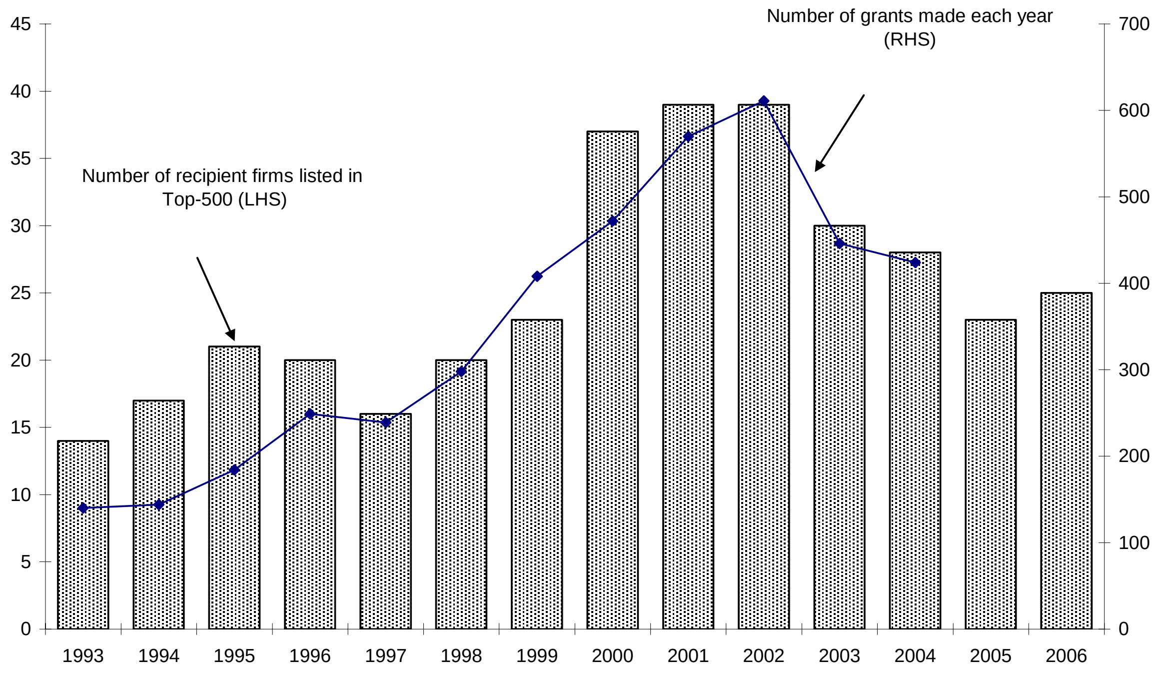
Figure T.1 **Breakdown of recipient firms that achieved BRW listing after commencement and completion of grant funding**



Data source: Box T.1.

Over the period, an average of 25 recipient firms were listed in the Top-500 each year. This has been steadily increasing from around 10 in the early 1990s to around 25 in 2006. However, caution is needed in interpreting this result. The number of firms that received grants has also increased strongly over the period, with the two measures being positively correlated over time (figure T.2).[2]

Figure T.2 Number of recipient firms listed in Top-500 public companies and number of grants made each year, 1993 to 2006



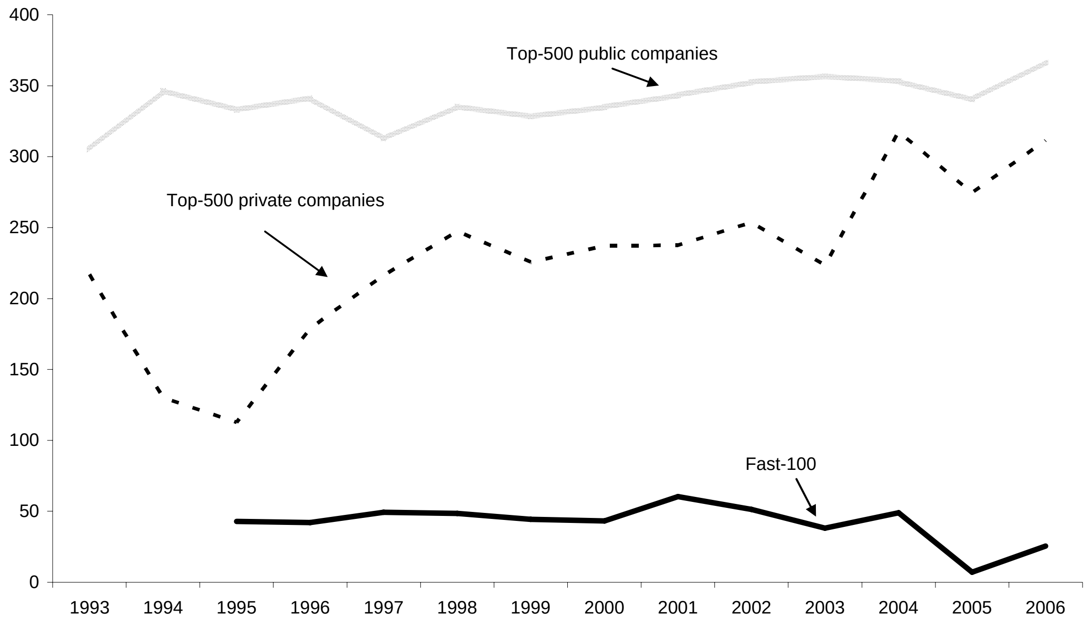
Data source: Box T.1.

The average ranking of recipient firms was 342 over the period. In 2005-06, firms around this rank typically had market capitalisation levels of $100–150 million and net profits (most recent half year) of around $4–5 million (current prices). By comparison, Australia's top 25 public companies each had an average market capitalisation of $24 billion and net profits of around $1.2 billion.

Over the period, average rankings for recipient firms in annual Top-500 public company lists remained consistently in the bottom half of the list (between 300 and 350) although a slight downward trend (lower ranking) was evident over the period (figure T.3).

2 Moreover, the stock of firms that have received grants also increased as new firms were added each year.

Figure T.3 Average ranking of recipient firms in BRW lists, 1993 to 2006



Data source: Box T.1.

Top-500 private companies

The BRW Top-500 private companies list covers a wide range of enterprises including privately owned family businesses, non-listed public companies, cooperatives and partnerships. Listed or foreign owned companies are not included and companies are ranked according to total revenue. When the recipient firms were cross matched with these data it was found that 13 (or 0.8 per cent of) recipient firms were listed in Australia's Top-500 private companies between 1993 and 2006 (table T.2). This amounted to one per cent of the total number of Top-500 public companies over the period.

Just under half, 6 (46 per cent) of the 13 recipient firms achieved their ranking following the first year of receipt of grant funding. This figure falls to 3 (23 per cent) for firms that achieved their ranking following the conclusion of funding (figure T.1).

Over the period, an average of 7 recipient firms were listed in the Top-500 each year. The average ranking of these firms was 230. In 2005-06, firms around this rank typically had revenues of $170–180 million (current prices) and employed a few hundred people. By comparison, Australia's top 25 private companies had average revenues of $2.1 billion and employed around 2400 people each.

Average rankings for recipient firms in Top-500 private company lists were around the average for the group (250), although a downward trend was evident over the period (figure T.3).

Box T.1 **About the data**

Data for each list were first collected on an annual basis and then collated into panels for each indicator. The R&D grant recipient database, for example, initially had over 4500 separate entries, as listed in the IR&D Board annual reports (http://www.ausindustry.gov.au/content/azindex.cfm?Keyword=annual%20report and various years). Due to the spreading of payment of grants over a number of years the actual number of supported firms is much smaller than this, hence, firms that received grants over a number of years were matched to produce a panel. This reduced the number of firm names to 1655. For the most part, this was achieved using electronic matching. However, in some cases, firm names differed slightly in spelling and punctuation — including different abbreviations, spacing, word order and suffixes such as P/L, Co, Limited etc — which meant that manual checking was required. Moreover, as noted earlier, in some cases firms' names changed over the period.

The list of recipient names was checked using the Commonwealth Government's ABN lookup software which matches ABNs to business names. This software provides a list of possible ABNs with scores which indicate the strength of the match for each ABN. Scores range from 0 to 100, with 100 representing the highest probability of a match. The software also lists firm histories including trading names and name changes. Although the information held in the ABN register is based on information supplied by businesses to the Registrar of the Australian Business Register, the software comes with the proviso that 'neither the Registrar nor the Federal Government guarantee the information is accurate, up to date or complete'. Nevertheless, although it was unable to match all the businesses contained in the various lists, in general the software found ABNs for around 90 per cent of names in each list with match scores of between 95 and 100 (for more information on how the software works see http://abn.business.gov.au).

Despite this checking, the list of recipient firms almost certainly overstates the actual number of recipient firms as it is likely that a number of matches have been missed due to name changes and takeovers. Nevertheless, for the purpose of this exercise, the actual number of firms is less important than having a full list of all possible firm names for cross reference. These were then matched against the performance lists from BRW (http://www.brw.com.au), Australian Design Awards (http://www.designawards.com.au), Australian Export Awards (http://www.exportawards.gov.au) and IPRIA (http://www.ipria.org).

Fast-100

The BRW Fast-100 list covers companies that have demonstrated consistently high year-on-year turnover growth. In 2006 the threshold was at least 50 per cent (nominal) over three years — up from an annual growth rate of 46 per cent for 2005. This compares with an average growth rate of 7 per cent (nominal) for all Australian companies. Overall, service firms dominated the Fast-100 list, as was the case with the Top-500 public and private company lists.[3]

When the recipient firms were cross matched with these data it was found that 23 (or 1.4 per cent of) recipient firms were listed in the Fast-100 between 1995 and 2006 (table T.2). This amounted to 3.1 per cent of the total number of Fast-100 companies over the period. Just over half, 13 (57 per cent) of the 23 recipient firms, achieved their ranking following the first year of receipt of grant funding. This figure falls to 5 (29 per cent) for firms that achieved their ranking following the conclusion of funding (figure T.1).

Over the period, an average of 5 recipient firms were listed in the Fast-100 each year. The average ranking of these firms was 46. In 2005-06, Fast-100 firms around this rank typically had turnover of $5–10 million (current prices) and employment ranged from around 10–100 people.[4] Average rankings for recipient firms remained around the middle of the group (50), although a slight upward trend (higher ranking) was evident from 2001 (figure T.3).

Export and design awards

Australian Export Awards

The Australian Export Awards are one of the longest running business awards programs in Australia. They have a range of objectives including to: identify and reward Australia's most successful and innovative exporters; promote top exporters as corporate role models in order to stimulate greater involvement in exporting amongst Australian businesses; promote Australia’s leading exporters to the same status and public recognition as sporting and entertainment heroes; and to further

[3] This is consistent with economy wide indicators of economic growth, with the service sector accounting for around 75 per cent of GDP and 80 per cent of employment in Australia over the past decade and a half. Moreover, over the last two decades services firms have grown around twice as fast as manufacturing firms in real terms (PC 2005e).

[4] As Fast-100 firms are ranked according to growth in turnover — rather than absolute levels of turnover, profits or employment — this size range was typical of the majority of Fast-100 firms listed in 2005-06.

develop community awareness of the importance of exporting to Australia's economic future. Assessment criteria for the 2006 awards include: the degree of innovation in the applicant's marketing strategy; export growth achieved and the ability to sustain that growth; and the overall company commitment to international market development (Ausindustry 2007).

Data on Australian Export Award winners were obtained for the period 1990 to 2005. Over the period, 836 awards were awarded to an estimated 582 companies. When the recipient firms were cross matched with these data it was found that 78 (or 4.7 per cent of) recipient firms won an export award between 1990 and 2005 (table T.3). This amounted to 13.4 per cent of the total number of Australian Export Award winners over the period.

Table T.3 Australian export and design award winners matched with R&D grant recipients ,1990 to 2005

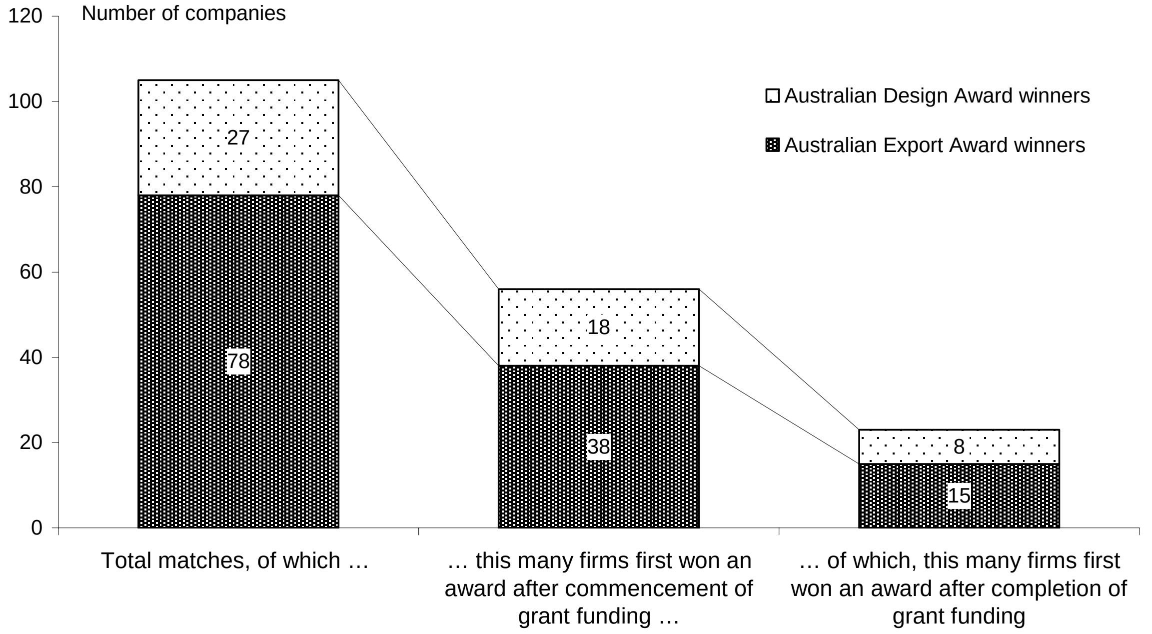
	Australian Export Award winners	*Australian Design Award winners*
Total matches (no of firms)	78	27
Share of recipients (per cent)	4.7	1.6
Share of listed firms (per cent)	13.4	10.0
Average number of recipients listed each year	8	2
Firms that achieved first listing after commencement of grant funding		
(number)	38	18
(per cent)	*49*	*67*
Firms that achieved first listing after completion of grant funding		
(number)	15	8
(per cent)	*19*	*30*

Data source: Box T.1.

Just under half, 38 (49 per cent) of the 78 recipient firms, achieved their award following the first year of receipt of grant funding. This figure falls to 15 (19 per cent) for firms that won an award following the conclusion of funding (figure T.4).

Over the period, an average of 8 recipient firms received an Australian Export Award each year. This has been steadily increasing from around 4 in the early 1990s to around 10–12 in 2005. However, caution is needed in interpreting this result. The total number of Australian Export Awards has presented each year has also increased strongly over the period. Overall, the two measures are positively correlated over time (figure T.5).

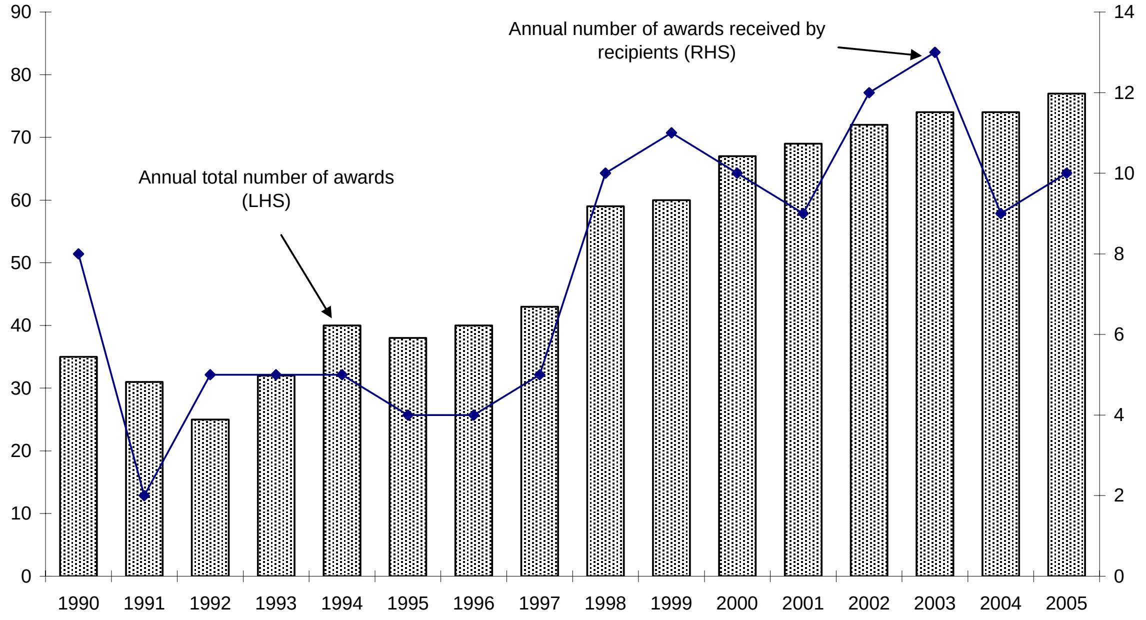
Figure T.4 **Breakdown of recipient firms that first won export and design awards after commencement and completion of grant funding**



Data source: Box T.1.

Figure T.5 **Annual export award winners — total number and number won by R&D grant recipients**

1990 to 2005



Data source: Box T.1.

Australian Design Awards

The Australian Design Awards have a range of objectives including to: recognise and reward excellence in Australian design and innovation; improve the awareness and promote the benefits of professional design to industry and the general public; and demonstrate the importance of design in the link between invention and the commercial success of products. Assessment criteria include: innovation; cleverness of design; visual impact; functionality; originality; appropriateness/need; longevity; quality; ergonomics; safety and standards compliance; environmental sustainability; and presentation (Standards Australia 2007).

Data on Australian Design Award winners for the period 1997 to 2005 were provided by Standards Australia. Data from 1990 to 1996 were complied from published lists of award winners. Although care was taken to ensure as complete a list as possible was complied, there are likely to be a number of gaps in these years.

Over the period, 335 awards were won by an estimated 269 companies.[5] When the recipient firms were cross matched with these data it was found that 27 (or 1.6 per cent of) recipient firms won an export award between 1990 and 2005 (table T.3). This amounted to 10 per cent of the total number of Australian Design Award winners over the period. The high representation of R&D grant recipients here indicates they are more heavily oriented towards the manufacturing sector rather than the service sector, which tends to have a greater orientation towards nontechnical innovation.

Overall, two-thirds (18 of 27) recipient firms achieved their award following the first year of receipt of grant funding. This figure falls to 8 (or 30 per cent) for firms that won an award following the conclusion of funding (figure T.4).

IPRIA data

IPRIA is a national centre for multi-disciplinary research on the law, economics and management of intellectual property. It produces a number of annual ‘Top-50’ lists of firms based on different measures of innovation including R&D spending, patent, trade mark and design applications. These indicators are weighted together to form an annual composite index of Australia’s Top-50 innovative companies.[6]

[5] Although the actual number of companies shortlisted as well as those listed in the ‘winners directory’ was many times this number.

[6] The index only contains Australian non-government enterprises that are included in the IBIS World Pty Ltd database for which R&D spending and assets are available (IPRIA 2006).

When the recipient firms were cross matched with the IPRIA data the following results were found:

- Innovation Index — 28 (or 1.7 per cent of) recipient firms were listed over the period (table T.4, figure T.6). This amounted to 15.6 per cent of the total number of listed firms over the period. The average rank was 22.

Table T.4 **IPRIA Top-50 lists matched with R&D grant recipients**
1997-98 to 2005-06

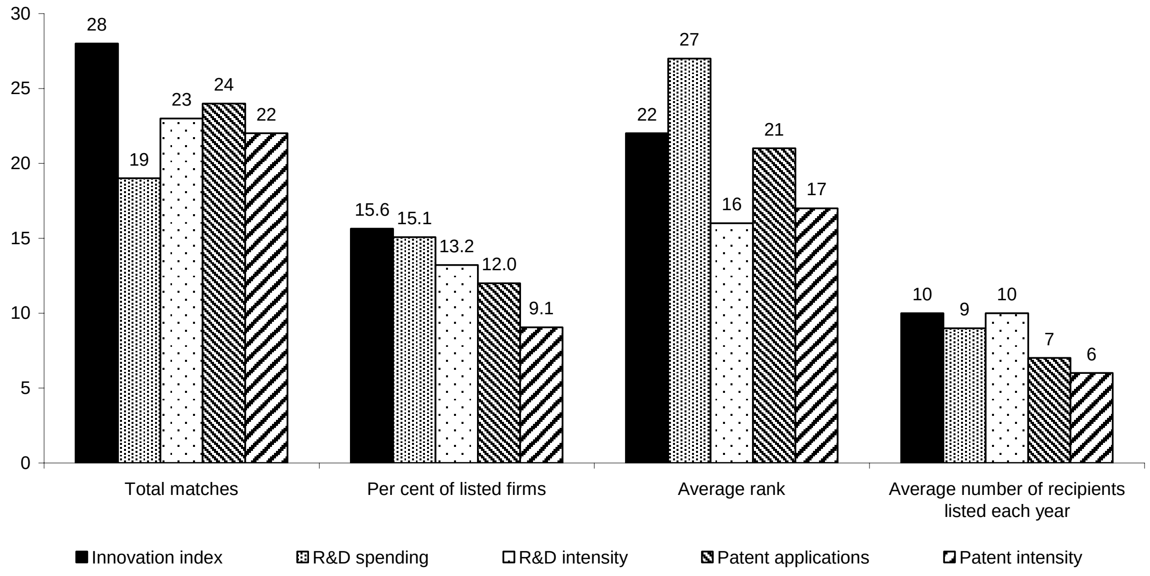
	Innovation Index	*R&D spending (absolute amount)*	*R&D intensity*	*Patent applications (absolute amount)*	*Patent intensity*
Total matches (no of firms)	28	19	23	24	22
Share of recipients (per cent)	1.7	1.1	1.4	1.5	1.3
Share of listed firms (per cent)	15.6	15.1	13.2	12.0	9.1
Average rank	22	27	16	21	17
Average number of recipients listed each year	10	9	10	7	6

Data source: Box T.1.

- R&D spending — 19 (or 1.1 per cent of) recipient firms were listed over the period. This amounted to 15.1 per cent of the total number of listed firms. The average rank was 27.
- R&D intensity — 23 (or 1.4 per cent of) recipient firms were listed over the period. This amounted to 13.2 per cent of the total number of listed firms. The average rank was 16.
- Patent applications — 24 (or 1.5 per cent of) recipient firms were listed over the period. This amounted to 12 per cent of the total number of listed firms. The average rank was 21.
- Patent intensity — 22 (or 1.3 per cent of) recipient firms were listed over the period. This amounted to 9.1 per cent of the total number of listed firms. The average rank was 17.

Overall, these results suggest that R&D grant recipients are overrepresented in IPRIA measures of innovativeness, relative to the average Australian firm. However, as noted earlier, causality cannot be inferred from this result. Due to time constraints for this study, as well as the relatively shorter timeframe for this dataset, no attempt has been made to compare the order of occurrence of listing and receipt of an R&D grant.

Figure T.6 **IPRIA Top-50 lists matched with R&D grant recipients**
1997-98 to 2005-06



Data source: Box T.1.

T.3 Implications and further work

On the basis of the evidence presented above three broad conclusions can be drawn.

First, the $1.4 billion provided in R&D grants and loans over the past decade and a half has not resulted in the emergence of any firms with the size and growth capable of transforming Australia's industry structure towards 'high-technology' industries. As Australia's economy currently generates just under $1 trillion in GDP annually and employs over 10 million people, any appreciable shift in the national structure of production and employment would require the emergence of either a few firms of global scale or a number of very large high technology firms. While it is already known that Australia has no global scale high technology firms of a comparable size to Nokia and Siemens, there is also no compelling evidence that the R&D grants have promoted the growth of firms at the next tier down. Hence, these results do not support claims for substantial increases in public support for business R&D based on the rationale of achieving transformation of industry structure.

Second, it is difficult to establish causal links between commercial success and receipt of an R&D grant given the available data. However, it is clear that not all of the apparent success observed in recipient firms can be traced to R&D START or predecessor programs. On the basis of the results presented above it appears that firms that received R&D grants between 1990-91 and 2003-04 are more likely to be commercially successful, more innovative and more likely to win export and design awards than the average firm in Australia.[7] But for most indicators, at least half of the recipient firms achieved listing or won their awards *before* the commencement of an R&D grant. This is hardly a surprising result given the competitive selection and screening processes involved in determining which firms will receive grant funding.

Moreover, even for those firms that achieved awards or strong growth following the commencement or conclusion of receipt of an R&D grant, it is not clear how much of the ensuing success can be attributed to the grant. In some cases, firms are likely to have achieved success without government support. This was highlighted by the findings of the CIE evaluation of R&D START (chapter 10). That said, it seems clear that R&D grant recipients are not 'average' firms, in terms of their actual (and potential) commercial success, innovativeness and export orientation. This highlights the importance of finding the right control group if meaningful evaluation of the program is to occur (appendix M).

Third, the limitations of the methodology and data employed in this appendix highlight the need for better and more comprehensive analysis. A suggestion for further work is set out below.

Further work

The feasibility of providing comprehensive empirical comparisons of the performance of grant recipients relative to an appropriate baseline group of firms was examined by the Commission as part of this study. As such analysis requires longitudinal firm data, the Commission discussed with the ABS the feasibility of obtaining data on the performance of recipient firms — suitably aggregated by the ABS to ensure that individual firms could not be identified. Although the Commission understands that such work is, or soon will be, technically feasible, data and time limitations have meant that this more detailed work was not possible for this study.

Nevertheless, the Commission sees merit in further work in this area. As a starting point, the performance of firms in terms of real growth in turnover, value added, wages and exports in the years prior to receipt of an R&D grant could be compared with the period following receipt. These results would shed more light on the pre-

7 At June 2004 the number of business entities registered with the Australian Business Register for an active ABN was 3.0 million, of these around 840 000 (28%) were employing businesses (ABS 2005e).

and post-grant performance of firms than is possible using the simple data matching approach employed in this appendix.

The next step would be to explore a range of possible control groups for comparison with the performance of recipient firms. Even if a control group of firms was standardised for industry structure it would be expected that successful grant applications would have higher growth potential, be more innovative and have better human capital than the average for firms within their industries. Given the relatively high representation of recipient firms in the IPRIA annual lists of innovative firms, consideration could be given to using non-recipient firms in these lists as a possible baseline for comparison. There would also be merit in tracking aggregate performance indicators for unsuccessful (but eligible) grant applicants over the same period.

To ensure maximum benefits from such an exercise, results would need to be reported in a consistent and transparent manner. The information gleaned from such a process would make for better program evaluation and refinement and would supplement data collected from other sources such as firm surveys as was used in the CIE evaluation of the R&D START program (discussed in chapter 10). Clearly, the maintenance of an accurate and ongoing database of this type as well as the publishing of regular statistics on firm performance would involve some resource commitment. However, any expenditures would be small relative to the amount of funds distributed.

As the Commission has noted elsewhere, there are dangers in focussing on commercial success at the expense of a consideration of the broader spillover benefits and questions of additionality. However, the collection and analysis of data on commercial success of recipient firms would not, of itself, promote such a focus. The collection of these data should *supplement,* not replace, existing and future efforts at gathering information on spillovers and additionality stemming from R&D grant funding.

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