



INNOVATION &  
THE KNOWLEDGE  
ECONOMY IN  
AUSTRALIA

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## PREFACE

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This publication, *Innovation & the Knowledge Economy in Australia*, comprises two papers prepared in 2004 and 2005 for the Australian Business Foundation by the internationally recognised innovation researcher, Professor Keith Smith. Together, they advance knowledge about the dynamics of innovation and its contribution both to the business performance of firms and to the growth and prosperity of nations.

This publication has the following sections:

- An Overview.
- Promoting Innovation in Australia: Business and Policy Issues.
- The Knowledge Economy in the Australian Context.
- References.

### ABOUT THE AUTHOR

Professor Keith Smith is the co-founder of the new Australian Innovation Research Centre at the University of Tasmania in Hobart. He was previously with the European Commission Joint Research Centre in Seville, Spain for some years, prior to which he was at the Institute for New Technologies, United National University, and Professor at the Norwegian University of Science and Technology (NTNU).

Originally trained at the Universities of Cambridge and Sussex, Professor Smith's academic background is economics and development studies. Following nine years as Lecturer in Economics at the University of Keele, he was appointed as Economic Adviser to the Science Policy Council of Norway in 1988. From 1990 to 2000, he was Research Director of the STEP Group in Oslo, carrying out a wide range of research on innovation issues for Ministries, Research Councils and the European Commission.

Professor Smith's main fields of research are innovation and economic growth, the development of innovation statistics, the use of science in industry, innovation in 'low technology' industries, and knowledge studies. He has worked extensively as a consultant to policy agencies on innovation policy, both at a national and international level – he has been a member of the expert panel 'Innovation Policies in the Knowledge-Based Society' for the European Commission and deputy chairman of the Norwegian Government Commission on Tax Incentives for Business-Financed Research & Development.

### ABOUT THE AUSTRALIAN BUSINESS FOUNDATION

The Australian Business Foundation is an independent research think tank founded in 1997 by the eminent industry organisation, Australian Business Limited, to help foster fresh insights and practical intelligence to boost Australia's capabilities and global competitiveness. The body of research generated over 9 years focuses on business innovation, new forms of competitiveness and opportunities arising from a knowledge-based economy.

For more information and background on earlier research reports, visit the Australian Business Foundation at [www.abfoundation.com.au](http://www.abfoundation.com.au).

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# INNOVATION & THE KNOWLEDGE ECONOMY IN AUSTRALIA

## AN OVERVIEW

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The Australian Business Foundation brings together two insightful contributions to the debate on innovation and the knowledge economy in Australia in the form of papers by Professor Keith Smith of the Australian Innovation Research Centre at the University of Tasmania.

These two papers, published in a single volume by the Australian Business Foundation, were authored during 2004 and 2005 by Professor Keith Smith. They are titled:

- *The Knowledge Economy in the Australian Context, April 2004.*
- *Promoting Innovation in Australia: Business and Policy Issues, October 2005.*

These papers, considered together, offer the following key insights and arguments about the forms of knowledge and innovation that are driving today's economic transformations and growth. When considering the realities of innovation, these papers put the case that business challenges and policy issues intersect.

### **LOW TECHNOLOGY INDUSTRIES ARE INNOVATORS TOO**

The conventional view of the knowledge economy based on high technology industries and frontier technologies, like biotech and nanotechnology, presents an incomplete picture. Don't overlook the significance of low and medium technology industries in services and manufacturing (eg. food processing, transport, financial services, timber and metal products) that are innovative, knowledge-intensive and growing steadily.

*Convention has it that the knowledge economy is based on high technology industries & frontier technologies. This is an incomplete picture that overlooks the significance of low and medium technology industries in services and manufacturing, industries that are innovative, knowledge-intensive and growing steadily.*

In Australia, like most advanced economies, high technology or science-based industries and the technologies underlying them are very important, but they are also very small. Such high technology industries account for only around 3 per cent of GNP in most OECD economies.

More significant to our understanding of the knowledge economy is the way innovation and growth occurs in the low and medium technology sectors, which form the bulk of the economy in Australia and in the OECD. These sectors include food processing, metal products, chemicals, timber products, printing and publishing, transport, mechanical engineering, mining, the hospitality industry, financial services, health and the like.

Innovation in such industries is not based on investment in research and development, but on the painstaking development of new product concepts that either solve consumer problems or meet market demands. The reality of innovation is that it rests not on scientific discovery, but on learning and problem-solving by firms.

### **NOT RESEARCH, BUT LEARNING BY DOING**

Research and development is certainly not the main, nor the most important, ingredient in the production of economically useful knowledge or innovative capabilities in business enterprises.

Much of the analysis of innovation in Australia and elsewhere focuses on expenditure on research and development as the main source of knowledge used by firms to innovate by producing novel products and services.

*Research and development is certainly not the main, nor the most important, ingredient in the production of economically useful knowledge or innovative capabilities in business enterprises.*

Professor Smith's papers argue against research and development being the most important knowledge input to innovation. To the contrary, he identifies two critical dimensions of knowledge creation, neither of which are easily visible in available innovation statistics.

These are:

- (i) Non-research and development inputs and expenditures including market research, design skills, engineering development, in-house training and operational skills related to new capital goods.
- (ii) Indirect flows of knowledge, including research and development, into firms from a distributed 'knowledge infrastructure' of universities, research institutes, industry organisations, standards bodies, consulting engineers and the like.

Innovation comes from learning, experimentation and recombination or re-use of knowledge such as in design, prototyping and trial production, rather than from the discovery of new technical or scientific principles. The installation and operation of new machinery and equipment is knowledge-creating, because it results in new capabilities. Similarly, firms can purchase licences to use protected knowledge created or discovered by others, or can explore and learn about markets and consumer preferences by investing in market research and other intelligence-gathering exercises. Furthermore, firms can gain the benefit of new knowledge through their association with others, eg. personnel movements, inter-firm cooperation, strategic alliances, links to professional and regulatory bodies and so on.

In reality, the knowledge underpinning innovation capabilities in firms is rarely based on direct research and development, but comes from learning by doing, learning by using technology and equipment and learning by interacting with others.

These flows of knowledge, not the stocks of knowledge in themselves, seem to be most instrumental in promoting and sustaining innovation.

## **BUSINESS TRANSFORMATION IS THE KEY**

Transformation in the capabilities of business enterprises is the key to achieving innovation and consequent productivity and performance gains, both for firms and for nations.

Professor Smith's analysis results in a more diverse and complex picture of innovation than just the commercialisation of knowledge from research and development.

*Transformation in the capabilities of business enterprises is the key to achieving innovation and consequent productivity and performance gains, both for firms and for nations.*

Innovation is described as:

- pervasive, not just restricted to a small array of high tech industries;
- reliant on collaboration and interactive learning;
- highly uncertain in terms of the risk / return decisions to be made by firms;
- affected by geographical clustering and by the cumulative patterns of industrial and technological specialisations built up over time by regions and nations;

- influenced by a strong interaction between technology and science; and
- systemic, where the innovation behaviour of firms is framed by external factors like social and cultural conditions, regulatory regimes, institutional and organisational governance and infrastructure.

Against this backdrop, the cornerstone for achieving innovation outcomes are the investment decisions by enterprises that create greater business value by transforming their capabilities and the way they do business.

Such business innovation involves competency-building and learning by firms. More than just entrepreneurial flair, it requires proficiency in sustaining all the everyday business systems and management competencies to bring attractive products and services to market, and continually improving and refreshing business offerings in response to market changes.

This in turn, rests on deliberate and long term strategies that support investment in the enterprise's tangible and intangible assets eg. training and skills acquisition, risk management, recruitment, organisational design, technology transfer, sales and marketing proficiency, specific production and managerial capabilities and so on.

Both business strategies and public policies must be framed to address this reality of Australian innovation.

## **REFOCUS AUSTRALIA'S INNOVATION POLICY**

Australia's current stance on innovation policy is excessively focused on high tech industries and frontier technologies and the commercialisation of research, at odds with the reality of Australia's industrial base and pattern of business innovation.

*Australia's current stance on innovation policy is excessively focused on high tech industries and frontier technologies and the commercialisation of research, at odds with the reality of Australia's industrial base and pattern of business innovation.*

A policy shift is needed towards greater support for alleviation of business risks and obstacles to innovation, and for universities and research institutes in their knowledge support role in business problem-solving.

The case is made that competing by innovation and knowledge delivers economy-wide benefits, not only advantages to individual enterprises. Therefore, innovation is a key issue both for corporate managers and for public policy makers, as it affects both the business performance of firms and the path of national economic development.

But, it is argued that current approaches to innovation policy in Australia lack a coherent perspective, appreciating neither the importance of non-R&D activities nor the characteristics of Australia's industrial structure.

Consequently, action is recommended on three pivotal policy challenges:

- Helping to mitigate the financial risks taken by innovating firms.
- Re-focusing the role of Australia's 'knowledge infrastructure' like research institutes and universities.
- Establishing a long-range strategic forum for integrated efforts to anticipate, pursue and resource Australia's innovation opportunities.



**PROMOTING INNOVATION**

**IN AUSTRALIA:**

**BUSINESS AND POLICY ISSUES**

Professor Keith Smith  
Australian Innovation Research Centre  
University of Tasmania

October 2005

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## EXECUTIVE SUMMARY

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Innovation is a key issue for both corporate managers and public policymakers because it jointly determines the business performance of firms and the path of economic development. The argument presented in this paper is that business challenges and policy issues intersect. The aim is to explore how innovation happens, the importance of innovation for growth, and some key challenges for Australia.

This paper explores the following issues:

- The ways in which corporate sectors interact with and rely on public policy backgrounds.
- Innovation policy and its role in the 'reform agenda'.
- The significance for growth and productivity of innovation as well as research and development, and hence the importance of innovation as an issue for government.
- Specific characteristics of knowledge creation and innovation processes.
- Characteristics of the Australian innovation system and innovation policy implications.
- Business and policy innovation challenges.

Australia has a "low tech" industrial structure that nevertheless innovates significantly. It can be argued that current policy directions exhibit two main flaws:

- they are excessively focused on high-technology industries (neglecting the real nature of the Australian system); and
- they are excessively focused on commercialisation of research and development associated with 'frontier technologies'.

At the business level, the key problems of innovation relate to the need to commit major financial and human resources in conditions of great uncertainty. Australian businesses need greater support in coping with the dimensions of this problem, in terms of new tax policies and financial support mechanisms.

In terms of the wider 'knowledge infrastructure' of universities and research institutes, current policy is excessively focused on commercialisation, and should be reoriented to a broader role of knowledge support, where these institutions assist firms themselves to create and use knowledge for problem-solving.

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## ON INNOVATION, POLICY & GROWTH

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### WHY INNOVATION MATTERS

Innovation can be seen as the development of technologically changed processes, products and services, the creation of new markets, and the use of new products. With that definition in mind, innovation is a key issue for both corporate managers and public policymakers because it jointly determines the business performance of firms and the path of economic development.

The argument presented in this paper is that business challenges and policy issues intersect – which means that business managers who do not take public policy issues seriously are failing their shareholders, and policymakers who misunderstand the role of the public sector in innovation are failing also (with potentially serious consequences for economic growth, employment and incomes). The aim of this paper is to explore how innovation happens, the importance of innovation for growth, and some key challenges for Australia.

For businesses, innovation matters because it is central to the competitive process. Of course, competition is very much to do with prices, and the drive for improved efficiency is an integral part of managing for competitiveness.

However, competitiveness cannot be reduced to costs, because it depends far more on the technical characteristics of products – that is, on the services that they deliver to buyers, and the ways in which those services are delivered. That is to say, competition is primarily technological. Firms compete by seeking to create performance characteristics and attributes in products that differentiate their product lines from competitors, building new product concepts and 'islands' of technological capabilities and specialisation that insulate them from imitation.

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When firms succeed in this they are able to appropriate the benefits of innovation, and creating a flow of innovation over time is the only basis of sustained profitability. Therefore, the central strategic challenge facing any management team involves defining and building innovative capabilities to meet dynamic market conditions. Some core problems involved in this will be discussed later in this paper.

For policymakers the issues appear broader. They are concerned with such problems as the growth path of the economy as a whole, levels and structures of employment, per capita incomes and the income/wealth distribution, the fiscal position of the government and the external trade and Balance of Payments position. But, results in all of these areas depend on innovation performance – on the technological characteristics of the complex product mix that makes up GDP, and on the market success of that mix. It is innovation and its effect on the level of technology that shapes economic welfare and economic outcomes.

All this in turn depends on innovation by the businesses that comprise such a large part of the economy. It is widely assumed by policymakers that there is something that can be termed a 'market mechanism' that allocates resources into their most efficient uses, and that

*The conditions determining innovation behaviour in firms ought to be a key concern for policy makers.*

and that therefore government should stay well away from involvement in business. However, despite

the undoubted influence of capital markets on the selection of projects, markets do not allocate resources – businesses do. It is managers who allocate resources to investment in innovation, and the extent to which they do so are critical to achieving wider policy objectives. So the conditions that determine innovation behaviour in firms ought to be a key concern for policy makers.

This paper deals with the business and public policy dimensions of the innovation system in Australia. It explores the following issues:

- The ways in which corporate sectors interact with and rely on public policy backgrounds.
- Innovation policy and the ‘reform agenda’.
- The significance of research and development and innovation for growth and productivity, and hence the importance of innovation as an issue for government.
- Specific characteristics of knowledge creation and innovation processes.
- Characteristics of the Australian system and innovation policy implications.
- Business and policy innovation challenges.

This paper extends the ideas advanced by the author elsewhere on the knowledge economy in Australia<sup>1</sup> and those expressed in a recent submission to the Australian House of Representatives Standing Committee on Science and Innovation<sup>2</sup>.

In terms of the knowledge economy in Australia, it was elsewhere argued that although the Australian industrial structure rests on what are often called low technology and medium technology industries, such industries are in fact innovative and knowledge-based. Indeed many of Australia’s mature industries deploy complex scientific knowledge bases, but relying on substantially external knowledge bases. These scientific knowledge bases are developed and maintained in external organisations such as universities, CRCs, research institutes and government labs. Such organisations constitute a ‘knowledge infrastructure’, and the relevant knowledge results flow in indirect and complex ways into industrial uses.

The submission noted argued for a strong distinction between the roles of the corporate sector and the public sector in innovation. Specifically, the task of government is not to support commercialisable research and development. It is businesses that should focus on the commercialisation of new products and processes. Attempts to push the university and research institute systems into a stronger focus on commercialisation are misplaced because they rest on a misunderstanding of how innovation happens in industry. Rather, the policy challenge is twofold:

*The task of government is not to support commercialisable research and development ... it is businesses that should focus on commercialisation of new products and processes.*

- First, it is to provide a strong framework of **incentives and risk management devices that promote innovation and business growth in firms, via tax policy and financial mechanisms**. Here the challenge is to help innovation-based firms to overcome problems of growth. By far the biggest problem faced by businesses is risk, which has major effects on innovation finance. Government should consider innovative financial instruments aimed at promoting innovative investment by spreading risk.
- Second, government should focus its direct support for innovation on the background **knowledge infrastructure that facilitates knowledge creation in firms**

**themselves. Here the challenge is to support problem-solving, not to produce commercialisable knowledge.**

## **TWO DIMENSIONS OF INNOVATION**

There are two broad dimensions of innovation behaviour and performance in any country, namely firm-level activity and the operations of the public policy system. These aspects of innovation performance complement and interact with each other, and often have structural characteristics that reflect particular national environments.

For example, the corporate sector in any country is strongly affected by the nature of the corporate governance system (especially as it affects finance and corporate strategies), regulatory and tax environments, and the characteristics of the financial system. These often reflect distinctively national characteristics, such as differences in management cultures and labour relations, and are also shaped by policy choices. Innovation policy systems have even stronger national differences related to the ranking of innovation on the policy agenda, the structure of policy instruments, the organisation of the 'knowledge infrastructure' and the general scope of government activity.

This complex of public and private national characteristics makes up what is often called the "national innovation system", a set of institutions and behaviours that form the context and background within which firms and sectors innovate.

Creating and maintaining innovation capability is a major problem for any firm. The basic problem is that innovation requires sustained commitments of financial resources, human resources and capital investment in conditions of serious uncertainty.

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Innovation by firms also rests on the creation of specialized competence or related capabilities that are directed towards new methods of organisation and production, or to new products that improve marginally or significantly on the old. These are a product of learning, of a myriad of forms of knowledge creation. Competence-building and innovative learning are far more than a matter of innovative or entrepreneurial attitudes – they rest on corporate strategies that support investment (often over long periods) in tangible and intangible assets.

It is important to stress that innovation is not just a matter of bright ideas, still less of scientific breakthroughs. It really requires sustained commitment by firms to:

- new product concepts,
- the painstaking development of product and process technologies, and
- changed forms of production and marketing.

Critical to innovation performance in the first instance are those factors that support or inhibit corporate managers in their asset creation decisions on which sustained innovation rests. These factors include:

- the availability of technological opportunities,
- incentives (such as research and development tax credits and general tax conditions),
- financial conditions,

- the nature of corporate organization, and
- especially, the impact of corporate governance procedures (such as the performance requirements of owners and financial markets) as they affect investment behaviour.

Factors external to the firm are also crucial in shaping innovation investment. This is so because innovations rarely result exclusively from knowledge-creating behaviour by firms themselves. This is particularly true of such radical innovations as computing, mobile telephony or biopharmaceuticals. All of these have emerged from major (and long term) public commitments. But it is also the case that smaller-scale innovations constantly draw on knowledge developed by collaboration partners.

This is so because innovations usually have a wide range of knowledge inputs, many of which originate outside the innovating firm. External knowledge inputs may include:

- technical standards,
- educational backgrounds of skilled personnel,
- contributions of collaborating firms, and
- knowledge flows from the science and technology infrastructure.

In innovation studies, these external factors and inputs are often referred to as part of the “innovation system” – a set of institutions and organisations that affect the overall creation and distribution of knowledge in society and, through that, the innovative performance of firms.

This suggests that to gain a useful and productive understanding the innovation activities of firms, one must also understand the innovation system in which firms are embedded. This way of approaching the innovative firm also provides a handle on policy, since some important elements of the innovation system are either directly provided by government, or are structured by policy decisions.

## **THE INNOVATING ECONOMY AND THE REFORM AGENDA**

Before turning specifically to innovation policy, it is important to consider a major aspect of change in the policy environment in recent years. In recent years the basic policy focus in Australia has been on macro- and micro-economic reform<sup>3</sup>: trade liberalization, deregulation of financial markets, privatisation, and labour market reform. This has been accompanied by attempts to reduce public expenditure as a proportion of gross domestic product, and by shifts in the provision of public services towards more market-oriented approaches. In Australia as elsewhere, this broad policy has had two aims:

- cost-reducing efficiency improvements that enhance productivity<sup>4</sup>; and
- creation of an economic environment that promotes sustained economic growth.

It is certainly too early for any serious evaluation of the effects of reform, although there are already comprehensive studies of reform processes that argue a strong link between reform and subsequent growth in output and productivity. For Australia, growth performance in recent years has been very impressive. However, it would be wrong to draw the immediate conclusion that reform has changed Australia’s long-run growth potential, for two reasons. The first is Australian growth since the

*It would be wrong to draw the immediate conclusion that reform has changed Australia’s long-run growth potential.*

1990s may have short-run determinants other than those of the changed policy environment. The second is that, in the longer term, recent policy change may have effects on the allocation efficiency of the economy, but not necessarily on its growth potential, which has a wider set of determinants that have quite complex inter-relationships.

The question of how economic reform affects long-run growth is difficult to answer. From a theoretical perspective, the economics discipline gives little clear guidance as to how moves towards greater allocative efficiency<sup>5</sup> in the short term may improve long-term growth potential. That is, no definitive, unambiguous link has been expressed between improving the deployment and use of available resources to maximise outputs in the short term, and changing for the better the capacity for net positive economic growth in the long term.

At the aggregate level, the measure of productivity for the total economy is usually given as output per worker per hour. This result can always be improved in the short term by making cost reductions, by the intensification of work, by extending working hours, and so on. But factors contributing to these outcomes are many and various, and their relative impacts ebb and flow over the long term. So improved productivity results in the short term are not necessarily indicative of fundamental change in the underlying determinants of productivity. These determinants are two things only: work organisation and technology<sup>6</sup>.

*The measure of underlying productivity in the economy is output per worker hour. Productivity itself depends on two things only: work organisation and technology.*

To elaborate, moves to better assign resources now will typically produce short term output gains, as resources are transferred to more productive uses, and as costs associated with a specific level of output decline (or more output is produced for the same costs). In the long term, countervailing and contradictory influences come into play, and may well negate or reverse the expected beneficial impacts of reforms.

To take an example, trade liberalization or similar economic reforms can have impacts on the prices and availability of capital and intermediate inputs, and the technologies that they embody. In the short term, this type of reform may drive down costs which are evidenced by productivity, but demonstrating a definitive chain of causation is problematic, and even more so over a time horizon beyond the short term. This is important for countries such as Australia which import most of their capital goods and which generally are technology importers.

**So, in the longer run, growth performance depends on a complex array of factors that may or may not be affected by the macro reform process, but that are rarely fully considered in assessing the likely outcomes of reform.**

First, there are effects on the scale and time horizons of investment by firms, and hence of levels of technology. Then, there are the effects on the institutions and organizations that affect the creation, maintenance, distribution and use of knowledge in the economic system. These include firm-level innovation capabilities, but also universities, research institutes, regulatory agencies, standards-setting organizations, and intellectual property systems.

At the level of firms, one significant effect of reform on capabilities comes via privatisation of publicly-owned enterprises. Around the world, under public ownership, utilities in such fields as energy and telecoms had major technology development capabilities, often maintaining significant research labs and creating important innovations with wide effects. Privatisation has affected these capabilities, with generally falling research and development intensities, and a greater focus on innovation related to current lines of business.

There is a second dimension of reform that is relevant to innovation performance. The wider set of knowledge institutions and agencies has also been subjected to reform of different types. In Australia, university administration and finance, the CSIRO system, and the

intellectual property rights framework have all changed. Some of the Australian reforms are driven by internal policy changes, while others stem from international initiatives (such as the intellectual property agreements within the WTO).

The basic thrust of such reform has been to connect such organisations more closely to the corporate sector, and to focus knowledge creation on commercialisation. The logic of this approach is based on a particular concept of innovation, one in which innovation consists of commercialising specific outputs of the research and development process. In the OECD economies, it is an article of faith that particular economies are good at research and development, but poor at commercialisation. It is certainly the core approach to knowledge institutions in Australia, where assessment of such institutions tends to focus on commercialisation. For example, a recent Government report remarked that “Australia’s commercialisation record has improved over time but remains low compared to other countries ... challenges remain in fostering science and innovation collaboration and linkages, especially between publicly-funded research providers and industry”<sup>7</sup>.

However, it is far from clear whether this kind of approach is an appropriate way of thinking about the tasks and functions of universities and research institutes, and alternative views are integral to the ideas posited in this paper.

The important question for long-term growth performance is the interaction between the reform processes related to efficiency and the reform processes related to knowledge. However, the problem here is not so much to assess the impacts of macro reform on knowledge creation and distribution, as to look forward to how knowledge-related policy issues should be approached in the contemporary economic context.

*The important question for long-term growth performance is the interaction between the reform processes related to efficiency and the reform processes related to knowledge.*

## **INNOVATION AND THE AGENDA OF GOVERNMENT**

Does innovation deserve a high ranking on what Keynes called the “agenda of government”? The answer to this depends on the conceptual and empirical evidence for a link between research and development, knowledge creation and economic growth outcomes.

From a policy standpoint, there are three broad questions concerning knowledge:

- Is there an identifiable link between knowledge and growth at all?
- Is the effect on growth of knowledge creation substantial?
- Is there an argument for public support of knowledge creation?

Within the economics discipline, such questions have usually been addressed by exploring the links between public and private research and development on the one hand, and between research and development and productivity on the other. A key question has been whether the social returns to research and development outweigh private returns, and thus provide an argument for public support based on private under-investment.

This section gives an overview of this literature, and then raises some questions about whether research and development is a good indicator of knowledge creation. To anticipate the conclusions, this section will show that there are strong associations between research and development on the one hand, and investment

*Research and development is certainly not the only knowledge input to production, or even the most important knowledge input.*

and productivity and growth outcomes on the other. But it will also argue that some important questions of interpretation remain, which turn on the fact that research and development is certainly not the only knowledge input, or even the most important knowledge input, in production.

Econometric approaches to returns on research and development ultimately derive from the pioneering work of Moses Abramowitz and Robert Solow on the sources of American economic growth<sup>8</sup>. The analysis suggested that output in the USA over the long run resulted not from increased inputs of labour and capital, but primarily from a residual factor which Abramowitz called "a measure of our ignorance" and which Solow labelled "technical change". Solow showed that over the period 1909 -1949 "gross output per man-hour doubled ... with 87.5 percent of the increase attributable to technical change and the remaining 12.5 percent to increased use of capital".

This startling result led to an extremely large research effort in the economics fraternity worldwide, to refine and test Solow's result both in other countries and over other time-periods in the US. One important theme in this work has been the need to adjust for improvements in the quality of capital and labour inputs (particularly labour as an effect of educational expansion).

The enormous literature which ensued could be summed up by saying that while the contribution of technical change to increases in per capita output is generally agreed to be less than Solow's estimates, it remains nevertheless by far the most important contributory factor in economic growth; invariably more important than increases in the use of capital.

*The contribution of technical change to increases in per capita output is by far the most important contributory factor in economic growth.*

The growth of output over and above the growth of capital and labour inputs is total factor productivity growth (sometimes multifactor productivity growth). Since it is such an important contributor to overall growth, it is extremely important to understand its sources: in particular, does it result from investments in research and development? Consequently, an important research program in applied economics and econometrics has essentially consisted of seeking statistical associations between output or total factor productivity growth, on the one hand, and research and development input on the other.

There are essentially two methods for studying the link between research and development and output, and two types of focus for such studies. The methods are case studies and econometrics, respectively, and the foci are firms on the one hand, and economy-wide country-level outputs on the other. In recent years, the economy-wide approach has expanded significantly, mainly as a result of attempts to test the propositions of "New Growth Theory". So there is a literature that basically divides into four (related) types: firm-level or economy-wide case studies, or firm-level or economy wide econometric or time-series studies.

What kinds of results have emerged from this major research effort? Even a brief overview of the relevant literature would be a lengthy document. However, in understanding the economic importance of technological change to the growth process, some well-established empirical results are relevant and worth noting. These are covered below.

### *Technical Change*

**'Technical change' is the most important contributory factor in economic growth. In this context, technical change refers to causes of economic growth other than increased inputs of capital and labour. It can therefore include new techniques, organisational change, better education and knowledge and so on: all of the components of technological change broadly defined.**

In a challenging study in the mid-1950s (see above), Solow showed, in an analysis of the long-run sources of US economic growth, that technical change accounted for almost 90% of the growth of output in the US between 1909 and 1949; increased use of capital and labour played a relatively insignificant role.

This led to a substantial body of work from a variety of perspectives, both in the USA and internationally, to check the validity of Solow's work. Although some studies have argued for a lower contribution by technical change to growth, all have confirmed that it is indeed the most important contributory factor in shaping the rate of growth of output, particularly in the post-war period.

### *Innovative Activity*

Innovative activity, as measured by research and development and by patenting, is closely associated with the level of output and income at country level. There are of course significant differences in the level of income per capita among the countries of the world. These differences are strongly correlated with inventive and innovative activity, as measured by research and development per capita and the extent to which a country patents new inventions. That is to say, countries with higher levels of inventive and innovative activity also tend to have higher levels of gross national product per capita<sup>9</sup>.

### *Social Rates of Return*

Social rates of return to research and development are consistently higher than private rates of return<sup>10</sup>. This suggests that inter-sectoral spillover effects of research and development are as important, or more important, than the direct effects of such investment. It has been shown<sup>11</sup> that social returns are higher than private returns across a set of industries, with the highest margins being (as would be expected) in those industries that provided capital or intermediate inputs. Some years ago, Mansfield<sup>12</sup> estimated economy-wide benefits from academic research and development surveying a sample of large USA corporations, in this case 76 firms in 7 industries. He asked research and development and production executives responsible for commercial innovations for data "concerning the proportion of the firm's new products and processes that ... could not have been developed (without substantial delay) in the absence of academic research carried out within 15 years of the first introduction of the innovation"<sup>13</sup>. Sales of such products turned out to be about 5% of US manufacturing output. The costs of this were all academic research costs, world-wide. This led to an internal rate of return to academic research and development of 28 percent per year: clearly a very high figure, implying high social returns.

### *Productivity Growth at Firm Level*

Research and development is strongly associated with productivity growth at firm level. One of the main ways in which companies and countries seek new technologies is through research and development, and this has led many economists to explore links between the level of expenditure on research and development and the rate of productivity growth, especially at company level. A consistent result of such work has been that there are indeed positive and significant correlations between productivity at firm and industry level, and the amount of research and development which firms and industries perform<sup>14</sup>.

### *World Trade Shares*

Shares in world trade, at industry level, are correlated with innovative activity. Within technology intensive industries, the degree of innovative activity (again measured by research and development and patenting) is the most important determinant of export performance by the industries of particular countries. That is, within any particular industry, countries with higher levels of innovative activity have higher shares of world trade<sup>15</sup>.

## *Public Research & Development Returns*

There are strong returns to public research and development. Such issues largely have been studied econometrically. For the OECD as a whole, publicly funded research and development is a very substantial part of the overall research and development effort – often more than 50% of research and development in particular countries. There are two potential effects of this:

- public research and development can generate specific commercialisable outputs that affect growth and productivity directly; and
- it can provide background knowledge that stimulates research and development by firms.

In a major cross-country study testing this, carried out in the OECD<sup>16</sup>, it was shown that public research and development has positive but limited direct effects on productivity, but also has important effects via stimulating business research and development.

### **RESEARCH & DEVELOPMENT, KNOWLEDGE AND GROWTH – A PRELIMINARY ASSESSMENT**

The results described above provide a strong rationale for concluding that research and development performance and innovation activity have very important impacts on economic performance more generally. In general, all quantitative studies (whether based on case study or econometric approaches) have shown strong links between:

- measures of scientific and technological performance (including not only research and development data, but also using such indicators as patents and bibliometric data); and
- levels and rates of growth of gross domestic product.

Much of this work has focused on the USA, but the results have also been found in cross section studies, and in studies of rapidly industrializing countries such as South Korea.

There is a clear scientific case, deriving from this work, for regarding science and technology as key inputs to innovative behaviour and to long-term growth. There is also a substantial and growing literature using direct innovation data, mainly drawn from the EU's Community Innovation Survey, that suggest strong links between wider measures of innovation and firms performance and growth<sup>17</sup>. All this suggests a strong prima facie case for placing science, technology and innovation high on the agenda of government.

However, there are some very basic difficulties with these approaches which mean that they cannot be drawn upon directly as an approach to policy. A first problem is that, intentionally or not, they picture research and development (and often direct research and development by firms) as the only significant input to innovation and technology creation.

*It is not valid to picture research and development as the only significant input to innovation and technology creation.*

**This leads to a misrepresentation of the technological change process (by focusing excessively on research and development as an input), and in particular to a more or less complete neglect of non-research and development aspects of the innovation process.** Moreover, focusing primarily on research and development as an input leads to an underestimation of the costs of innovation (and hence to an overestimation of the returns to research and development).

At the very simplest, returns to research and development are overestimated when non-research and development inputs are neglected. But there are also methodological

problems: if the innovative process involves not only research and development but also improved labour skills, changed organisation, enhanced equipment and so on, then the inputs to innovation relate to labour inputs and the capital stock as well as to research and development. These inputs are not separable and returns cannot be estimated in isolation.

The really important problem here is that the **overemphasis on research and development leads to the adoption of some version of the so-called 'linear model' of innovation – namely the idea that innovation is essentially based on processes of scientific or technological discovery, and that the innovation process consists of translating research results into new products.**

*Very few industries innovate in the manner of the "linear model" of innovation.*

**In this approach, innovation depends on science or research and development as its originating moment, and then sequentially develops discoveries into engineering concepts and then into product development. In fact, very few industries innovate like this.**

A different (and equally simplified) view of innovation would be that firms seek to develop new product concepts in response to conjectures about market dynamics. They try to build such products on the basis of their existing technological capabilities. If they run into irresolvable problems in the development process, then they may turn to research and development for a solution. However, research and development is expensive and uncertain in outcome, and really a last resort.

Such points suggest a need for a more nuanced approach to the understanding of innovation processes, especially as basis for analysing the role of government in support of innovation. The following section looks at some of the issues involved.

## **WHAT DO KNOWLEDGE-CREATION & INNOVATION REALLY LOOK LIKE?**

This section sketches a wider framework for addressing issues of knowledge creation and innovation. **Suppose that, instead of seeing knowledge in terms of direct research and development, some more differentiated notion of technological knowledge is adopted.** This would involve two changes to 'conventional' thinking about processes of knowledge creation:

- First, it would imply attention to indirect research and development as a source of knowledge across industries.
- Second, to non-research and development forms of learning and knowledge, such as engineering experimentation, skill development, design activities, etc.

Any technology concept must involve knowledge, but this should not be seen simply as the kind of generalised knowledge, of the kind that is implicit in much economic theory. Rather, technological knowledge often takes the form of tacit, non-codified knowledge, and skills related to the use of hardware. Such knowledge

*Technological knowledge often takes the form of tacit, non-codified knowledge and skills related to the use of hardware. Such knowledge is localised and hard to transfer.*

is localised and hard to transfer. These modes of knowledge are usually produced by on-the-job training, by learning associated with normal engineering activities, by learning-by-doing and learning-by-using. That is, they are not a result of research and development. Productive knowledge can also be embodied in equipment, with its rules of operation; this means that equipment acquisition, adaptation and maintenance are key elements in technology. Finally, and perhaps most importantly, technology must involve organisation: knowledge, skills and equipment can only be put to work in a framework of managerial and cooperative relationships.

**The spinning point involved is that just as technology is much more than abstract knowledge, so changing technology involves forms of learning that extend well beyond research and development.** Of course, if research and development is not necessarily the primary source of technological innovation, then the returns to innovation are returns to a much wider set of activities than research and development (which have a very different cost structure).

The question then becomes how do research and development and non-research and development elements of the innovation process interact to generate technological change? Such questions have important implications for the nature of innovation policy, suggesting that it should not be seen simply as a matter of research policy, but there are implications also for understanding the returns to innovative activity.

If knowledge creation extends further than research and development, then it follows also that the innovation process will consist of much more than the commercialisation of research and development. What is actually known about innovation processes? Here it is important to note that innovation research has been a major area of growth in recent years, and that there has in fact been a major program of studies on innovation over the past two decades.

*If knowledge creation extends further than research & development, then the innovation process is more than the commercialisation of research and development.*

What has been learned from this? This section attempts to sum up some of the results, and their relevance for policy challenges. In summing up innovation research, there are core results that are 'robust' in the sense that they are strongly confirmed by widely applicable data and empirical research across countries and industries. These results are covered in the remainder of this section.

Within the mainstream of the economics discipline, the operation of firms is in general not seen as problematic. Firms make optimal decisions (concerning both what to produce and how to produce it) in the face of more or less well-defined decision environments, and the capabilities that are needed for this are usually neither in question nor in focus. Innovation, however, rests on quite specific and differentiated areas of competence and capability that must be constructed. This in turn requires investment in tangible and intangible assets, the latter including a wide range of skills and knowledges that make up the intellectual capital of the enterprise.

The process through which this happens is complex and highly problematic. There are difficult issues concerning strategic decision-making, and managers face a constant tension between, on the one hand, the demands of current production and the requirements of current profitability, and on the other, the need to create assets for the future. The inherent difficulty is partly that the commitment of resources reduces current profitability (in the context of competing claims for these resources), and partly that the innovation process is unpredictable and uncontrollable, and outcomes are often radically uncertain.

*Innovation outcomes rest on complexity and variety in investment patterns that transform the capabilities of enterprises.*

At the same time, there is no general path towards innovative success, and this introduces considerable diversity and variety in approaches to innovation, even among enterprises in similar lines of business, let alone across industries and sectors. From the perspective of enterprises, the implication is that innovation rests on the ability of managements to engage in knowledge creation and

*Innovation requires engaging in knowledge creation and asset building in experimental circumstances where no methodological guidelines exist.*

asset building in experimental circumstances where no methodological guidelines exist. From a theoretical perspective, there must be doubts about whether any general theory of innovation is possible<sup>18</sup>.

Innovation is not something that happens only in a relatively small group of high-technology industries, nor something that is driven by a small set of industries or technologies. The new innovation data, particularly from the EU, show clearly that innovation in the sense of development and sales of new products is distributed right across the system in all advanced countries. Industries that are regarded as 'traditional' or mature or 'low-tech' often generate substantial amounts of sales from technologically new products and processes. Likewise, the service sector is also strongly innovative, across almost all of its component activities, and this is particularly important since the service sector is the largest sector in all advanced economies<sup>19</sup>.

*Innovation is pervasive.*

Enterprises very rarely innovate without technological cooperation or collaboration. Knowledge creation happens through an interactive process with other enterprises, organisations, and the science and technology infrastructure and so on. Empirical research in a number of countries (under the auspices of the OECD) has shown that:

*Innovation relies on collaboration and interactive learning.*

- innovating enterprises are invariably collaborating enterprises,
- collaboration persists over long periods, and
- the publicly-supported infrastructure (such as universities and research institutes) is important collaboration partners.

This is strong empirical confirmation of the idea that innovation should be seen as a collective phenomenon<sup>20</sup>.

Innovation involves fundamental uncertainty, both in technological and in economic terms. It has very rarely been possible to predict the path of innovation, even in general terms. It is rarely possible to predict the economic outcomes for new products and processes. Enterprises very often make major forecasting mistakes, even when they are very well informed, and managed by highly competent and knowledgeable people. This leads to major problems for enterprises in making investment decisions involving innovation activity<sup>21</sup>.

*Innovation is highly uncertain.*

Geographic clustering appears central to competitive advantage, a result that has emerged from a wide variety of studies. 'Horizontal' clusters – meaning groups of enterprises in the same line of business – are widely found, and seem to be associated with better economic performance of enterprises in the clusters. Vertical clusters, meaning sustained relationships between enterprises upstream and downstream from each other, can be identified using input-output techniques, and reflect country specialisations that often differ widely. There is some evidence that cross-border clusters may be becoming more important. These patterns of specialisation are cumulative, built up over long periods, and appear to be hard to change<sup>22</sup>.

*Clusters are important, and reflect national and regional patterns of industrial and technological specialisation.*

The science system is important for innovation, and there is a strong interaction between technology and science. Many inventions draw on science; for example, analyses of patents show that there have been dramatic increases in citations from patents to scientific research,

*There is strong science - technology interaction in innovation.*

and that a very high proportion of the papers cited are produced within public sector scientific research organisations. Other studies have shown strong but indirect interactions, through which industries both affect the process of scientific research and use its results. Many traditional industries, from this perspective, draw intensively on scientific results in industry-level knowledge bases. Although science does not provide the raw material for innovation in any simple way, it remains a key element of industry knowledge bases across the economy, including in low tech industries, and therefore a key element of innovation capability<sup>23</sup>.

One of the most persistent themes in modern innovation studies is the idea that innovation by enterprises cannot be understood purely in terms of independent decision-making at the level of the enterprise. Apart from collaboration, discussed above, there are broader factors shaping the behaviour of enterprises: the social and cultural context, the institutional and organisational framework, regulatory systems, infrastructures, and the processes which create and distribute scientific knowledge, and so on.

*Innovation is systemic.*

Taken together these factors make up a system, and system conditions can have a decisive impact on the extent to which enterprises can make innovation decisions, and on the modes of innovation which are undertaken. These characteristics suggest important differences between economies, and between the ways in which innovation occurs across economies, that persist over time<sup>24</sup>.

Are the general characteristics of innovation, outlined above, relevant to Australia? The following section explores some of the empirical aspects of innovation in Australia, before addressing some business and policy issues.

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## THE AUSTRALIAN INNOVATION SYSTEM – BASIC DIMENSIONS

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This section is not a detailed discussion either of the nature of the Australian innovation system<sup>25</sup> or of the structure of the Australian economy, either of which would go beyond the scope of this paper. Rather, this section makes some general empirical points about the Australian structure, and then looks at what is known about innovation in Australia at the economy-wide level, in terms of resources devoted to innovation, and outputs and impacts of innovation processes in Australian firms.

Australia possesses an industrial structure relatively heavily focused on agricultural and resource extraction activities, a large services sector (with education and health as the largest components), and a company demographic structure strongly shaped by the effects of Foreign Direct Investment (FDI). Within manufacturing, there is a very small high-technology sector, and large medium and low technology sectors (using the OECD definitions of these terms).

This is shown below in Figure 1:

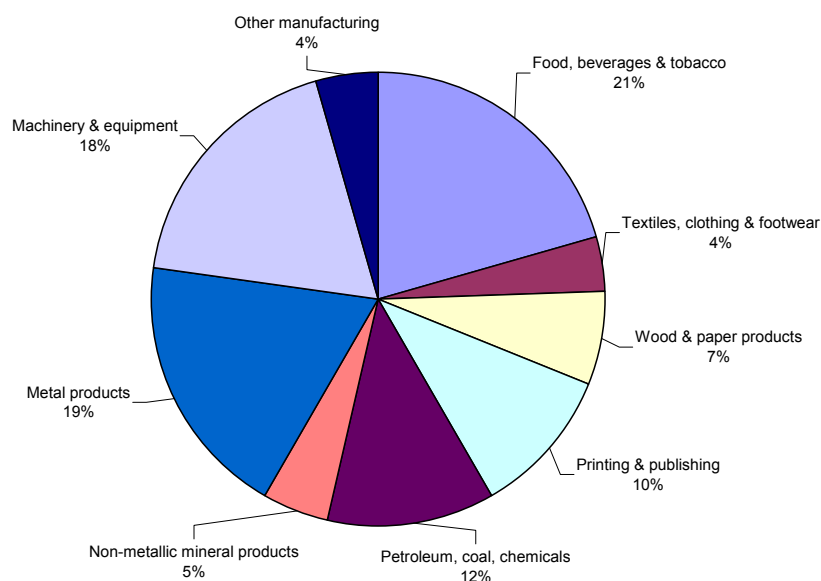


Figure 1: Share of value added within Australian manufacturing, 2002-03<sup>26</sup>

The really big sectors are machinery, metal products and food products. The small high technology activities are dominated by foreign multinational corporations, while there are significant proportions of small-to-medium enterprises within the mid-ground and “low-tech” sectors. These simple points lead to some immediate issues concerning innovation, and especially the possibilities for innovation-based growth. First, unless there is some substantial effort to change the industrial structure towards “high-tech” activities, then innovation and growth are not likely to emerge in such typically “high-tech” sectors as information and communications technology or pharmaceuticals, nor is it likely to emerge

from the existing multinational corporations sector. Second, if growth is to be based on medium and low technology manufactures and services, then there will be a need for greater attention to factors promoting the growth of firms.

What can be said about general dimensions of innovation in Australia in relation to these issues? Turning to an empirical discussion of some basic facts about innovation from an economy-wide perspective, the discussion rests on data emerging from the 1993 ABS survey of Australian firms<sup>27</sup>. The primary aim of the ABS survey was to develop internationally-comparable data on the following topics:

- data on numbers of firms engaged in innovation activity, such as new product development, new process implementation and organisational change;
- expenditure on activities related to the creation of new or technologically changed products (these activities include research and development, training, design, market exploration, equipment acquisition and tooling-up etc);
- outputs of new or significantly changed products, and estimates of sales flowing from these products;
- sources of information relevant to innovation;
- technological collaboration and linkages in the innovation process; and
- perceptions of obstacles to innovation, and factors promoting innovation.

Three primary points emerge from this data:

- Innovation by Australian businesses is spread across all industrial sectors. New product development, and the implementation of new processes, are widely distributed across all industries. Innovation is not just a matter of high technology activities, and is equally found in so-called “low-tech” sectors, including resource-based sectors.
- Firms do not generate innovation simply via research and development. On the contrary, they commit significant resources to innovation across a range of non-research and development inputs, such as training, design activities, trial production and engineering development, and so on.
- Financial risk is perceived as a major obstacle to innovation.

So, how widely is innovation activity dispersed across the Australian industrial structure? The ABS survey covered manufacturing and services sectors, and defined innovating firms as those introducing new products, those implementing new processes or those introducing an organisational innovation. This ‘screening’ question enables us to look at the proportions of firms in each industry that are engaged in some form of innovative activity. Table 1 shows the broad dimensions of this:

	%
Mining	30.9
Manufacturing	45.5
Electricity, gas & water	50.8
Construction	30.7
Wholesale trade	42.9
Retail trade	31.4
Accommodation, cafes and restaurants	26.5
Transport & storage	34.9
Communication services	51.1
Finance and insurance	44.3
Property and business services	31.7
Cultural and recreational services	36.7
<b>Total</b>	<b>34.8</b>

Table 1: Innovation by ANZSIC Industry, 2001 - 2003<sup>28</sup>

The main point here is that, as in other countries, innovation is widely dispersed across sectors. The mean is reasonably high (indicating that more than a third of firms are innovating across the board), while the dispersion around the mean is rather low (indicating that there are no strikingly innovative sectors, and no strikingly non-innovative sectors).

Taken together, this means that innovation in Australia is multi-sectoral in character, it is sectorally pervasive, and is certainly not confined to high-tech activities.

It was argued earlier that research and development is only one form of innovation cost for firms, and that there are many other dimensions of innovation expenditure that need to be taken into account. Is this also the case in Australia? The ABS survey asked for estimates of expenditure on such non-research and development innovation activities as training, market research, design, engineering development, etc. The results are shown for all firms in Table 2:

	\$m
Expenditure on R&D	5800.6
Expenditure on innovation	13123.4
<b>Total</b>	<b>18924.0</b>

Table 2: Expenditure on Innovation and Research & Development, Innovating Businesses 2002 - 2003<sup>29</sup>

The important point to note here is that non-research and development expenditures on innovation amount to more than double research and development expenditures. This is a result which accords with results from innovation surveys in other countries, notable in all member states of the EU, which show substantial levels of non-research and development expenditures on innovation.

*Innovation expenditure is skewed strongly to non-research & development activities.*

For Australia, this result immediately suggests that:

- The current policy emphasis on research and development, and research and development-based firms, exemplified through such measures as research and development tax credits, is at best a partial way of supporting innovation.
- The financial commitments of firms to innovation are far larger than can be grasped through the research and development figures, and this implies that the financial risks being borne by firms are very substantial indeed.

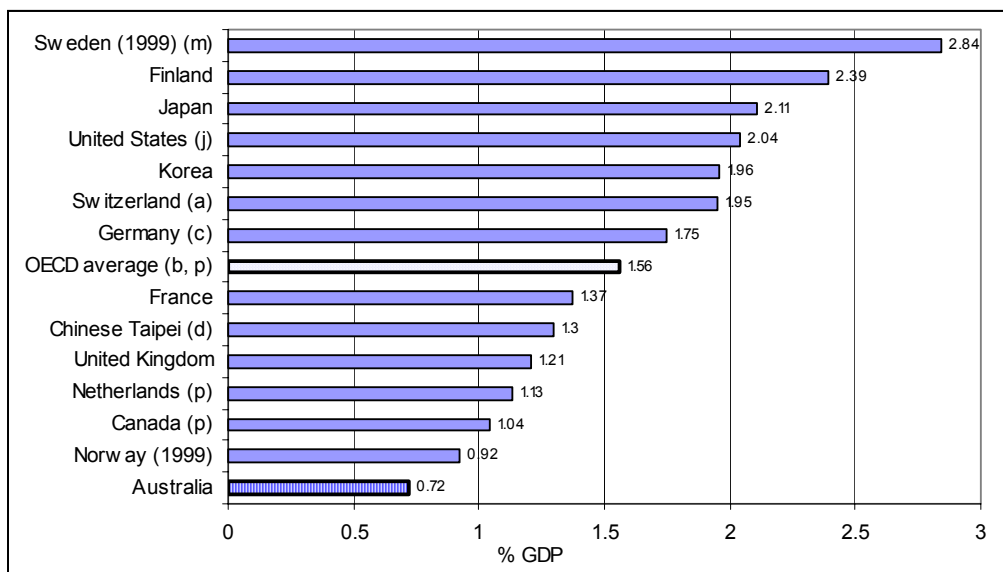
The issue of financial risk associated with innovation should be seen in the context of how firms perceive hindrances and obstacles to innovation. The ABS survey explored this also, asking firms to rank various forms of obstacles to innovative activity. Table 3 shows the results related to financial aspects of innovation:

<i>Cost-related barriers</i>	<i>%</i>
Excessive economic risk perceived by business	24.4
Excessive economic risk perceived by financiers	6.7
Cost or availability of finance	19.2

*Table 3: Obstacles to innovation  
(proportion of firms reporting an obstacle as important)<sup>30</sup>*

What can be said about Australia's performance compared to other countries? Because of the non-comparability of the innovation data, the discussion unavoidably falls back on research and development data (which has higher, though far from perfect, comparability).

Australia is well known to have a lower overall research and development intensity (intensity being measured as research and development expenditures as a percentage of GDP) than most OECD economies. This is shown in Figure 1 below, and is often argued to be a very basic problem for Australia:



*Figure 2: BERD as a percentage of GDP, selected OECD countries, 2000<sup>31</sup>*

However, it is important to distinguish between two different potential causes of this relatively low research and development intensity.

It could be an effect of the industrial structure, since countries with a large proportion of output coming from research-intensive industries will naturally have a higher research and development intensity than countries with larger shares of low research-intensive industries. So:

- Does this result simply from the fact that Australia has only a very small share of output coming from high technology industries that perform a lot of research and development?
- Alternatively, is it that Australia performs badly across the board?

Turning to industrial research and development intensities (that is research and development to GDP ratios) across a number of sectors and industries, and using OECD data from the STAN and ANBERD databases<sup>32</sup>, Table 4 compares Australia with three small economies with roughly comparable industrial structures:

		<i>Australia</i>	<i>Belgium</i>	<i>Denmark</i>	<i>Finland</i>
	<i>ISIC</i>	<b>1999</b>	<b>2001</b>	<b>1999</b>	<b>2001</b>
<b>TOTAL MANUFACTURING</b>	<i>ISIC Rev.3</i> <b>15-37</b>	<b>3.11</b>	<b>7.66</b>	<b>6.00</b>	<b>9.36</b>
FOOD PRODUCTS, BEVERAGES AND TOBACCO	15-16	1.01	1.66	1.48	2.34
TEXTILES, TEXTILE PRODUCTS, LEATHER AND FOOTWEAR	17-19	0.81	3.59	0.81	2.60
WOOD, PULP, PAPER, PAPER PRODUCTS, PRINTING & PUBLISHING	20-22	0.76	1.07	0.34	1.29
WOOD AND PRODUCTS OF WOOD AND CORK	20	..	1.21	0.58	1.62
PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	21-22	..	1.03	..	1.23
CHEMICAL, RUBBER, PLASTICS AND FUEL PRODUCTS	23-25	4.42	14.02	17.45	12.22
....COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	23	1.12	2.92	0.00	5.78
....CHEMICALS AND CHEMICAL PRODUCTS	24	6.93	17.77	23.71	17.57
.....CHEMICALS EXCLUDING PHARMACEUTICALS	24ex2423	..	..	8.06	7.05
.....PHARMACEUTICALS	2423	..	..	33.58	63.73
....RUBBER AND PLASTICS PRODUCTS	25	1.53	4.38	4.36	6.01
OTHER NON-METALLIC MINERAL PRODUCTS	26	0.83	2.90	1.21	1.70
BASIC METALS AND FABRICATED METAL PRODUCTS	27-28	2.24	3.28	1.04	3.60
....BASIC METALS	27	..	..	1.23	2.88
.....IRON AND STEEL	271+2731	..	..	8.53	2.04
.....NON-FERROUS METALS	272+2732	..	..	0.14	4.80
....FABRICATED METAL PRODUCTS, except machinery and equipment	28	..	..	1.00	4.05
MACHINERY AND EQUIPMENT	29-33	9.56	16.52	9.45	19.76
....MACHINERY AND EQUIPMENT, N.E.C.	29	5.10	6.45	7.13	7.33
....ELECTRICAL AND OPTICAL EQUIPMENT	30-33	13.62	24.67	12.36	25.90
.....OFFICE, ACCOUNTING AND COMPUTING MACHINERY	30	..	..	13.93	23.37
.....ELECTRICAL MACHINERY AND APPARATUS, NEC	31	..	..	8.10	14.64
.....RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	32	..	..	12.99	30.18
.....MEDICAL, PRECISION AND OPTICAL INSTRUMENTS	33	..	..	15.57	11.04
TRANSPORT EQUIPMENT	34-35	6.71	4.79	6.36	4.40
....MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS	34	8.14	..	..	3.69
....OTHER TRANSPORT EQUIPMENT	35	3.96	..	9.89	4.76
.....BUILDING AND REPAIRING OF SHIPS AND BOATS	351	..	..	13.20	2.05
.....AIRCRAFT AND SPACECRAFT	353	..	..	..	8.09
.....RAILROAD EQUIPMENT AND TRANSPORT EQUIPMENT N.E.C.	352+359	..	..	0.61	16.87
MANUFACTURING NEC; RECYCLING	36-37	..	2.24	1.44	2.79
ELECTRICITY, GAS AND WATER SUPPLY	40-41	0.37	0.70	0.25	2.02

Table 4: 4 country comparison of research and development intensity<sup>33</sup>

The key point emerging from this is that the differences in overall research and development intensity between Australia and the other economies, in particular Finland, do not appear to follow from the industrial structure. It appears to follow from the fact that Australian research and development intensities are lower across all industries.

At its simplest, the explanation is of the difference is not that Finland has a higher research and development intensity than Australia because it possesses companies such as Nokia who are performing massive amounts of research and development in information and communications technology, with a much larger telecommunications sector. Rather, the explanation is that Australia has a lower research and development intensity than Finland because it is weak precisely in the large mature industries in which it is specialised, such as food products, wood products, basic metals, machinery and utilities. Australia has a higher research and development intensity than these comparable economies in only one sector, namely transport equipment, where the vehicle industry consists entirely of multi-national corporations.

A final point to be made about the empirics of innovation in Australia is that innovation across the large sectors of the Australian economy seems to depend heavily on collaboration between innovating firms and other firms (both suppliers and customers, but sometimes competitors), with consultants, with technical institutes and with universities.

Moving away from the ABS survey (which does collect data on this topic, but which also has some significant survey design issues), a specific survey on collaboration was conducted by AEGIS at the University of Western Sydney<sup>34</sup>. This survey covered a representative sample of about 2000 firms in Australian manufacturing. Table 5 shows that the proportions of innovating firms uncovered by this survey are similar to those of the ABS survey.

The important point is that very high proportions of innovating firms are also collaborating firms. Across all sectors, innovation appears – as the innovation research described above suggested – that innovation in Australia is a collective process as it is elsewhere. Innovation in Australia is not simply a matter of individual innovating firms.

Industry sector	% of which innovating	% of which collaborating
Wood, paper	17	88
Printing, publishing	20	73
Metal products	32	88
Textiles, clothing, footwear	37	65
Food, beverages, tobacco	43	89
Other manufacturing	44	80
Petroleum, coal, chemical	46	89
Non-metallic minerals	50	86
Machinery, equipment	53	85

*Table 5: Innovation & collaboration in Australian manufacturing sectors (percentages, unweighted)<sup>35</sup>*

This data suggests a structure of innovation activity and expenditure in Australia that does not at all accord well with either Federal or State government priorities and actions, which tend to emphasise “high-tech” research and development and the commercialisation of research and development results. This appears to be a structure of extended innovation that is distributed across all industries, and that has very substantial non-research and development elements. Innovation in Australia has strong elements of collaboration across organizations, and faces serious obstacles in terms of finance.

Broadly speaking, this conclusion appears to conform to results from innovation surveys across other countries, although direct comparisons are unfortunately impossible (since the ABS survey differs significantly in its design characteristics from those of the EU). The question is how to adapt both business strategies and public policy to these empirical dimensions of innovation in Australia.

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## AUSTRALIAN INNOVATION – CHALLENGES FOR POLICY

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The Australian Government's recent report *Mapping Australian Science and Innovation* is an interesting point of departure for discussing current policy perspectives on the knowledge economy. The report's point of departure is somewhat contradictory, remarking that:

*...all technological innovations can be traced back, at least in part, to science and engineering. In some areas, such as biotechnology, information and communication technology (ICT), medicine and new materials, scientific progress is particularly important in driving innovation. In addition, firms can innovate by improving production and manufacturing processes, changing management practices, and modifying or acquiring new equipment. Much innovation is incremental, involving small improvements to existing technology or practices.<sup>36</sup>*

The latter forms of innovation – which themselves are far from complete in terms of established knowledge about how innovation happens – do not at all accord with the opening science-based perspective. However, the report handles this contradiction in a simple way - by ignoring company-level innovation and devoting all of its significant attention to the science system.

There is a relentless focus on science and scientific publication, on patenting, commercialisation and information and communications technology diffusion. The report lacks any systematic structure of analysis, and there is a very wide range of ill-digested material on quite a variety of topics. However, underneath a barrage of data on research and development, publication, patenting and education there is a persistent idea: that science creates innovation capability, and even that scientific publication is in some way an indicator of innovative creativity.

Lacking any coherent view of innovation processes in Australia, and not making any use at all of Australia's innovation data, the report consequently pays no attention to the knowledge bases underpinning production and innovation in Australia. **What if patterns of innovation in Australia do not rest on prior scientific discovery? What if innovation only rarely occurs via commercialisation out of the public sector?** Such issues are not answered because they are not addressed, since the report adopts a purely science-based approach to innovation, presupposing that science capacity determines innovation capability.

This emphasis is reflected in policy priorities. In Australia – as in virtually all other advanced countries – this leads to priority research policy areas placing a strong emphasis on information and communications technology, biotechnology, and nanotechnology<sup>37</sup>. These fields, and by extension the industries based on them, are intensive in their use of research and development, science-based and closely linked to university research. The argument behind this set of priorities is partly that industries such as information and communications technology hardware and software, pharmaceuticals (including biopharma), and semiconducting materials have shown rapid growth in output and trade (although not in Australia), and partly that they represent a new paradigm for the 'knowledge-based economy'. These arguments are misplaced however, because growth is not confined to such industries, and neither innovation nor major knowledge creation and use are confined to these industries.

In this context, there are three pivotal policy challenges which are outlined below.

## **ADDRESS THE PRIMARY OBSTACLES**

Addressing the real policy problems related to Australian industry requires two shifts of focus. The first is to address the primary obstacles to the growth of innovating firms. Australia has significant numbers of innovating firms but they appear to have major problems of growth. Certainly Australia has not succeeded, as other advanced small economies have, in creating a population of dynamic domestic firms able to act globally and to survive in the leading echelons of their sectors at global level. The comparisons with the Netherlands, Belgium, Sweden, and Finland are very instructive here. The basic problem appears to be the ways in which corporate strategies are inhibited by problems of risk as scale increases. One of the arguments here has been that innovation strategies require the sustained commitment of significant financial resources. In the face of the major uncertainties and risks associated with innovation, the economic risks are very great indeed.

Potential solutions to this include the development of more sophisticated taxation incentives, extending well beyond the research and development tax credit. This might include tax credits related to wider innovation costs, as well as incentives related to profit taxation on innovative products. A second area for potential development might include a system of income-contingent loans, run through the existing banking system but backed by government, aimed at enhancing overall investment in innovation by sharing and spreading risk<sup>38</sup>.

## **CLARIFY ROLES FOR BEST IMPACT**

Beyond this, there are major problems related to the knowledge infrastructure on which Australian industry rests. This is currently in the throes of sustained change, largely aimed at enhancing the social and economic relevance of the research and development and knowledge-creating and knowledge-maintaining activities which the infrastructure supports. There is nothing wrong with these objectives, but there are many problems in how they are being approached. The infrastructure should support the creation and evolution of the background knowledge bases on which Australian industry rests. It should not be aiming at taking over the tasks of business, which are the elaboration of new product/process concepts, and the commercialisation of technology. This confusion of roles is likely to be unproductive, and Australia badly needs a new oversight body to determine the functions, governance and funding of its knowledge infrastructure.

## **INTEGRATED EFFORT**

There is one final task of policy. Innovation systems work well if they fulfil certain overall functions well. At the broadest level, these include the creation of capabilities and skills, the management of risk, and the maintenance and growth of knowledge bases. But innovation systems should also be able to recognise opportunities. This means that they need mechanisms for identifying potential innovation-based economic opportunities, directing resources towards search and elaboration of technological alternatives, and redirecting infrastructures in support of such opportunities. This is a strategic function, requiring a strategic forum that integrates business, policymakers and the knowledge infrastructure. Such a development might incorporate functions of foresight, economic analysis, monitoring, co-ordination, and long-term research and development. Such long-range functions can be found in some economies, such as Finland, and have often provided important inputs to the long-run shape of economic development. Such a forum, with its appropriate back-up, is urgently needed in Australia.

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## ENDNOTES

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- <sup>1</sup> Smith (2004), the other paper in this compendium
- <sup>2</sup> Smith and West (2005)
- <sup>3</sup> Economic reform is conventionally defined as policy change aimed at improving the efficiency of resource allocation in the economy in question (whether national, regional or local).
- <sup>4</sup> In the economics discipline, productivity is the output produced per unit of input, and is usually measured as 'labour productivity' (output per worker or labour-hour) or 'total factor productivity' (any change in output owing to factors other than growth in inputs, notably technological change or the adoption of more efficient techniques).
- <sup>5</sup> Allocative efficiency (or sometimes static efficiency) is an economist's construct. Allocative efficiency is achieved when the deployment of 'scarce' resources (resources that are limited in their availability such as natural entities, capital, labour etc) is such that output is maximised with the given inputs, or a given output is produced with minimal (least possible) inputs.
- <sup>6</sup> Moreover, for economists productivity is ultimately a concept describing the effects of technology on output, and as such it is only temporarily affected by measures aimed at costs.
- <sup>7</sup> DEST (2003), pp16-17
- <sup>8</sup> Abramowitz (1956), Solow (1957)
- <sup>9</sup> Fagerberg (1989), Fagerberg, Knell and Srholec (2005)
- <sup>10</sup> Griliches (1992), Griffith (2000)
- <sup>11</sup> Bernstein and Nadiri (1991)
- <sup>12</sup> Mansfield (1991)
- <sup>13</sup> *ibid*
- <sup>14</sup> Griliches (1987) did the pioneering studies on this, then Nadiri (1993) showed that gross firm-level rates of return tend to be between 20-30% across a wide set of industries.
- <sup>15</sup> For those interested in more detail, Fagerberg (1989) provides an empirical analysis within the context of a theoretical model of international competitiveness.
- <sup>16</sup> Guellec and van Pottelsberghe de la Potterie (2001)
- <sup>17</sup> See Smith (2004), the second paper in this compendium.
- <sup>18</sup> Van der Ven (1999, Part 1)
- <sup>19</sup> European Commission (2004, p.238-9)
- <sup>20</sup> See Howells (2000) for an overview of research on this topic, and OECD (2001) for a range of cross-country studies of innovation.
- <sup>21</sup> Rosenberg (1996)

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- <sup>22</sup> OECD, (1999)
- <sup>23</sup> Martin and Nightingale (2000)
- <sup>24</sup> Edquist (1997)
- <sup>25</sup> For a recent discussion, see Roos et al (2005)
- <sup>26</sup> Source: Australian Bureau of Statistics (2004)
- <sup>27</sup> Source: Australian Bureau of Statistics (2005)
- <sup>28</sup> Source: Australian Bureau of Statistics (2005)
- <sup>29</sup> Source: Australian Bureau of Statistics (2005)
- <sup>30</sup> Source: Australian Bureau of Statistics (2005)
- <sup>31</sup> OECD (1999) and OECD (2001)
- <sup>32</sup> For background on ANBERD, see [http://www1.oecd.org/dsti/sti/stat-ana/stats/eas\\_anb.htm](http://www1.oecd.org/dsti/sti/stat-ana/stats/eas_anb.htm)
- <sup>33</sup> Source: consolidated from OECD, STAN and ANBERD databases
- <sup>34</sup> As reported in Basri (2001) and Basri (2006)
- <sup>35</sup> Source: Basri (2006), Australian DISKO survey. For DISKO background, see <http://www.dest.gov.au/NR/rdonlyres/B1E59939-A49E-4599-92C1-324252B3D332/1354/linkages.pdf>
- <sup>36</sup> DEST (2003)
- <sup>37</sup> See [http://www.dest.gov.au/priorities/transforming\\_industries.htm#1](http://www.dest.gov.au/priorities/transforming_industries.htm#1) for an overview of Australia's research priorities in economic fields.
- <sup>38</sup> Smith and West (2005)



**THE KNOWLEDGE  
ECONOMY IN THE  
AUSTRALIAN  
CONTEXT**

**Professor Keith Smith  
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**April 2004**

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## EXECUTIVE SUMMARY

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This paper discusses the nature of the knowledge economy, and some of the challenges facing Australia in circumstances where business competitiveness and economic growth rest on innovation capabilities.

It is conventional to think of the knowledge economy in terms of a relatively small array of activities that are science-based or that are intensive in their use of research and development, including information and communications technologies, aerospace and biotechnology and pharmaceuticals. Public technology and research policies often focus on the so-called 'frontier technologies' which are held to underpin these and future high technology activities – electronics, genetics and molecular biology, nanotechnology and the like.

*It is conventional to think of the knowledge economy in terms of a relatively small array of activities that are science-based or that are intensive in their use of research & development.*

By contrast, this paper emphasises the fact that Australia – like other small advanced economies – is based not on such industries, but on low and medium technology industries in services and manufacturing. These include food processing (Australia's largest industry), metal products, chemicals, transport, mining, financial services, the hospitality industry and so on. These are mature industries that have persisted over very long periods. Yet they continue to grow, and considerable innovation is found within them. The Australian wine industry, for example, part of the food and beverages sector, has seen compound annual output growth rates of around 12% per year for more than 15 years – it is a high-growth industry by any standard.

Innovation in such industries is based not on research and development, but on the painstaking development of new product concepts. Knowledge creation in these industries has two main characteristics. On the one hand, there is substantial use of non-research and development knowledge inputs, such as design skills, market exploration, engineering development, in house training and the operational skills related to new capital goods. On the other hand, there is substantial use of research-based and scientific knowledge. However, such knowledge inputs are indirect – they flow into these industries from a distributed knowledge infrastructure of universities, research institutes, industry organisations, consulting engineers, and so on. The scope and significance of these knowledge flows are hard to measure and remain little understood.

The argument proffered here is that, as a result of these knowledge flows, apparently low-technology industries are often knowledge-intensive activities. In fact, they are the main bearers of the knowledge economy in Australia.

*Apparently low-technology industries are often knowledge-intensive activities because of the knowledge flows that they employ. In fact, they are the main bearers of the knowledge economy in Australia.*

With this in mind, public policy for this type of knowledge economy should have two dimensions:

- The maintenance, support and governance of the knowledge infrastructure. The paper argues in favour of "re-conceptualising" policy in this area, away from an emphasis on 'frontier technologies' and towards a focus on the complex knowledge bases of the industries Australia actually possesses.

- A greater focus on business transformation and development. Non-research and development forms of knowledge creation actually require sustained investment by firms in tangible and intangible assets. Public policies should take a more innovation-oriented approach to policy areas that impact on the investment capabilities and governance of firms.

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## INTRODUCTION

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The purpose of this report is to discuss the nature of the 'knowledge economy', its implications for Australia and innovation policy options and responses. The argument is that Australia faces quite specific policy challenges deriving from the fact that its economy rests on activities that are conventionally defined as low or medium technology industries.

There are problems with the conventional definitions. Many Australian industries are neither low growth nor low innovation activities, and they are major creators and users of knowledge. This paper makes the case, within such industries, innovation occurs on the basis of two specific forms of knowledge creation and use. These are a strong use of non-research and development inputs to knowledge creation, and major flows of knowledge (often in the form of high grade science-based knowledge) from other firms and from the 'knowledge infrastructure'.

*Within many Australian industries, innovation occurs on the basis of two specific forms of knowledge creation and use. These are a strong use of non-research and development inputs to knowledge creation, and major flows of knowledge from other firms and from the 'knowledge infrastructure'.*

The policy challenges are:

- to maintain and develop the knowledge infrastructure (especially universities, research institutes and industry-specific research agencies), and
- to create incentives and governance mechanisms that support investment by firms in these modes of knowledge creation.

The perspective here is that both creation and distribution of knowledge are economically important, primarily because they are the foundation of innovation, which in turn drives business and industry growth. Although many types of economic agents innovate, innovation happens largely through firms, and so knowledge and learning at the firm level are in focus here. However, firm-level innovation processes are strongly shaped by the industries in which firms are operating, and by the wider system of knowledge creation in universities, research institutes and related agencies.

What follows draws on these considerations and rests on two broad arguments. The first argument is that because processes of knowledge creation and use differ across industries, it is important for Australia to focus on the real characteristics of innovation processes in the businesses and industries on which the Australian economy rests. The second argument is that in such Australian industries, knowledge creation tends to be 'distributed' across many organisations, so innovation by firms or industries is best understood by keeping the wider context of knowledge creation in view. This context therefore plays an important role in the analysis which follows.

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# THE KNOWLEDGE ECONOMY

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## TOWARDS AN UNDERSTANDING OF THE KNOWLEDGE ECONOMY

How should one approach the idea of a 'knowledge economy'? In recent years, both business and policy attention to learning and knowledge have increased as a result of claims that knowledge-intensive industries are now at the core of growth, and that we have entered a new type of knowledge-driven economy. These claims usually rest on three main ideas:

- The idea that knowledge is now the key input to production, and is more important than capital investment or labour inputs.
- The idea that unskilled forms of work and employment are diminishing (at least in more developed economies), and that employment and income levels now depend on educational inputs and qualifications and specialised knowledge capabilities.
- The idea that economic growth at the present time is based on what are variously called knowledge-intensive, or science-based, or high technology industries (such as information and communications technology or biotechnology).

Although such ideas are widely accepted, and are even part of a current conventional wisdom, they are actually more difficult to assess than might first appear. They seem to be true for some countries but not others, for some time periods but not others, for some activities but not others. It is far from clear that these ideas are an appropriate way to think about the knowledge economy of our time.

For a start, it is important to remember that human economic activity has always been knowledge-based<sup>1</sup> and the claim that the modern market economy is science-based was being made a century and a half ago. So it is probably unwise to categorise the Australian economy, in terms of the general use of knowledge, as having had some decisive break with the past.

Nevertheless, there seem to be good grounds for thinking that knowledge creation and use are probably more intensive than in the past. There is statistical evidence from research and development surveys showing that over time research and development is absorbing a higher proportion of firms' expenditures across most industries. There is statistical evidence that non-research and development investment in knowledge creation is significant across industries. There is good evidence that educational enrolments and attainments have been rising steadily since the early 19th century. Finally, there is considerable case study evidence on innovation processes suggesting that knowledge is indeed an increasingly important resource for firms.

The large questions that arise out of this are:

- What kind of knowledge economy are we living in?
- How can we characterise the use of knowledge in this economy?
- What are the implications for public policy?

## THE SHAPE OF THE KNOWLEDGE ECONOMY

From analytical and policy perspectives, it could be argued that the prevailing understanding of the knowledge economy has been seriously one-sided. Most attention has focused on directly science-based industries, in the sense of industries with high levels of direct research and development and strong links to universities. Computing, aerospace, pharmaceuticals and biotechnology are the prime examples of such activities. Research policies have tended to focus on the 'frontier technologies' which are held to underpin these activities: data processing and software technologies, biotech products and techniques, new materials and nanotechnology in particular. These are the priority fields of the EU's current 6th FRAMEWORK programme, of Australia's Australian Research Council and the Backing Australia's Ability programs, and of most other advanced countries. In fact, there seems to be an unusual cross-country agreement on these priorities.

Quite apart from the dangers of duplication, there are several big difficulties in this. First, such policy approaches rest on a somewhat 'science - centric' model of innovation that stresses scientific discovery rather than learning as the basis of innovation, and thereby neglects the real characteristics of innovation in the activities on which particular economies actually rest.

Second, it might be added that such approaches also neglect the real complexity of science inputs across industries. There is a kind of asymmetric attention to 'frontier' knowledge fields (including scientific disciplines). Scientific fields that lie outside the alleged 'frontier' area, but which may be of strong relevance to particular economies, can easily be ignored or receive insufficient attention and support.

Third, little or no attention is paid to the roles of mature industries in shaping the creation and use of advanced technologies.

Finally, little attention is paid to heterogeneity across economies, to the fact that there is substantial diversity, and hence different patterns of knowledge creation and use across countries. It is very strange indeed that countries with widely differing industrial structures tend to share the same set of 'frontier technology' priorities.

High technology or science-based industries, and the technologies underlying them, are very important. But they are also very small. Taken together, these high-technology activities – using the conventional OECD definitions of high-technology industries - account for only around 3 percent of GNP in most OECD economies.<sup>2</sup> Any focus on these industries as the bearers of the knowledge economy automatically tends to neglect the role of major low and medium technology activities (both manufacturing and services) in the prevailing understanding of the knowledge economy.

This is a serious failing, because in Australia (as in most OECD economies in fact) these are the sectors on which the economy is really based. Industries such as food processing, timber products, printing and publishing, textiles and clothing, mining, wine, mechanical engineering, and services such as hospitality, transport, health or finance are large. They perform little direct research and development. Yet innovation survey data shows that innovation - in the form of the developing and marketing of technologically new or improved products - is occurring within all of these sectors, and many parts of these sectors are growing rapidly. For example, the food sector is growing only slowly (though rather steadily) across most OECD economies, but the sub-sector producing prepared fresh food is growing rapidly worldwide. The footwear industry has declined in terms of its share of manufacturing across the OECD, but sports footwear has grown rapidly both in volume and unit value.

*"High tech" industries are very important. But they are also very small.*

In Australia, an excellent example of this phenomenon is the wine sector. Table 1 shows a set of indicators implying compound growth rates in the region of 12-14 per cent per year.

In fact, the wine industry worldwide exhibits high growth of world trade, quality upgrading, substantial technological change, and growth in unit values. These performance results show that wine (an industry that has of course existed in the world for many millennia) is a growth industry by any definition. Examples of growth within such mature or traditional industries can readily be multiplied across many countries.

	1988	1992	1996	1999
Volume of wine production (000 hl)	4942	4585	6734	8511
Share of world wine production	1.8	1.6	2.5	3.0
Volume of wine exports (000 hl)	491	930	1481	2581
Exports as % of wine production volume	9.9	20.3	22.0	30.3
Exports as % of world wine export volume	1.2	2.0	2.5	3.7
Exports as % of world wine export value	1.3	2.4	3.6	5.3
Wine's share of value of all merchandise exports	0.26	0.49	0.72	1.37
Index of comparative advantage in wine	1.07	2.08	3.20	5.31
Unit value of wine exports (\$US per litre)	1.79	2.27	2.92	2.98

*Table 1: Growth of the Australian Wine Industry - Key Indicators<sup>3</sup>*

An important general point about the growth process, consistent with recent work in economic history, can be drawn from such examples. It is sometimes argued that growth depends primarily on the creation of new industries, usually resting on new technologies. The basic idea is that industries have a kind of life-cycle, consisting of birth, rapid growth, maturity and then decline. These life-cycle effects therefore require the creation of new industries from time to time, whose rapid growth compensates for the inevitable decline of others. This kind of approach to growth places a lot of emphasis on scientific breakthroughs to provide the technological basis of new industries, venture capital to create new firms, and new forms of skills.

In this perspective, growth depends primarily on structural change in the economy. Now it cannot be denied that structural change occurs, and is in part driven by the creation of new industries. Indeed, sometimes these new industries become very large, and cause a restructuring of the entire economy, as with the emergence of motor vehicles in the early 20th century. However, an alternative view would be that there is also considerable

persistence in the structure of the economy: many mature industries do not stagnate and die, but continue to grow over time. In most advanced economies, the largest manufacturing industry two hundred years ago was food processing, and it remains the largest today in most OECD economies.

*Many low or medium-technology mature industries are growing, and they are growing on the basis of innovation.*

That said, the basis of this persistence is underlying change – in the technological character of products and processes, which may change slowly or rapidly, but become very different as time passes. So the services and outputs provided by these mature industries – such as food, transport, housing, clothing, etc – are technologically upgraded over time, in ways that are as genuinely radical as the changes underlying completely new industries.

The point here, then, is that many low or medium-technology mature industries are growing, and they are growing on the basis of innovation. A question of great importance for understanding the knowledge economy is: what is the knowledge basis of 'upgrading' innovation in long-standing or mature industries?

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## ISSUES FOR LOW/MEDIUM TECHNOLOGY ECONOMIES

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### INNOVATION PROCESSES IN LOW/MEDIUM TECHNOLOGY INDUSTRIES

How does innovation occur in the low and medium technology industries that have been referred to earlier? It is truly difficult to generalise about this, because innovation processes are so heterogeneous across firms and industries. But it can reasonably be claimed that these industries rarely or never innovate on the basis of scientific or technological breakthroughs emerging from a research process. Rather, firms seek to develop new product concepts on the basis of their interactions with consumers and their conjectures about likely patterns of demand.

In this framework, the implementation of a new product concept is a problem-solving process, in which existing technologies may be combined in new ways, and new technologies created. The innovation of a new product concept often seems to generate problems that lie outside the existing competencies of the firm, and in seeking solutions to these problems firms either undertake development of new competencies (which may or may not take the form of research and development), or they look outside.

The key point in all this is that innovation rests not on discovery but on learning and problem solving. Learning need not necessarily imply discovery of new technical or scientific principles, and can equally be based on activities which recombine or adapt existing forms of knowledge; this in turn implies that activities such as design and trial production (which is a form of engineering experimentation) can be knowledge-generating activities.

*The key point in all this is that innovation rests not on discovery but on learning and problem solving.*

Within this mode of innovation, research and development can be very important. However, it is important not in providing the innovation opportunity, but rather in solving problems during the ongoing innovation process. This means that firms may not need research and development as a point of departure for innovation, but they need connectivity with the research and development system as problems emerge and are addressed.

In understanding the knowledge-creation dimensions of this, greater emphasis needs to be placed on two dimensions of knowledge creation in such industries, neither of which is particularly visible in available economic or science and technology statistics. The two dimensions are:

- the use of non-research and development inputs; and
- the indirect flows of knowledge, including research and development.

These two dimensions are discussed further below.

Low and medium technology industries have significant non-research and development inputs to and expenditures on innovation include:

- market research,
- training and skill development,
- design,

- the application of new capital goods,
- engineering development, and
- knowledge drawn from patents and licenses.

Firms create economically vital knowledge by exploring their markets. Given that innovations are economic implementations of new ideas, then the exploration and understanding of markets, and the use of market information to shape the creation of new products, are central to innovation. As will be shown below, in all industries, these non-research and development inputs are significantly greater than research and development expenditures. Such non-research and development aspects of innovation are sometimes referred to in the making of innovation policy, but are often ignored in practice.

That said, it should also be noted that these industries are often intensive users of research and development, and intensive users of scientific knowledge. However, the key point about research and development inputs in such industries is that they are *indirect*: they flow from the 'knowledge infrastructure' of society, through personnel movements, inter-firm co-operation, links with universities or research institutes, engineering consultants, etc. Firms interact with other institutions in a range of ways including the purchase of intermediate or capital goods embodying knowledge. The installation and operation of such new equipment is also knowledge creating. Then there is the purchase of licences to use protected knowledge. Even now, relatively little is known about the full scope and content of such knowledge flows.

The science and research and development use of mature industries is either not measured with available science and technology indicators, or not measured well. This is largely why they are often regarded as traditional and low technology sectors, which are irrelevant to the new knowledge economy. Yet many of these industries – in particular food processing – have a good claim to be at least as science-based as something like information and communications technology. This indirect use of science and research and development has important policy implications. The science and research and development use of these industries flows indirectly from the overall knowledge infrastructure. Consequently the growth and innovation performance of such industries – and hence of the overall economy – depends on the composition, efficiency and funding of this knowledge infrastructure.

#### **AUSTRALIAN INDUSTRIAL STRUCTURE & ITS INNOVATION IMPLICATIONS**

The suggestion thus far has been that research and innovation policy tends to focus excessively on high technology industries and/or frontier technologies, neglecting the significant low and medium technology sectors that generate most output and significant amounts of innovation. Are these points relevant for the Australian context? Figures 1 and 2 simply outline the overall structure of GDP in Australia, and the structure of manufacturing output.

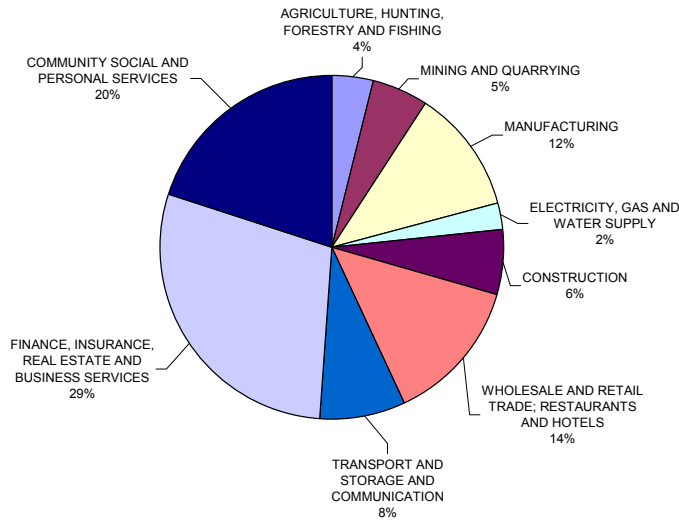


Figure 1: Structure of GDP in Australia

Compared with other OECD economies, Australia has a somewhat smaller share of manufacturing, a larger share of agriculture and mining, and a very substantial services sector. Roughly 70% of GDP is generated in the broad sectors of community services, business services, transport, and trade and hospitality. This structure alone goes a long way to explaining Australia's relatively low research and development to GDP ratio, since most research and development is performed in manufacturing, and Australia's manufacturing is small. But it also suggests that directly research and development-based innovation is likely to be the exception rather than the rule in Australia. This perception is strengthened by looking directly at the structure of the manufacturing sector:

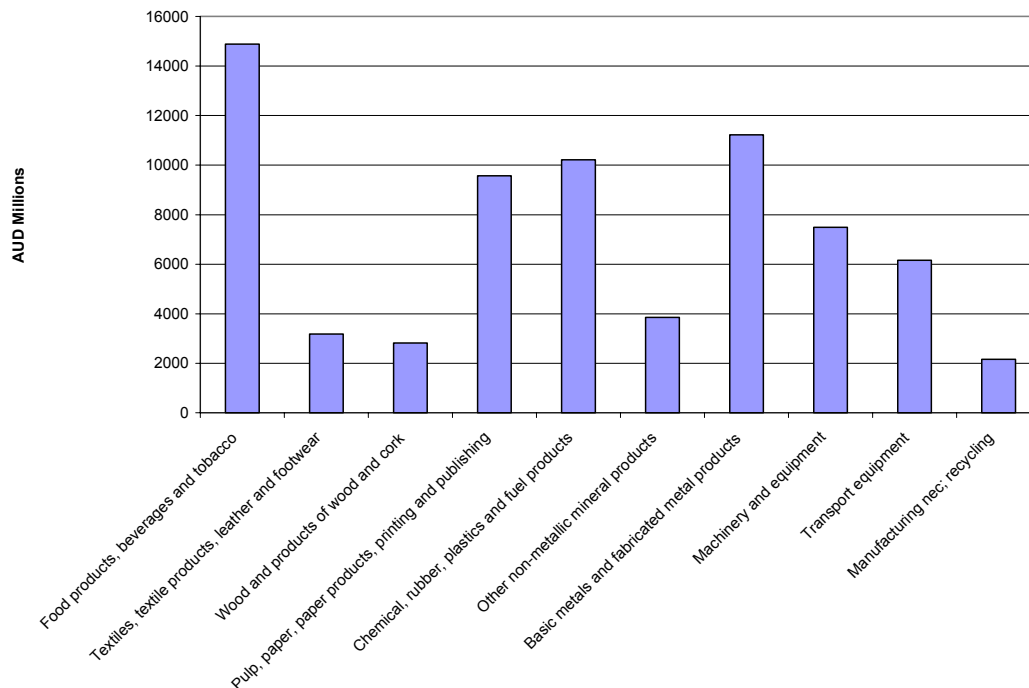


Figure 2: The structure of Australian manufacturing

The basic picture here is not too dissimilar from many other OECD economies (particularly the Netherlands and the Nordic area). The largest sector is food processing, followed by printing and publishing, chemicals and metal products. At this level of aggregation, the high technology sectors are not visible as they are very small components of the chemicals and machinery and equipment sectors.

The point here, of course, is that Australian manufacturing is dominated by low and medium technology activities that perform little research and development, and that do not generate the conventional indicators of a knowledge-based economy. However, these industries do innovate.

In Europe, the Community Innovation Survey (which will be referred to more specifically below) shows that low and medium technology industries typically generate around ten percent of their turnover from technologically new or significantly changed products. In Australia, an innovation survey carried out by the ABS in 1994 asked firms whether they were engaged in innovation activities, and the results – shown in Table 2 - suggested no noticeable difference between high, medium and low technology industries.

ANZSIC code	Industry subdivision	Type of technological innovation		
		Product %	Process %	Total %
21	Food, beverages and tobacco	33.0	29.1	36.3
22	Textiles, clothing, footwear & leather	14.7	13.6	15.4
23	Wood and paper products	11.8	12.0	15.7
24	Printing, publishing and recorded media	17.6	20.7	25.6
25	Petroleum, coal, chemical and assoc. prods	34.8	29.3	42.1
26	Non-metallic mineral products	32.6	20.7	35.5
27	Metal products	20.3	12.7	21.1
28	Machinery and equipment	33.0	19.8	35.3
29	Other manufacturing	18.9	14.7	20.9
21-29	Total manufacturing	22.9	17.8	26.0

Table 2: Proportion of Australian businesses undertaking technological innovation by industry<sup>4</sup>

#### THE USE OF KNOWLEDGE IN A LOW/MEDIUM TECHNOLOGY ECONOMY

It was argued above that in the Australian economic structure, that innovation and knowledge use in the sectors on which the Australian economy is based exhibit two basic features: significant use of non-research and development inputs to innovation, and significant inter-sectoral flows of knowledge. In this section these features are explored in more detail, following which their implications for the Australian knowledge economy are discussed.

### *Non-Research & Development Inputs to Innovation*

One of the great problems in understanding innovation is the constraint imposed by the available indicators. By far the most prevalent indicators are research and development data and patent data. The primary difficulty with such indicators is that relatively few industries perform significant amounts of internal research and development, and even fewer patents on any noticeable scale. So, relying on these indicators gives a very skewed picture of innovation efforts (let alone innovation outputs). Many firms and industries commit significant resources to innovation, by building tangible and intangible assets in the forms of firm-specific skills and capabilities related to design, engineering, the operation of capital goods etc. These inputs are not captured by the conventional indicators (which incidentally implies that calculations of returns to research and development are often overstated because other innovation costs are not being measured).

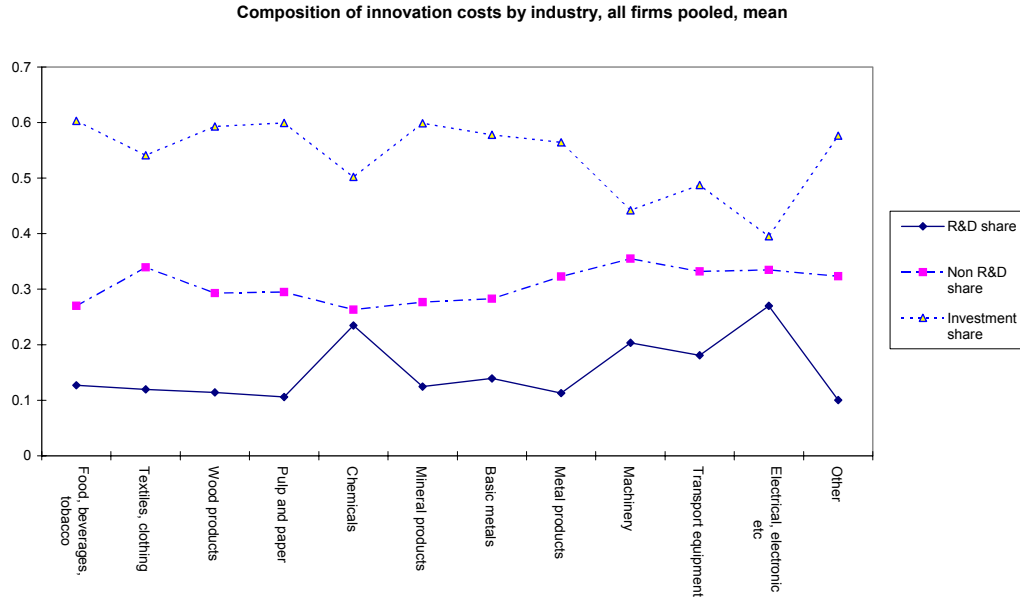
However non-research and development expenditures on innovation are in principle measurable. Collection of data on such phenomena has been attempted in probably the only systematic data source on non-research and development innovation expenditures, namely the EU's Community Innovation Survey (hereafter CIS) which collects data for all European countries, not only on research and development but also on non-research and development innovation expenditures including training, market research related to new product development, design, expenditures on patents and licenses, and most importantly on capital investment (again related to new product development).

Some results relevant here are from CIS data from the Europe-wide survey of 1992, on the industry distributions of research and development and non-research and development expenditures on innovation. This is followed by a look at some roughly similar Australian data. The data relates to the 1992 CIS, and the results are drawn from a European Commission report on innovation expenditures in European industry. The data is divided into three categories:

- capital investment related to new product development,
- research and development, and
- non-research and development expenditures (covering training, market research, design, trial production and tooling up, and intellectual property rights costs).

It should be emphasised that capital goods investment here does not mean overall capital investment but refers only to the purchase of capital goods which are acquired as part of new product development. So it is specifically innovation-related, and is only a component of overall capital investment.

The first point, perhaps a rather obvious one, is simply that research and development is but one component of innovation expenditure, and by no means the largest. Between 40 and 60 percent of innovation expenditures, across all industries, is comprised of capital goods acquisition for the purpose of innovation. The next largest category is the complex of non-research and development inputs. Finally, there is research and development.

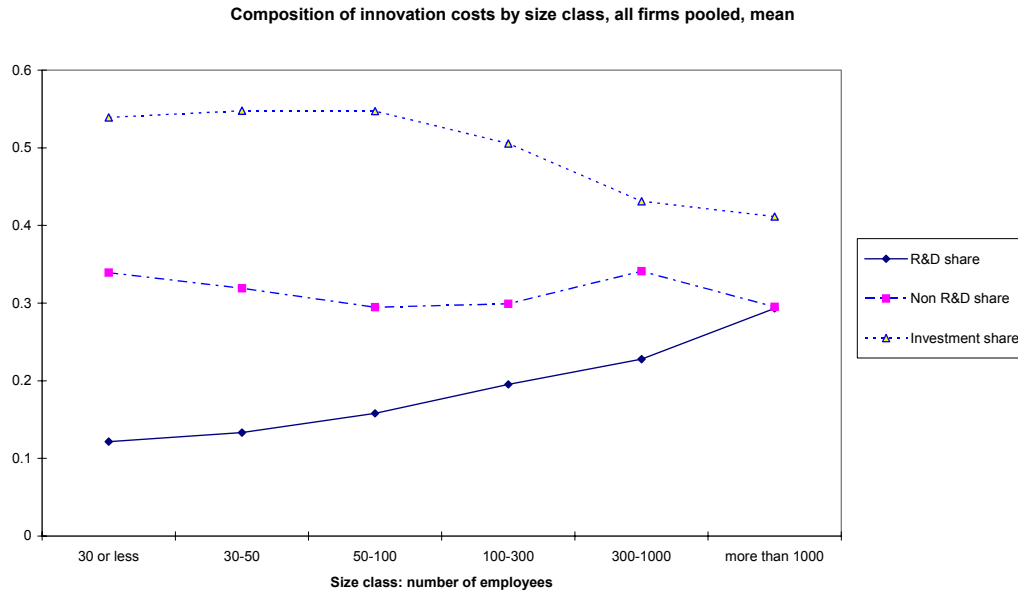


*Figure 3: Composition of innovation expenditures by industry<sup>5</sup>*

There is, as one would expect, variation in the share of research and development expenditures in total innovation expenditure across industries, with electrical, electronics, and chemicals (here including pharmaceuticals) having high shares. This is exactly what would be expected from the research and development statistics. To this variation across industries there roughly seems to correspond a variation in the opposite direction for the share of investment expenditures. Firms that have relatively low research and development shares have higher capital investment shares.

This in turn implies that non-research and development expenditures (design, training, market research etc) vary somewhat less across industries. The mean research and development share by industry varies between about 0.1 and 0.25, the mean non-research and development share is generally close to 0.3, while the mean investment share varies between about 0.4 and 0.6. For the low technology sectors such as food processing, chemicals, metal products or timber based production, which we saw above were the largest sectors in Australian manufacturing, capital goods acquisition is extremely important as an innovation expenditure.

Figure 4 shows the composition of innovation expenditures by size of firms for all countries pooled.



*Figure 4: Composition of innovation expenditures by size of firm<sup>6</sup>*

What this shows is, once again, a rather consistent non-research and development expenditures share, but on the other hand a clear relationship between firm size and the share of research and development expenditures, with this share increasing consistently with firm size. To this there seems to correspond, though less clearly, a decrease in the share of investment expenditures with firm size. The implication here is that small firms rely more on the acquisition of capital goods in innovation expenditures, so that knowledge structures in small-to-medium enterprises are likely to be more heavily dependent on knowledge embodied<sup>7</sup> within capital equipment.

Similar results have been found for Australia, in the 1994 ABS innovation survey, shown in Table 3. This data is classified by firm size, rather than industry, and does not include capital expenditures for innovation. On the other hand, it gives a very detailed breakdown of non-research and development expenditures in Australia. The message is similar to the European data: research and development increases with firm size, and non-research and development inputs are large.

Type of innovation activity	Less than 10	10-49	50-99	100-499	500 or more	Total
EXPENDITURE (\$'000)						
Research and development	99.7	266.4	134.2	446.5	1037.9	1984.7
Acquisition of technology developed by others (e.g. patents, trademarks)	*21.7	*40.0	*15.1	44.2	52.9	173.9
Training and further education related to introduction of innovations	*14.8	26.0	**27.4	26.5	43.1	137.8
Expenditure on tooling-up, industrial engineering and start-up	128.5	222.3	117.8	188.9	482.3	1139.8
Marketing of new or improved products	43.0	*82.9	47.4	119.2	128.3	420.8
Other	**3.5	10.5	27.4	8.9	33.4	83.8
Total Expenditure	311.2	648.1	369.4	834.2	1777.9	3940.8
Average \$'000/employee	2.2	3.1	3.8	3.7	5.3	3.9
PERCENTAGE OF TOTAL (%)						
Research and development	5.0		6.8	22.5	52.3	100.0
Acquisition of technology developed by others (e.g. patents, trademarks)	*12.5	*23.0	*8.7	25.4	30.4	100.0
Training and further education related to introduction of innovations	*10.8	18.9	*19.9	19.2	31.3	100.0
Expenditure on tooling-up, industrial engineering and start-up	11.3	19.5	10.3	16.6	42.3	100.0
Marketing of new or improved products	10.2	19.7	11.3	28.3	30.5	100.0
Other	**4.2	12.6	32.7	10.6	39.9	100.0
Total Expenditure	7.9	16.4	9.4	21.2	45.1	100.0

Table 3: Expenditure on technological innovation by type of activity and size of firm<sup>8</sup>

### Measuring Indirect Uses of Research & Development

The data presented above suggests a strong case for not focusing simply on direct research and development, when expenditure by firms and industries on innovation and knowledge creation is considered. Further, it suggests a need to look into the significance of other sources of knowledge. It seems particularly important to look at capital investment, which represents the largest component of innovation expenditure in every industry. In this context, it is important to note that capital expenditure is a key mode of 'embodied' knowledge spillover from the capital goods sector to using industries. Could a way be found to incorporate such embodied spillovers into the shared understanding of the knowledge intensity of the using industry by an empirical account of their knowledge contents?

Table 4 uses OECD data to compare direct and indirect research and development inputs across industries. One modification of this has been the addition of 'acquired technology', calculated as the research and development embodied in capital and intermediate<sup>9</sup> goods

used by an industry, and computed via the most recent input-output table. The method for calculating acquired research and development is to assume that the research and development embodied in a capital good is equal to the capital good's value multiplied by the research and development intensity (that is, the research and development to turnover ratio) of the supplying industry. The most recent year for which relevant input-output data is generally available is 1990. The overall structure of the classification can be seen in Table 4, which shows direct research and development intensities for the main industrial groups for 1997, plus the proportion of acquired to direct research and development for 1990, the last year for which it was calculated by OECD.

	<i>ISIC Rev 3</i>	<i>Direct R&amp;D Intensity 1997 (1)</i>	<i>Acquired R&amp;D intensity as % of direct R&amp;D intensity, 1990 (4)</i>
<b>High technology industries</b>			
Aircraft and spacecraft	353	12.7	15
Pharmaceuticals	2423	11.3	8
Office, accounting and computing machinery	30	10.5	25
Radio, television and communications equipment	32	8.2	17
Medical, precision and optical instruments	33	7.9	29
<b>Medium-high-technology industries</b>			
Electrical machinery and apparatus	31	3.8	42
Motor vehicles and trailers	34	3.5	29
Chemicals	24 exc 2423	2.6	18
Railroad and transport equpt. n.e.c.	352+359	2.8	88
Machinery and equpt n.e.c.	29	1.9	104
<b>Medium-low-technology industries</b>			
Coke, refined petroleum products and nuclear fuel	23	0.8	30
Rubber and plastic products	25	0.9	127
Other non-metallic mineral products	26	0.9	285
Building and repairing of ships and boats	351	0.7	200
Basic metals	27	0.7	289
Fabricated metals products	28	0.6	133
<b>Low-technology industries</b>			
Manufacturing n.e.c. and recycling	36-37	0.4	
Wood, pulp, paper, paper products, printing and publishing	20-22	0.3	167
Food products, beverages and tobacco	15-16	0.4	267
Textiles, textile products, leather and footwear	17-19	0.3	250

Table 4: Classification of Industries Based on RESEARCH AND DEVELOPMENT Intensity<sup>10</sup>

Table 4 shows that 'acquired technology' as a proportion of direct research and development rises dramatically from high technology to low technology industries. High technology industries perform high levels of direct research and development, and realise only a small proportion of their research and development use in the form of embodied inputs. Medium and low technology industries realise most of their research and development in the form of research and development embodied in capital and intermediate inputs.

Of course, the absolute amounts of research and development being used remain higher in many of the high-technology sectors. However, the key point is that many low and medium technology sectors are gaining access to significant volumes of research and development in ways that are not reflected in usual research and development data. This suggests, incidentally, that technology intensity is likely to be very sensitive to how the measurement of acquired technology is carried out.

## KNOWLEDGE FLOWS

### TECHNOLOGICAL COLLABORATION

The argument thus far has been that the knowledge economy rests strongly on non-research and development forms of knowledge creation, and that flows of knowledge embodied in capital goods are important. However inter-industry and inter-firm flows of knowledge are wider than just those embodied in goods: there is also a continuous and widespread process of technological collaboration under way in modern economies.

*The knowledge economy rests strongly on non-research & development forms of knowledge creation. Flows of knowledge embodied in capital goods are important. Beyond this, there is a continuous and widespread process of technological collaboration under way in modern economies.*

An important result of the innovation survey activity described above was that technological collaboration was very widespread indeed among innovating firms. This result has led to a series of specific surveys on the motivations for, extent and management of technological collaboration in OECD economies. These surveys showed that very high percentages of innovating firms were also engaged in ongoing technological collaboration, often with a range of partners. Basri (2001) explored a representative sample of 1000 Australian firms, and showed that 86% of firms engaged in innovation were also engaged in technological collaboration. This suggests that the flow of knowledge between innovating firms and other organisations in their environment is very strong.

Turning to types of partners, collaboration appears strongest with customers and suppliers, confirming the importance of user-producer interactions in innovation. But other suppliers, including universities are important. Across the countries that participated in these surveys, the distribution of partners was as follows:

	<i>Australia</i>	<i>Austria</i>	<i>Denmark</i>	<i>Norway</i>	<i>Spain</i>	<i>Sweden</i>
Private customers	64	56	71	59	53	61
Government customers	15	33	21	20	25	30
Suppliers of materials and components	52	62	74	57	58	83
Suppliers of machinery and production equipment	26	29	44	35	49	55
Suppliers of technical services, testing and control	43	42	43	45	-	42
Marketing/management consultants	28	18	32	18	33	-
Competitors	7	20	13	28	15	35
University and research centres	17	33	17	23	60	36
Parent/subsidiary	30	39	33	-	37	-

*Table 5: Distribution of collaboration partners in selected countries (percentages, unweighted)<sup>11</sup>  
NB: Firms can have more than one collaboration partner.*

The combination of capital goods flows and complex technological collaboration suggests a very powerful role for knowledge flows across firms and industries. A key question then is how do knowledge bases interact, and what forms do knowledge flows take?

### **KNOWLEDGE FLOWS ACROSS INDUSTRIES**

How do these patterns of capital investment, intermediate goods acquisition and non-research and development expenditures relate to the structure of knowledge in an industry? The material presented above suggests that:

- many activities contribute to the knowledge base of a firm or industry,
- such knowledge bases are likely to be complex, and
- the knowledge base of firms is heavily influenced by flows of knowledge into the firm.

So how can the knowledge content of an industry be understood and described? Three areas of production-relevant knowledge can be distinguished:

- firm-specific knowledge,
- sector or product-field specific knowledge, and
- generally applicable knowledge.

At the firm level, the knowledge bases of particular firms are highly localised, and usually linked to very specialised product characteristics, either in firms with one or a few technologies which they understand well and which form the basis of their competitive position, or in multi-technology firms.

There are also knowledge bases at the level of the industry or product-field. At this level, modern innovation analysis emphasises the fact that industries often share particular scientific and technological parameters. There are shared intellectual understandings concerning the technical functions, performance characteristics, use of materials and so on of products. This part of the industrial knowledge base is public (not in the sense that it is produced by the public sector, but public in the sense that it is accessible knowledge which in principle available to all firms). It is this body of public knowledge and practice which shapes the performance of all firms in an industry. Of course, this knowledge base does not exist in a vacuum. It is developed, maintained and disseminated by institutions of various kinds, and it requires resources (often on a large scale).

Finally, there are widely applicable knowledge bases, of which the most important technically is the general scientific knowledge base. This is itself highly differentiated internally and of widely varying relevance for industrial production. Some fields – such as molecular biology, solid-state physics, genetics or inorganic chemistry – have clear connections with high-technology industrial sectors. But there are many other fields that have direct or indirect links with major economic activities. The connections between seismology and oil or mining, between microbiology and the food and beverages sector, or between psychology and the printing industry (where exploration of tactile and colour perceptions and magazine publishing have been important), may be less obvious but are equally important.

### **DISTRIBUTED KNOWLEDGE BASES**

If these points about knowledge bases are reasonable, then the relevant knowledge base for many industries is not internal to the industry, but is distributed across a range of technologies, actors and industries. What does it mean to speak of a 'distributed knowledge

base'? A distributed knowledge base is a systemically coherent set of knowledges, maintained across an economically and /or socially integrated set of agents and institutions.

It has been argued above that inter-agent or inter-industry flows conventionally take two basic forms, 'embodied' and 'disembodied'. Embodied flows involve knowledge incorporated in to machinery and equipment. Disembodied flows involve the use of knowledge, transmitted through technological collaboration between firms, scientific and technical literature, consultancy, education systems, movement of personnel and so on.

The basis of embodied flows is the fact that most research-intensive industries (such as the advanced materials sector, the chemicals sector, or the information and communications technology industrial complex) develop products that are used within other industries, as capital or intermediate inputs into the production processes of other firms and industries. When this happens, performance improvements generated in one firm or industry therefore show up as productivity or quality improvements in another. The point here is that technological competition leads rather directly to the inter-industry diffusion of technologies, and therefore to the inter-industry use of the knowledge which is "embodied" in these technologies. The receiving industry must of course develop the skills and competencies to use these advanced knowledge-based technologies. Competitiveness within 'receiving' industries depends heavily on the ability to access and use such technologies.

As examples, consider fishing and fish farming, both of which are apparently low technology sectors in terms of internal research and development. These are a large activities worldwide, with aquaculture growing particularly strongly. Examples of embodied flows in fishing include use of new materials and design concepts in ships, satellite communications, global positioning systems, safety systems, sonar technologies (linked to winch, trawl and ship management systems), optical technologies for sorting fish, computer systems for real-time monitoring and weighing of catches, and so on. Within fish farming, these high-technology inputs include pond technologies (based on advanced materials and incorporating complex design knowledges), computer imaging and pattern recognition technologies for monitoring (including 3D measurement systems), nutrition technologies (often based on biotechnology and genetic research), sonars, robotics (in feeding systems), and so on. These examples are not untypical of 'low-technology' sectors; on the contrary, most such sectors can not only be characterised by such advanced inputs, but are also arguably drivers of change in the sectors that produce such inputs.

The disembodied flows and spillovers are also significant. Underlying the technologies for fishing and fish farming mentioned above are advanced research-based knowledges. Ship development and management relies on fluid mechanics, hydrodynamics, cybernetic systems, and so on. Sonar systems rely on complex acoustic research. Computer systems and the wide range of IT applications in fisheries rest on computer architectures, programming research and development, and ultimately on research in solid-state physics. Even fishponds rest on wave analysis, CAD/CAM design systems, etc. Within fish-farming, the fish themselves can potentially be transgenic (resting ultimately on research in genetics and molecular biology), and feeding and health systems have complex biotechnology and pharmaceutical inputs. In other words, a wide range of background knowledges, often developed in the university sector, flows into fishing: mathematical algorithms for optimal control, molecular biology, and a wide range of sub-disciplines in physics for example.

Perhaps the most spectacular example of these processes in Australia in recent years has been the wine industry, which has been revolutionised on the basis of serious scientific understanding of complex processes in viticulture and viniculture, supported by a large array of university courses, research programmes and research and development institutions.

This kind of thinking seems closely relevant to Australia's largest manufacturing industry, food production. Clearly many different kinds of skills, scientific disciplines and knowledge areas are involved in the functions and activities in the food processing industry.

Nevertheless, most of this knowledge can be categorised into two main knowledge areas, namely food science and food technology. The Institute of Food Science & Technology (UK) defines these terms as follows<sup>12</sup>:

*... food science integrates the application to food of several contributory sciences. It involves knowledge of the chemical composition of food materials (for all food consists entirely of chemical substances); their physical, biological and biochemical behaviour; human nutritional requirements and the nutritional factors in food materials; the nature and behaviour of enzymes; the microbiology of foods; the interaction of food components with each other, with atmospheric oxygen, with additives and contaminants, and with packaging materials; pharmacology and toxicology of food materials, additives and contaminants; the effects of various manufacturing operations, processes and storage conditions; and the use of statistics for designing experimental work and evaluating the results.*

*Likewise, food technology draws on, and integrates the application to food of, other technologies such as those of steel, tinplate, glass, aluminium, plastics, engineering, instrumentation, electronics, agriculture and biotechnology."*

These knowledge bases feed directly into the key activities of food processing, such as selection and preparation of materials, cooking, nutritional and contaminations monitoring, packaging, and distribution. To sum up: despite the fact that food processing is an industry with relatively low levels of internal research and development, it might well be claimed that this is one of the most knowledge-intensive sectors of the entire economy. Presumably this is not unrelated to the fact that many of the sub-sectors of the industry are growing rapidly.

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## KNOWLEDGE INFRASTRUCTURES

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### KNOWLEDGE INFRASTRUCTURES & THE KNOWLEDGE ECONOMY

How important is the 'knowledge infrastructure' of universities, research institutes, and other publicly supported agencies in knowledge creation and use in Australia? It was suggested above that collaboration is a widespread phenomenon that is important in the structure of knowledge bases for economies such as Australia. Of firms engaged in technological collaboration, 17% reported that they were collaborating actively with universities and research institutes. There is of course a question of interpretation to be asked here: is this a high number or a low number? It should be noted that this collaboration is unevenly distributed across industries. It is heavily concentrated in the petroleum and chemicals, metal products, and machinery and equipment sectors. But these are major low and medium technology sectors in Australia, and so it might be concluded that universities are playing an important collaborative role.

It is important to remember that knowledge infrastructures produce effects that cannot be grasped even by looking at short-term collaboration, or other forms of direct interaction. Infrastructures produce complex effects via education and training, interpersonal contacts, personnel exchange, the general flow of ideas, consultancy, design of instrumentation, and so on. Within such important sectors for Australia as food and wine, infrastructural organisations interact with firms and through this, shape and reshape the knowledge bases of the sectors. Mapping the specific content and evolution of these knowledge bases is well beyond the scope of this paper, but for such sectors as food, wine, mining and exploration, the knowledge infrastructure appears to have contributed important components of the overall knowledge base.

From this perspective, the Australian 'knowledge economy' depends on these infrastructures, and the composition, funding, management and strategic direction of the knowledge infrastructure are central to future performance. It might be added that infrastructures provide crucial location-specific assets that shape the location decisions of global firms; this too is important for Australia in the global knowledge economy.

### FIRMS & BUSINESSES: INVESTING IN THE KNOWLEDGE ECONOMY

Processes of knowledge creation (both by research and development and non-research and development means) and the absorption of knowledge flows from outside the firm involve significant investment programmes by firms, and difficult management challenges. Innovation rests on the creation of specialised competences or capabilities that are directed towards new methods of organisation and production, or to new products that improve marginally or significantly on the old. Competence building and innovative learning are far more than a matter of innovative or entrepreneurial attitudes – they rest on corporate strategies that support investment (often over long periods) in tangible and intangible assets. It is important to stress that innovation is not just a matter of bright ideas, still less of scientific breakthroughs. It really requires sustained commitment of financial and human resources by firms in the painstaking development of technologies, and in changed forms of production and marketing.

So, a key element of innovation performance involves those factors that support or inhibit corporate managers in their asset creation decisions to develop, use, transfer and sustain technologies in their operations. These factors include the availability of technological opportunities, incentives (such as research and development tax credits and general tax conditions), financial conditions, the nature of corporate organisation, and especially the

impact of corporate governance procedures (such as the performance requirements of owners and financial markets) concerning investment behaviour.

The key challenge for firms is how they assess potential innovation markets, and under what circumstances they can muster the resources to invest in the complex of physical and intangible assets that make up a knowledge-intensive approach to production. This is primarily an issue in corporate strategy and control.<sup>13</sup>

Learning and knowledge creation involve the development of competencies and capabilities. This takes time and costs money, and depends on the ability to learn, to change production processes and organisation, and to develop and introduce new products.

The learning capabilities, which underpin innovation performance, depend primarily on the creation and maintenance of intangible assets: human capital, skills, new organisational forms, improved monitoring and understanding of markets, and so on. These in turn require the commitment of resources - to training, research and development, product design, organisation skills and specific production capabilities. This kind of resource commitment is investment in the strict sense - that is, it involves the use of finance in the present period or periods to create assets which will deliver benefits over future time periods.

A major problem in the innovation process is of course that the flow of such benefits is in principle difficult to predict and in general highly uncertain. At the same time, because most of the assets that are thus created are intangible, they are not capitalised in the balance sheet of the firm, and are often treated for accounting purposes as current costs that impact on current profitability.

Beyond the creation of intangible assets, successful innovation invariably requires physical capital investment. It is well established within quantitative studies of innovation that product change is usually associated with process change, and that the latter requires new plant and equipment. More generally, as shown above, most innovations involve investment in new plant and equipment, and this indeed is one of the primary mechanisms through which new technologies diffuse.

A key element of innovation, then, is the ability to invest: to commit resources to projects with uncertain outcomes, and long (more or less) time horizons. It is widely recognised that this may involve conflict between present and future returns in companies. Of course, any firm must not only invest for the future, but must make profits today, and there are necessarily conflicts over this. On the one hand, the management may be overly concerned with the short run, as Martin Fransman points out:

*The need to generate satisfactory profits in the short to medium term ... bounds the vision of the corporation, contributing in some cases to a degree of 'short-sightedness'. One example is the creation of technologies for 'the day after tomorrow' where the degree of commercial uncertainty is frequently great. In view of their bounded vision, corporations often tend to under invest in the creation of such technology<sup>14</sup>.*

But such shortsightedness may in fact be a definite effect of the governance system. There is a real need to think through – from the point of view of knowledge creation – the governance structures, incentives and support mechanisms that contribute to the investment patterns discussed here. The reason for this is that there is no point in creating outstanding knowledge infrastructures unless there are also business systems that are capable of exploiting the competitive benefits of a distributed knowledge-producing system.

Jonathon West has pointed out the importance of this in appropriating the benefits of a high-technology research field, namely biopharmaceuticals. His argument is that sustained commitment of research and development in Australia does not make much sense in the absence of businesses capable of fully developing the products, and marketing them

globally<sup>15</sup>. But this point applies with equal strength to the low and medium technology sectors. In wine, for example, Australia has created a knowledge system that is probably capable of gaining increased global market share for many years to come. But the large Australian firms in this sector have not had the management capabilities, the financial depth or the marketing skills to create globally sustainable operations. The result is a series of takeover and mergers that enhance foreign ownership and that may reduce the share of the benefits of this industry that are appropriated within Australia. So these issues of business growth are as important to the operation of the knowledge economy as the underlying knowledge infrastructures.

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## CONCLUSIONS

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This paper has argued that growth is based not just on the creation of new sectors but on the internal transformation of sectors which already exist, which necessarily involves continuous technological upgrading. This internal transformative capacity rests on:

- complex innovation systems that create, distribute and maintain advanced (often basic scientific) knowledge;
- firm-level capacities for both investing in and managing the creation of competences in non-research and development aspects of innovation, and for the absorption of externally-created knowledge; and
- business operations that can support the sustained investment processes that are required for innovation-based competitiveness.

Many so-called low-technology sectors are apparently intensive in their use of scientific knowledge – industries such as food production, machinery, printing and publishing, wood products, and a range of services, have significant indirect science inputs. At the same time, the creation of new product concepts, along with skills in design, engineering and marketing underpin knowledge creation in the types of industries which comprise the Australian economy.

The challenge for public policy is twofold. On the one hand the architecture, governance, resources and connectivity of the knowledge infrastructure must be adequate to support the industrial structure that the country really possesses, and to promote the upgrading innovation on which its survival depends.

To achieve this, priority areas should be chosen only insofar as they support this system, or insofar as they have a realistic prospect of creating new economic activities. These conditions are not met at the present time in Australia, where major research priority areas have no apparent connection to economic application or to the creation of new activities. Above all, there is a need for policy approaches that rest on an awareness of the real characteristics of innovation in Australia. At the present time the overwhelming emphasis of knowledge infrastructure policy is on ‘commercialisation’ – that is, on the idea that the function of the infrastructure is to discover new scientific or technical principles that can be commercialised into new products. But the infrastructure is not primarily a discoverer. It is more appropriate to think of it as a problem solver, and it is this function that needs to be enhanced, via better linkages and better connectivity.

The argument of this paper is not that science is unimportant to innovation – far from it. The argument is that its real functions and impacts are being misunderstood and, consequently, misrepresented (especially in policy making), and are not well served by research priorities that stress ‘frontier technologies’ whose links with innovation, and hence whose economic impacts, have not been thought through.

*The argument of this paper is not that science is unimportant to innovation – far from it. But its real functions and impacts are being misunderstood and consequently misrepresented in policy making.*

On the other hand, policies for the knowledge economy should focus strongly on business creation and business support. A business-friendly innovation policy is not necessarily passive with respect to the business sector. Strategy development, the monitoring, identification and exploitation of opportunity, training issues, and collaboration promotion

are all areas where government can be more active. More specifically, tax policies, employment legislation, accounting standards, competition policy and environmental regulation are all areas in which an innovation-oriented perspective can be taken. It is not usual to think of these areas from the perspective of knowledge and learning, but a key challenge for the future is to integrate such a perspective with an improved policy for the knowledge infrastructure of the country.

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## ENDNOTES

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<sup>1</sup> There is plenty of archaeological evidence for the existence of sophisticated knowledge in the Palaeolithic and Neolithic periods!

<sup>2</sup> By 'high technology industries' I mean those conforming to the OECD classification, namely industries that spend more than 4% of turnover on research and development. Medium technology industries spend between 1% and 3% of output on research and development, and low technology industries less than 1%.

<sup>3</sup> Anderson and Norman, pp.37, 41, 65, 71, 107, 111

<sup>4</sup> Source: Australian Bureau of Statistics

<sup>5</sup> Evangelista et al, p. 46

<sup>6</sup> *ibid*, p. 47

<sup>7</sup> See p 21 for distinction between embodied and disembodied in this context

<sup>8</sup> Source: Australian Bureau of Statistics

<sup>9</sup> Intermediate inputs: inputs to production that have themselves been produced and that (unlike real capital goods - the means of production) are entirely used up in production.

<sup>10</sup> Sources: OECD (1999) - Annex 1, p.106; OECD (2001) - Annex 1.1, p.13-139

Note: The ISIC classification was revised in 1996, though changes were relatively minor. 1990 data has been reassigned to the most relevant Rev 3 category.

<sup>11</sup> Source: Basri (2001), p.156.

<sup>12</sup> Source: [www.blacksci.co.uk/products/journals/ijfst.htm](http://www.blacksci.co.uk/products/journals/ijfst.htm)

<sup>13</sup> Lazonick and O'Sullivan (1996) and O'Sullivan (2000)

<sup>14</sup> Fransman (1990)

<sup>15</sup> West (2004)

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