Australian Government

Department of Communications, Information Technology and the Arts

PRODUCTIVITY GROWTH IN SERVICE INDUSTRIES

OCCASIONAL ECONOMIC PAPER

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Department of Communications,
Information Technology and the Arts

Productivity growth in service industries

Occasional Economic Paper

April 2005

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www.dcita.gov.au/ie

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Occasional Economic Paper

ISBN 0642 752 869 (hardcopy version)

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ISBN 0642 752 877 (online version)

Foreword

This research paper is part of ongoing research conducted by the Department of Communications, Information Technology and the Arts (DCITA) on the factors driving productivity growth in Australia and the role of information and communication technologies (ICT) in this growth. As such, it forms part of a series of projected research reports intended to assist public discussion of these issues.

An earlier report dealing with productivity growth in manufacturing was published in March 2004 by the former National Office for the Information Economy. The present report also presents some revised estimates pertaining to this earlier publication in the productivity series.

Because this report is part of on going research, its findings should be regarded as indicative rather than definitive. Comments are welcome on the methodological and data issues raised.

DCITA is grateful for referee comments provided by Dr Don Brunker of the Department of Industry, Tourism and Resources (DITR), Mr Carl Obst of the National Accounts Branch of the Australian Bureau of Statistics (ABS) and Dr Denis Lawrence of Meyrick and Associates. Internal referees were Mr Phil Flaherty of the Communications Research Unit of DCITA and Mr Greg Gurr of the ICT Innovation Branch of DCITA.

This report was prepared in the Information Economy Division by Mr John Revesz, in conjunction with Mr Harvey Anderssen and Dr Lee Boldeman. Ms Sonya Kim provided valuable editorial assistance.

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Abbreviations

ABS	Australian Bureau of Statistics
ANZSIC	Australia and New Zealand Standard Industrial Classification
ASIC	Australian Standard Industrial Classification
BIE	Bureau of Industry Economics
CD-ROM	Compact disc read-only memory
DISR	Department of Industry, Science and Resources
DCITA	Department of Communications, Information Technology and the Arts
EGW	Electricity, gas and water supply
FOB	Free-on-board
GDP	Gross domestic product
GFCF	Gross fixed capital formation
GPT	General purpose technology
ICT	Information and communications technologies
IED	Information Economy Division
IMF	International Monetary Fund
IS	Information system
IT	Information technology
LP	Labour productivity
MFP	Multi-factor productivity
NOIE	National Office for the Information Economy
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary least squares
PC	Productivity Commission
R&D	Research and development
VA	Value-added

Executive Summary

Background

This paper is one of a series of papers planned to examine the role of information and communication technologies (ICT) in productivity improvements in Australia. It follows the publication of *Productivity Growth in Australian Manufacturing* by the former National Office for the Information Economy (NOIE 2004).[1]

The paper reflects the extensive interest in the economic literature and in policy circles in the drivers of productivity growth and in particular on the specific role of ICT in raising productivity. A broad consensus has emerged in the literature that ICT has played a key role in overall productivity growth of industrialised countries in the last three decades.

While it is generally acknowledged that ICT has played some part in Australia's recent good productivity growth performance, previous research (based on growth accounting methods) leaves much of Australia's recent productivity growth unexplained. A major objective of this paper and the earlier one on manufacturing is to show that much of this previously unexplained growth is driven by the rapid advances in ICT.

Key finding

This study, when combined with the earlier NOIE study on manufacturing, covers around 53 per cent of gross domestic product (GDP) and 59 per cent of the national workforce. Both studies suggest that ICT has had a much more significant direct influence on productivity growth than previously reported. They also show that ICT has made a more significant direct contribution to productivity growth than changes in the economic environment.

Nevertheless, the effects of microeconomic reforms and rising education standards were also important, but less so than technological progress. In particular, this study found that microeconomic reforms had a significant impact in infrastructure sectors that were subject to industry-specific competition reform measures. These include communications, electricity and water supply as well as rail, sea and air transport. In terms of value-added, these infrastructure industries cover 21.8 per cent of the service industries examined.

This study

This study examines productivity growth in Australian service industries over the 17 years from 1984–85 to 2001–02. The main interest is to identify to what extent recent

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[1] On 8 April 2004, machinery of government changes led to the abolition of NOIE and the transfer of the information economy function of that agency to the Department of Communications, Information Technology and the Arts.

productivity growth was driven by technological progress, particularly the rapid advances in ICT, or by other factors.

Due to the limited availability of constant price value-added data, only a subset of service industries are analysed in this paper.[2] The nine broad service sectors covered in the present productivity analysis are:

- electricity, gas and water supply (EGW)
- construction
- wholesale trade
- retail trade
- accommodation, cafes and restaurants
- transport and storage
- communications (post and telecommunications)
- finance and insurance
- cultural and recreational services

The ABS supplied more disaggregated data for four sectors: retail trade, transport, EGW and finance/insurance. This yielded a total of 16 service industries for cross-sectional analysis. The major service sectors excluded from the present productivity study are:

- property, business and professional services
- government administration and defence
- education,
- health and community services
- personal and other services
- imputed rent on housing

Notwithstanding the exclusion of government and some important private service sectors, the present study covers around 40 per cent of GDP at factor prices. Together with the previous report on manufacturing (NOIE 2004), these two productivity analyses cover around 53 per cent of GDP and 59 per cent of the national workforce.

Over the 17 years covered in this latest study, aggregate labour productivity (LP) of the service industries examined increased by 45 per cent. The study found wide disparities in productivity growth rates. The general pattern suggests that capital intensive and/or ICT intensive industries tended to record higher LP growth rates than the rest.

The strong correlation between productivity growth and ICT intensity highlights the importance of 'technological innovation paths' in determining productivity growth. This concept refers to the widely observed phenomenon of different rates of significant technological innovations occurring between industries and sub-industries. In service industries different technological innovation paths are closely linked to different levels of utilisation of ICT technologies. ICT intensive industries such as communications,

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[2] According to the definition of the Australian Bureau of Statistics (ABS) and the Productivity Commission (PC) these industries belong to the 'market sector' of the economy.

electricity, finance and wholesale trade recorded high productivity growth. Less ICT intensive industries such as construction, hotels and restaurants, retailing and road transport recorded below average productivity growth.

In most of the service industries examined, technological progress is almost exclusively related to ICT. However, some significant non-ICT-related innovations have occurred in transport, electricity and water supply. No attempt was made in this report to assess the importance of non-ICT related technological innovations in these sectors.

The key methodological issues involved in this study

The estimation of productivity growth is beset by methodological and measurement difficulties. Further complications arise when analysing the data. A number of other studies have analysed Australian productivity growth at the national or sectoral level using growth accounting techniques. The present study contributes to the existing research by adding two novel approaches.

First, by comparing the productivity growth rates of light and heavy ICT user industries. Second, by going further than previous Australian growth accounting studies and employing simple regression techniques to infer the relative contribution of factors driving multifactor productivity (MFP) growth. MFP growth is LP growth minus the effect of capital accumulation on productivity. MFP represents the residual portion of output growth that cannot be explained by changes in labour and capital.

In addition, estimates are presented on the portion of capital deepening (that is, change in the capital-labour ratio) that can be attributed to falling ICT prices. This represents technical change 'embodied' into new investment. Using this estimate, it is possible to separate capital deepening into capital spending and 'embodied' technical change.

The growth accounting cum MFP decomposition estimates make it possible to present a fairly comprehensive decomposition of the drivers of LP growth and to compare the relative importance of technological and institutional-economic factors to productivity growth.

Comparison of growth rates

The study used a simple arithmetic method to assess the relationship between ICT and productivity growth by separating light and heavy ICT user industries. One criterion employed for ICT intensity is based on the level of ICT investment per working hour. Given the demarcation point chosen, heavy ICT user industries include communications, electricity, gas, water, finance/insurance, wholesale trade, air/rail/water transport and cultural/recreational services. Light ICT user industries include construction, hotels and restaurants, retail trade and road transport. Using another criterion, wholesale trade and cultural/recreational services are transferred from heavy users to the light ICT users group.

The average annual LP growth rate of heavy ICT users between 1984–85 and 2001–02 was over six times that of light ICT user industries under the first grouping and over four times under the second grouping. Needless to say, these figures suggest ICT intensity is closely associated with productivity growth.

The regressions

Differences in productivity growth rates were also investigated quantitatively through regression and correlation analysis. The explanatory variables in the regressions are categorised into four broad factor groups:

1. Change in the capital-labour ratio (capital deepening).

2. Technological variables include:
    - the ratio of ICT investment to industry value-added;
    - ICT investment per working hour;
    - the value of total capital stocks per working hour (capital intensity); and
    - sectoral labour productivity (LP) growth rates in other Organisation for Economic Co-operation and Development (OECD) countries. These provide some indication about international technological innovation paths.

3. Education variables include:
    - the share of persons with university degrees in the workforce;
    - the share of persons with post-school qualifications (from universities or technical colleges) in the workforce;
    - change over time in the share of persons with university degrees in the workforce; and
    - change over time in the share of persons with post-school qualifications in the workforce.

4. Other institutional variables include:
    - the reduction in the number of days lost due to industrial disputes;
    - the decrease in the share of union members in the workforce;
    - the decrease in the proportion of workers covered under general award pay conditions; and
    - dummy variable marking infrastructure sectors that were subject to significant industry-specific competition reform measures.

The results from the regressions were decomposed in two ways:

- the portion of variance explained by each independent variable;

- the components of the aggregate productivity growth figure in terms of regression coefficients multiplied by the mean values of the corresponding independent variables.

The main focus of attention in this study is on MFP growth, which is used in conjunction with growth accounting estimates to decompose the factors driving LP growth. The study examined over 30 regressions where MFP is the dependent variable. The regressions involve different specifications and combinations of explanatory variables. Most of the regressions reported in this paper are single-period regressions relating to changes between 1984–85 and 2001–02. Some multi-period regressions (involving two or four sub-periods) were also tested, but proved to have less explanatory power than the single-period ones. In single-period regressions, the explanatory variables were applied in a parsimonious manner, with usually no more than four explanatory variables in each regression. The explanatory variables comprised of one variable from each of the three factor groups listed above plus capital deepening in LP regressions. Alternatively, the study used composite variables obtained by amalgamating variables in each factor group.

The study also examined 20 LP regressions, mainly in order to test the plausibility of the MFP cum growth accounting decomposition estimates.

The decomposition of MFP growth

Results from the MFP regressions suggest that over half of MFP growth can be attributed to technological factors. Given the relatively low R^2 of the regressions (many of them below 0.5) the study adopted a rather conservative approach and estimates that between 35 and 65 per cent of MFP growth was driven by technological change (implying a mean estimate of 50 per cent). Using these figures combined with growth accounting estimates (including 'embodied' technical change related to falling ICT prices) yielded the decomposition of annual LP growth shown in the following table.

The drivers of labour productivity growth: 1984–85 to 2001–02

	Lower estimate		*Upper estimate*	
LP growth attributed to	*Annual contribution*	*Share*	*Annual contribution*	*Share*
	%	%	%	%
Increased capital spending per worker	1.02	46	1.02	46
Falling ICT prices	0.45	20	0.45	20
MFP growth due to technical change	0.27	12	0.50	22
MFP growth due to institutional change	0.50	22	0.27	12
Annual LP growth	2.24	100	2.24	100
Technological factors[a]	0.72	59	0.95	78
Institutional-economic factors[a]	0.50	41	0.27	22

[a] After discounting the effect of increased capital spending per worker.

The two bottom lines show that after taking away the effect of increased capital spending per worker, technological factors (the ICT revolution in particular) accounted for between 59 and 78 per cent of productivity growth in service industries.

Disembodied technical change

According to the upper estimate in the table, the technology driven component of MFP is larger than the ICT price fall related component, which represents 'embodied' technical change. The technological component of MFP corresponds to what is referred to in the growth literature as 'disembodied' knowledge, to distinguish it from innovative knowledge embodied into new equipment or goods. The productivity effects of disembodied knowledge are related to factors such as published knowledge in science and technology, innovation related externalities, learning-by-doing and network externalities.

Given the central importance of ICT in driving technological advances in service industries, in these sectors network externalities and the learning-by-doing aspect of technological takeup appear to be particularly important. On the subject of learning-by-doing, a cross-country econometric study by Delong and Summers (1992) found that investment in new machinery and equipment (such as ICT equipment) tend to contribute more to GDP growth than equal investment in structures or transport equipment. They explain this by the learning-by-doing process associated with investment in modern equipment. There is also a lot of learning and adaptation involved with the introduction and development of new ICT systems. This 'intangible' investment helps to raise productivity but is not reflected in National Accounts capital expenditure data.

A few caveats

Finally, a few notes of caution. Any decomposition between technological and economic variables is difficult, because the two groups are inter-related. Indeed, most explanatory variables in the model are interdependent to some extent, but the size of impact is inferred from statistically estimable direct effects, without taking into account possible indirect effects. In addition, the estimates could be subject to inaccuracies due to insufficiently strong cross-sectional proxy variables to represent changes in the competitive environment of individual industries. The application of regressions for the purpose of estimating contributions to productivity growth poses additional problems.

Given the methodological and practical difficulties involved in estimating constant price quality-adjusted volume measures of outputs and capital inputs at the sectoral level, the results should be treated with caution. Due to potentially serious data quality and methodological problems, the study draws attention to broad contours rather than to specific numerical results.

The general pattern of results from numerous regressions reported in this study, and the earlier one on productivity growth in manufacturing, points to the conclusion that the

main drivers of productivity growth in Australia over the last two decades were ICT-related innovations rather than changes in the economic environment. Competition reforms might have stimulated investment and the adoption of new ICT and other technologies, but the study was unable to estimate separately the size of these indirect effects.

1. Introduction

1.1 Background

This paper analyses productivity growth in Australian service industries over 17 years from 1984–85 to 2001–02.

The basic motivation is to clarify the role of technological progress, particularly of Information and Communications Technologies (ICT), in driving the strong productivity growth recorded in service industries over the last two decades. More specifically, the report compares the contribution to productivity growth of technological factors (such as falling ICT prices as well as capital and ICT intensities) with the contribution of various economic-institutional factors, such as competition reforms, changing industrial relations and rising education level of the workforce.

This paper is a sectoral macro-level productivity study (as distinct from a firm-level study) based on Australian Bureau of Statistics (ABS) data. It uses simple regression and correlation techniques to analyse productivity growth in selected service industries. Part of the analysis follows the same methodology as an earlier paper on productivity growth in Australian manufacturing (NOIE 2004).[3] In other areas the study breaks new ground.

1.1.1 Overseas studies

To present the background for the study, it may be appropriate to start the discussion with a brief review of other relevant studies. There is a long-running economic debate on the extent to which technological advances influence the structure and growth performance of economies (David 2000), including that of Australia.

Economic historians have long related successive surges in economic development to technological development. More recently, this debate has tended to focus on the particular role of ICT in fostering economic growth (see for example Stiroh 2001, Freeman & Louca 2001, Perez 2002 and Nairn 2002, Carlaw and Lipsey 2003 and Carlaw 2004). Much of this research attributes a great deal of the growth in the period after 1970 to the impact of ICT, while recognising the time lags and non-linear productivity impacts of new technology.

Particular emphasis has been placed on the influences of ICT in the growth surge of the 1990s, particularly in the United States. Recent USA sectoral productivity studies, including Stiroh (2001), Oliner and Sichel (2002) and Jorgenson et al (2002), indicate that much of USA productivity growth in the 1990s was concentrated in ICT producing

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[3] Section 3.6.2 reviews a markedly different research approach, based on firm-level studies on the effect of ICT on productivity growth.

industries and in heavy ICT using industries such as electricity, finance and wholesale trade. The International Monetary Fund (IMF) reported in 2001 that the world was in the midst of an all-purpose technological revolution involving ICT and that the longer term benefits for the global economy of this revolution were likely to continue, or even accelerate, in the years to come (IMF 2001).

Nevertheless, economists were slow to recognise and capture the impact of the information revolution in productivity estimates of National Accounts. This is partly because the estimation of productivity growth is beset by methodological and measurement difficulties, even before coming to the interpretation of results.

Part of the difficulty in capturing the impact of technology lay in the measurement of technological advances embodied in capital equipment. Research by Gordon (1990) demonstrated that the existing measurement methodology did not adequately capture the quality improvements and decreasing product cycles of computing equipment. Consequently, he argued that the use of hedonic (quality-adjusted) price index methodologies was necessary to bring this 'technological drift' to account. The use of this methodology has shown large increases in the contribution of ICT technology embodied in equipment to labour productivity, and equal declines in unidentified technological drift included as part of multifactor productivity (MFP) growth. Debate continues as to whether all the technological drift associated with ICT has been adequately captured.

Productivity growth in services has been subject to special attention in a few overseas studies such as OECD (2001) and OECD (2004). But given that services are the dominant sector in modern economies, productivity growth in services usually forms part of broader discussion about productivity growth in the economy at large.

1.1.2 Australian studies

A number of Australian studies analysed productivity growth at the national or sectoral level. Each has its virtues and drawbacks. The present study, like the earlier one on manufacturing (NOIE 2004), addresses the issue from a different perspective than the rest. It endeavors to decompose the drivers of productivity growth by comparing productivity growth rates between sectors and by using statistical inference techniques.

There are a number of other possible approaches to the problem, although the scarcity of suitable data imposes severe constraints on what can be applied in practice. Two recent studies (Parham et al 2001 and Simon and Wardrop 2002) examined the contribution of ICT to productivity growth of the Australian market sector (not only services) using a growth accounting approach. These studies sought to quantify the contribution of ICT to productivity growth by looking at how much ICT investment adds to capital deepening (that is, change in the capital-labour ratio) at the aggregate rather than sectoral level.

This study relies partly on growth accounting in the decomposition analysis. In the growth accounting framework technological advances in ICT are treated as 'embodied' in equipment purchases through the use of 'hedonic' (quality-adjusted) price deflators (Parham et al 2001), in line with the suggestions of Gordon (1990) mentioned earlier. The application of hedonic price deflators for estimating changes in capital stocks under rapidly falling ICT prices raises additional complications.

- The split between the two components of LP growth—that is MFP growth and the effect of capital deepening—depends on difficult-to-estimate quality-adjusted price deflators. Given the capital indexation problems involved (see sections 3.2 and 4.3), the measurement of MFP growth is probably less reliable than that of LP growth.

- The impact of technological progress is included partly in capital deepening and partly in MFP growth. The size of technical change 'embodied' into capital deepening is not reported. Hence essential information is missing.[4]

In any event, these studies found that ICT capital accounted for more than a quarter of output growth and over a third of LP growth. Over 40 per cent of LP growth remained unexplained, however, lumped under the heading of MFP. Now, this unexplained MFP may partly represent further contribution of ICT not picked up in 'capital deepening', as well as a host of other factors, including the effect of non-ICT related innovations, microeconomic reforms, globalisation, rising education standards and changes in labour and capital markets. A major issue with this macroeconomic growth accounting approach is that it leaves more unexplained than what it actually explains.[5]

The main objective of this paper (and the earlier one on manufacturing) is to shed more light on the composition of this previously unexplained MFP.

1.2 Scope and coverage

The basic measure of productivity is LP, which is defined as value-added (expressed in terms of a constant price chain volume index) divided by employment in each industry (measured in terms of working hours).[6] While labour force statistics are available at a fairly detailed industry level, the same does not apply to value-added estimates.

Due to the limited availability of time-series data on value-added volume indices, only a sub-set of service industries are analysed in this paper. The ABS does not publish

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4 For a theoretical discussion see Pakko (2002). Technological change included in new capital is referred to in the literature as 'embodied' change. The portion included in MFP is referred to as 'disembodied' change.

5 Coming from a different perspective (using sales markups), Diewert and Lawrence (2004) find from Australian data that growth accounting does not pick up the full impact of ICT inputs on productivity growth.

6 ABS chain volume measures refer to volume indices where the weights (prices) are updated each year instead of being kept constant for a number of years.

genuine constant price value-added estimates for government services, because in this sector changes in the value of output cannot be estimated using market valuation. In addition, there are no genuine value-added volume indices for a number of private service industries because of the difficulty in estimating changes in the real value of output. These industries include business, professional and personal services, real estate and property services.[7] The value-added volume estimates of these sectors in the National Accounts are based on total working hours, which means that LP growth (based on value-added divided by working hours) in these sectors is by definition zero.

For other industries in the economy the ABS publishes proper (constant price) value-added volume estimates, usually at the first division Australia and New Zealand Standard Industrial Classification (ANZSIC) level. These industries are referred to by the ABS and the Productivity Commission (PC) as the 'market sector' of the economy. The estimation of constant price volume indices of value-added in service industries is notoriously difficult (OECD 2004, Poole 1999, Lawrence and Diewert 1999). In the absence of adequate information, this study does not deal with these difficulties and takes the ABS estimates as given.

Notwithstanding the exclusion of government and some important private service industries, the present study covers around 56 per cent of the total value-added of services and around 40 per cent of GDP at factor prices in 2001–02. In terms of total employment (full-time and part-time combined) the service industries examined in this productivity study cover 46 per cent of the national workforce. Hence, the study is dealing with a substantial portion of the Australian economy.

As noted earlier, value-added volume indices are usually available only at the broad ANZSIC division level.[8] The nine service sectors at that level covered in the productivity analysis are:

- electricity, gas and water supply (EGW)
- construction
- wholesale trade
- retail trade
- accommodation, cafes and restaurants
- transport and storage
- communications
- finance and insurance

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[7] The ABS has not yet incorporated property and business services into market sector data because price indexation consistent with other market sectors started only since 1999. This is an important sector in respect to ICT because it includes software and computer services.

[8] For service industries the ABS publishes current price value-added estimates only at the broad ANZSIC division level, but the ABS has produced a few constant price (volume) estimates for service industries at the two digit ANZSIC level, which are used in this paper.

- cultural and recreational services

The ANZSIC division service industries excluded from the productivity analysis are:

- property and business services
- government administration and defence
- education
- health and community services
- personal and other services[9]

In addition, imputed rent on owner occupied dwellings, which represents over nine per cent of GDP at factor prices, is also excluded from the productivity analysis. Strictly speaking, this is a GDP item rather than a service industry.

The Department received from the ABS unpublished value-added volume indices for the sub-industries of four major service sectors listed earlier. The following sub-divisions are used in this report:

Electricity, gas and water, divided into:
- electricity and gas supply
- water, sewerage and drainage.

Retail trade, divided into[10]:
- food retailing
- personal and household retailing
- motor vehicle retailing and services

Transport and storage services, divided into:
- road transport
- air transport
- rail, water, pipeline and other transport
- storage and transport facilities (including ports and airports)

Finance and insurance, divided into:
- finance and services to finance
- insurance

Using these subdivisions, it was possible to expand the productivity study from nine into 16 service industries. The increase in the number of industries is of considerable importance in the statistical analysis presented in chapters 5 and 6, which is based

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9 Personal and other services also include some public services such as police and fire brigades.

10 Value-added volume indices for three sub-divisions of wholesale trade are only available since 1996, and therefore were not used in this productivity study.

largely on cross-sectional analysis of differences between industries rather than on time-series analysis.[11]

Although the basic data needed for analysing LP growth is available for 16 industries over the study period, it should be noted that for a number variables used in the statistical analysis data is available only for nine service sectors at the ANZSIC division level. These variables include capital deepening, capital intensity, MFP growth rates, OECD sectoral productivity growth rates, ICT investment divided by value-added and ICT investment per hour. With these variables, estimates for 16 industries were obtained by using pro-rata allocations, based on information for 16 industries on value-added per hour, the change over time in value-added per hour and ICT-related coefficients from input-output tables. With respect to OECD productivity growth rates, the estimates for main sectors were applied also to their sub-industries.

Direct information covering all 16 industries was available in respect to the remaining variables, including LP growth, education level of the workforce, union membership, award coverage and the frequency of industrial disputes.

With the exception of some OECD data, all other data used in this report is based on ABS estimates.

1.3 Structure of the report

The report is divided into six chapters.

Chapter 2 examines broad trends in Australian service industries from 1984–85 to 2001–02. The emphasis is on the 16 industries covered in the productivity analysis. Topics include output growth, employment, structural change and foreign trade. The aim is to present a broad-brush picture on Australian services as background information for subsequent discussions.

Chapter 3 presents a brief qualitative review of technological factors that affected productivity growth in service industries. The emphasis is on the impact of advances in ICT, but attention is also given to non-ICT related innovations. The chapter also reviews some ABS data on the takeup of ICT technologies in various industries and firm-sizes. The purpose of the discussion is to provide a better appreciation of technological factors and of ICT-related quality-adjusted (hedonic) constant price indexation problems, before the study turns to quantitative analysis.

Chapter 4 presents estimates of LP growth as well as MFP growth. MFP is the portion of productivity growth that can not be explained by changes in labour and capital. Analysing the components of MFP growth is the central objective of this paper. The

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[11] As will be discussed in section 6.2.5, single period cross-sectional regressions yield much clearer results than multi-period regressions based on panel data.

chapter examines some methodological problems involved in estimating capital deepening and MFP growth.

The chapter presents a partial decomposition analysis of LP growth in terms of capital deepening and MFP growth. Particular attention is given to the contribution of falling ICT prices 'embodied' into capital deepening.

Chapter 5 reviews a number of observable variables that can be used to explain productivity growth. Variables that provide indications about the technological characteristics of the industry include two ICT intensity measures (that is, ICT investment divided by value-added and ICT investment per hour), sectoral productivity growth rates in other OECD countries and capital intensity.

Education variables represent another group of explanatory factors. These include the share in the industry's workforce of persons with university or other post-school qualifications and changes in these shares between 1984–85 and 2001–02.

Other institutional-economic variables on which industry-specific data was found include the decreasing share of union members in the workforce, the decreasing proportion of workers covered under general award pay conditions and reduction in number of days lost due to industrial disputes. In addition, a dummy variable is used to mark infrastructure sectors that were subject to significant industry-specific competition reform measures.

The second-last section of chapter 5 examines the correlations between all the variables used in this study, including explanatory variables and productivity growth rates. The final section compares LP growth of service industries segmented according to ICT intensity. The results show that LP growth of heavy ICT user industries was much higher than that of light ICT users. The results strongly suggest that productivity growth is closely linked to ICT usage.

Chapter 6 uses the explanatory variables outlined in chapter 5 to estimate through regressions the contribution of various factors to productivity growth. Two approaches are used. One approach is to take the contribution of falling ICT prices to capital deepening as given (from section 4.3), and add to this the regression-estimated technology driven portion of MFP growth. The other approach is based on decomposing through regressions the drivers of LP growth. Both approaches provide strong indications that the primary driving force of productivity growth was technological progress, linked mainly to rapid advances in ICT technologies.

In the previous report on productivity growth in manufacturing (NOIE 2004), a promise was made to investigate in what way the incorporation of new industrial relations variables will affect the estimated contribution of technological and economic factors to productivity growth. In the meantime, the ABS supplied data for two such variables. One is the decrease in union membership over the last two decades and the other is the proportion of the workforce covered under award pay conditions. Section H.5 in the

appendix presents revised regression results for manufacturing, employing these two new explanatory variables. In addition, the study presents revised estimates for the contribution of technological and institutional-economic factors to manufacturing productivity growth, using the growth accounting combined with MFP decomposition method applied in the service industries study.

2. Broad trends in service industries

This chapter analyses broad trends in service industries in relation to output, employment, structural change and foreign trade. The emphasis is on the 16 service industries subject to productivity analysis. The interested reader can find more detailed discussion about recent trends in service industries in McLachlan et al (2002).

2.1 The share of services in GDP

Broadly speaking, services cover all sectors of the economy that do not belong to primary industries (agriculture and mining) or secondary industries (manufacturing). The definition of services (as used by the Productivity Commission and in this report) encompasses a wide range of industries. Some of these industries accord with the common usage of the term services, such as wholesale and retail trade as well as personal, educational and medical services.[12] Other industries producing tangible or semi-tangible output have much in common with good producing sectors—these include construction, electricity, gas and water supply (EGW), repairs, maintenance and telecommunications.

Services represent the largest section of the Australian economy and the fastest growing one after mining. Table 2.1 shows the share of major sectors in GDP and corresponding annual growth rates.

Table 2.1 Sectoral composition and growth of GDP

	Share in GDP		*Average annual growth*
	1984–85	*2001–02*	*1984–85 to 2001–02*
	%	%	%
Agriculture	5.0	4.2	2.6
Mining	4.3	5.2	4.8
Manufacturing	15.4	11.8	2.0
Total goods producing industries	**24.6**	**21.2**	**2.7**
Service industries used in the analysis	38.8	39.7	3.7
Property, business and personal services	10.6	14.0	5.3
Government services	16.3	15.4	3.2
Imputed rent on dwellings	9.6	9.7	3.7
Total services	**75.4**	**78.8**	**3.9**
GDP at basic prices	100.0	100.0	3.6

Source: ABS Cat. No. 5206.0.

These figures are based on value-added volume indices for two reasons. First, the ABS supplied consistent time-series value-added volume data covering the entire study

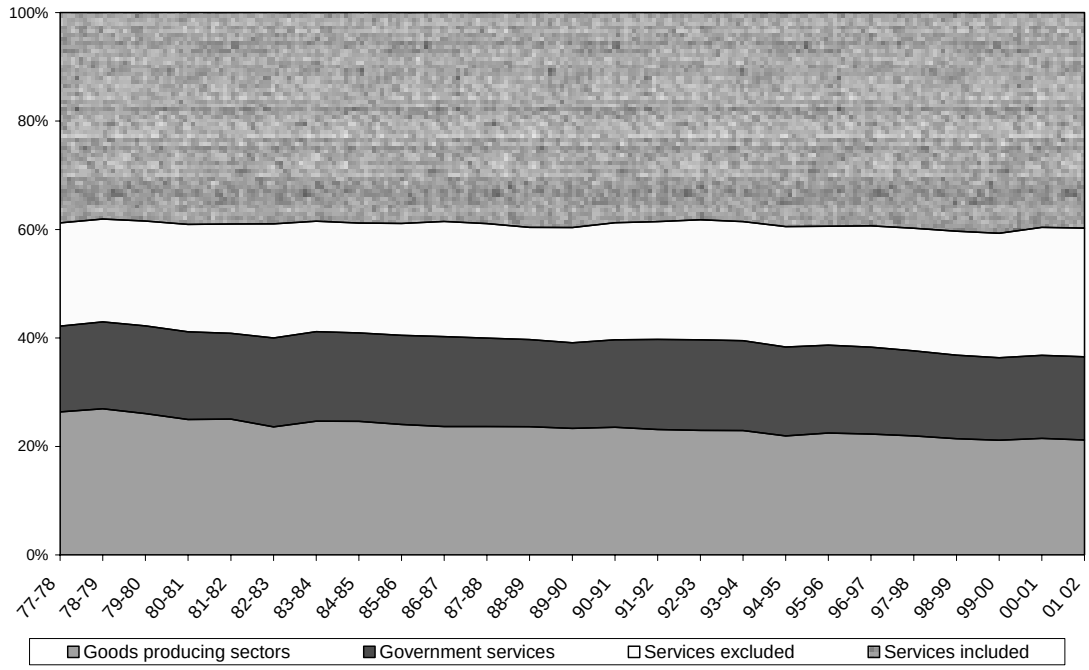
[12] The GDP item of imputed rent on dwellings was classified as part of services, though strictly speaking it is not a service industry.

period. By contrast, current price value-added data are not entirely consistent when comparing the period before 1989–90 with later years. Second, by virtue of examining productivity growth, the interest in this study is in volume rather than current price value-added estimates.

A number of interesting points emerge from table 2.1. While all major sectors of the economy expanded their output, there are large differences in growth rates, which are reflected in changing shares in GDP. The share in GDP of goods producing industries fell between 1984–85 and 2001–02, mainly due to the marked contraction in the share of manufacturing and agriculture, which was taken up by an increase in the share of services.

An interesting point in context of the present discussion is that most of the increase in the share of services did not occur in the service industries covered in the productivity analysis, but in the service industries excluded. In fact, most of the increase occurred in property and business services, which includes fast growing subsectors such as real estate, property rents, professional and engineering services, computer services and software. Since disaggregated time-series data on this sector are not available, the study does not analyse the components of this rapid output growth.

Figure 2.1 The changing composition of GDP



Source: ABS Cat. No. 5206.0.

Figure 2.1 illustrates the changing composition of GDP from 1978–79 to 2001–02. The graph clearly shows the falling share of goods producing industries and the increasing share of private service industries excluded from the productivity analysis. Notice that services was already the dominant sector of the economy in the 1970s.

2.2 Reasons for the increasing share of services in GDP

The reasons for the declining share of manufacturing and agriculture in GDP and the increasing share of services has been subject to extensive discussions in Australia and other OECD countries that experienced similar trends. As discussed in NOIE (2004), three major reasons were identified in the literature for these secular trends. These are:

Consumer demand

There has been a secular shift in consumer demand toward services. This shift was recently examined in McLachlan et al (2002) and DISR (2001). Briefly, the main explanation is that the income elasticity of consumer demand for many services is above unity and exceeds the average income elasticity of demand for manufactures and food/beverages. Service items with high-income elasticities include housing, tourism, recreational activities, medical services, banking and insurance. In addition, marketing and advertising tend to be more intensive with non-essential goods. These demand factors led to a more rapid growth in national expenditure on services than on manufactures or food and beverages.

Statistical transfer of activities from manufacturing to services

The statistical allocation of value-added into industries is based on the industry classification of reporting establishments.[13] Large manufacturing establishments often undertake activities such as transport, warehousing, wholesale trade, accountancy, computer work, cleaning, maintenance and engineering design that under a different organisational arrangement could be undertaken by outside contractors. Anecdotal and statistical evidence suggests that in the last two decades many large manufacturing establishments have followed increased specialisation and outsourced non-core activities to external contractors in order to improve efficiency. Such outsourcing results in value-added being reclassified from the manufacturing sector to services. To a lesser extent, similar transfer of activities also occurred in agriculture and mining.

The productivity price effect

In recent years productivity improvement in the 'goods' producing sectors (agriculture, mining and manufacturing) tended to exceed productivity improvements in most services.[14] In competitive markets productivity improvements are translated into lower prices. Due to uneven productivity gains, the relative prices of manufactures and farm produce tended to decrease compared with those of many services. These changing price relativities led to a slower increase in the value of manufacturing and agricultural output in current price terms than the rise in the current price value of services.

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[13] Since 2000–01, the reporting unit in the Manufacturing Survey changed from establishments to management units (usually corresponding to firms).

[14] Notable exceptions include telecommunications, electricity, wholesale trade, air and rail transport. These will be examined in detail later.

2.3 Structural changes

Output changes in service industries reflect structural changes in the economy. Table 2.2 shows the share in constant price GDP of the 16 service industries used in the productivity analysis and corresponding average annual growth rates of value-added between 1984–85 and 2001–02.

Table 2.2 Composition and growth of service industries covered in the productivity analysis

Based on value-added volume indices

	Share in GDP		*Average annual growth*
	1984–85	*2001–02*	*1984–85 to 2001–02*
	%	%	%
Electricity and gas	2.0	1.8	2.9
Water supply, sewerage and drainage	1.0	0.6	1.0
Construction	6.9	6.1	2.8
Wholesale trade	5.9	5.5	3.2
Food retailing	2.4	1.9	2.1
Personal and household retailing	2.7	2.6	3.3
Motor vehicle retailing and services	1.3	1.0	2.4
Accommodation, cafes and restaurants	2.3	2.2	3.5
Road transport	1.6	1.8	4.6
Air travel and transport	0.5	0.8	6.2
Rail and water transport and pipelines	0.8	0.5	1.4
Storage and transport facilities	2.3	2.2	3.2
Communications	1.4	2.9	8.2
Finance	3.5	5.2	6.1
Insurance	2.7	2.6	3.4
Cultural and recreational services	2.2	1.9	2.8
Total services covered	**39.2**	**39.7**	**3.7**

Source: ABS Cat. No. 5206.0 and unpublished ABS data at the two-digit ANZSIC level.

Table 2.2 shows that the strongest growth areas among the 16 service industries examined include communications, finance, air transport and road transport. Slowly growing sectors include water supply and sewerage, rail and water transport. Other industries recorded average annual growth rates between two and four per cent.

It should be noted that the exceptionally high growth rates in telecommunications, finance and air transport/travel were spurred by rapid technological advances in these areas, which led to increased demand due to falling relative prices. The study will present further information on this subject later.

In terms of value-added, the largest service industries in table 2.2 are construction, wholesale trade, retail trade, finance and insurance. In 2001–02 these industries represented 63 per cent of all service industries covered in the productivity analysis.

2.4 Employment in services

Another perspective on service industries can be gained by looking at employment statistics. Table 2.3 presents employment data on the entire economy, including disaggregated data on the 16 service industries selected.

Table 2.3 Employment statistics—all industries

	Employed Feb 1985	*Employed Feb 2002*	*Proportion part-time 1985*	*Proportion part-time 2002*	*Average annual growth 1985–2002*
	000s	000s	%	%	%
Agriculture, forestry & fishing	407	435	19.1	24.1	0.4
Mining	95	83	2.5	4.2	-0.8
Manufacturing	1144	1096	7.2	10.4	-0.3
Government services	1293	1940	21.5	33.4	2.4
Property & business services	419	1057	20.4	25.6	5.6
Personal and other services	219	356	25.7	29.6	2.9
Electricity and gas supply	91	45	1.2	4.3	-4.1
Water supply and sewerage	42	19	0.5	6.8	-4.6
Construction	476	713	11.5	14.4	2.4
Wholesale trade	421	442	10.1	16.2	0.3
Food retailing	298	551	38.7	59.1	3.7
Household good retailing	392	574	32.5	45.6	2.3
Motor vehicle retailing/service	185	274	11.6	18.7	2.3
Accommodation and restaurants	226	475	42.5	48.5	4.5
Road transport	147	221	12.7	20.0	2.4
Air transport/travel	29	50	10.5	16.9	3.4
Rail, water and other transport	110	41	1.3	7.8	-5.6
Storage and transport facilities	69	92	4.9	17.1	1.7
Communications services	150	178	6.6	12.8	1.0
Finance	209	274	10.6	20.1	1.6
Insurance	58	75	8.9	13.0	1.6
Cultural and recreational	132	256	40.8	43.8	4.0
Total services in productivity study	3034	4280	19.0	30.8	2.0
Total Australia	6610	9246	17.5	27.7	2.0

Source: ABS Cat. No. 6203.0.

A number of interesting points emerge from table 2.3. While overall employment increased by around 40 per cent over 17 years, in a number of service industries employment has actually dropped. These industries include electricity and gas supply,

water supply and rail/water transport. The decrease of employment in these industries is partly related to technological advances and partly to microeconomic reforms of infrastructure services, as will be discussed in section 5.6.

Apart from property and business services (which are not covered in the productivity analysis), the biggest employment gains in percentage terms occurred in food retailing, accommodation and restaurants and cultural/recreational services. In these industries a large portion of employment growth was in part-time employment.

The strong growth in part-time employment in most service industries has been one of the most notable economic developments in the last twenty years. The increase in part-time employment was mainly driven by the large influx of married women into the workforce. It should be noted that these changes do not affect the present productivity calculations, which are based on total working hours rather than the number of persons employed.

Comparing the numbers in tables 2.2 and 2.3 reveals that industries that recorded strong growth in value-added did not always record similarly strong growth in employment. The air travel/transport industry is an exception, having recorded strong growth in both value-added and employment. The disparities between value-added and employment growth rates indicate large dispersion in LP growth rates, a subject that will be examined in section 4.1.

Finally, it should be noted that contrary to popular beliefs, the service sector is not the lowest paying sector in the economy. McLachlan et al (2002) report that average full-time weekly earnings in services are above those in manufacturing and agriculture but below those in mining. The reason is that service industries such as health, education, utilities, construction, finance and insurance employ a higher proportion of educated or vocationally trained workers than manufacturing or agriculture. However, in services dominated by less skilled workers, such as retail trade, accommodation and restaurants and personal services, average full-time earnings are lower than in other sectors.

2.5 Trade in services

Trade in services represents over a fifth of Australia's foreign trade in goods and services combined. McLachlan et al (2002) report that since the mid 1980s the growth of world exports of services outstripped the growth in the exports of goods. Tourism and telecommunications have been strong growth areas in world trade and the same applies in Australia.

Table 2.4 shows the percentage share of services in the combined trade of goods and services in Australia. The statistics are presented for 2001–02 and for 1987–88. The

ABS has published detailed statistics on trade in services since 1987–88 and this is the reason for choosing that year as the starting period for comparisons.[15]

The trade deficit in services decreased from 5.5 per cent of the total exports of goods and services in 1987–88 to 0.56 per cent in 2001–02. The main reason for this improvement has been the increasing surplus on travel expenditure, as a result of the large increase in inbound tourism to Australia and the influx of fee paying overseas students. The decrease in transportation costs, due to the fall in the cost of sea and air transport, has been another important contributing factor (see section 3.4).

Improvements in technology related items also contributed to the positive change in the overall trade balance in services. The balance on computer services was slightly negative in 1987–88 but turned markedly positive by 2001–02. Trade in computer services is mainly related to software development. The trade deficit on royalties and license fees (mainly for technology transfer) also decreased markedly during the period examined.

Table 2.4 Foreign trade in services

As a percentage of total exports and imports of goods and services

	Exports[a]	Imports[b]	Surplus/deficit[c]
		2001–02	
	%	%	%
Transportation	5.03	7.00	-2.04
Travel	9.70	7.10	2.52
Telecommunications	0.69	0.92	-0.23
Computer services	0.72	0.39	0.33
Royalties and license fees	0.37	1.19	-0.82
Financial and insurance services	0.96	0.92	0.03
Business and professional services	2.23	2.42	-0.22
Other services	0.78	0.89	-0.12
Total services	20.47	20.82	-0.56
		1987–88	
Transportation	7.35	10.19	-3.37
Travel	7.13	7.04	-0.28
Telecommunications	0.81	1.01	-0.25
Computer services	0.16	0.18	-0.03
Royalties and licence fees	0.41	1.60	-1.27
Financial and insurance services	0.20	0.43	-0.25
Business and professional services	2.84	2.72	-0.02
Other services	0.09	0.09	-0.01
Total services	18.99	23.27	-5.49

[a] As a percentage of total exports of goods and services. [b] As a percentage of total imports of goods and services. [c] As a percentage of total exports of goods and services.

Source: ABS 1987–88a, 1987–88b and Cat. No. 5422.0.

[15] In the 1987–88 balance of payment statistics, royalties and license fees were included in the current account income side rather than under trade in services. Appropriate adjustments were made to ensure that the same items are covered under trade in services in the two years compared in table 2.4.

Services contribute to exports well beyond the figures recorded under trade in services. The goods producing sectors (agriculture, mining and manufacturing) spend large amounts on various internal services to support their export activities. According to estimates cited in McLachlan et al (2002), based on the analysis of input-output tables, the service sector's real contribution to Australia's total exports is around 40 per cent instead of the 20 plus per cent shown in table 2.4. Major service inputs that are included in merchandise exports but not in service exports include internal transport and communications, electricity, gas and water supply, construction for goods producing industries, as well as inputs of financial, computer and professional services. Evidently, productivity growth in these service industries has a major impact on Australia's international competitiveness.

3. A brief review of technological developments

According to the economic growth literature, the long term change in output per worker or per hour (labour productivity) is driven by three broad factors:

- change in the capital-labour ratio (capital deepening),
- changes in economic-institutional factors, and
- technological progress.

Capital deepening and changes in the economic environment will be discussed in the following chapters. This chapter concentrates on the effects of technological progress in services. While the main focus of attention is on advances in ICT, attention will be also given to other technological developments that affected the service industries covered in the productivity analysis. The purpose of the discussion is to provide the reader a better appreciation of technological factors driving productivity growth in services and how technological progress is partly reflected through price indexation in sectoral productivity measures.

3.1 The ICT revolution

Most economic growth studies suggest that ICT was responsible for a large portion of productivity improvements in the economy (particularly in services) in industrialised countries in recent years. Recent literature on this subject includes Schreyer (2000), OECD (2000), DeLong (2000), IMF (2001), Parham et al (2001), Freeman and Louca (2001), Stiroh (2001), Simon and Wardrop (2002), Perez (2002), Nairn (2002), Bassanini and Scarpetta (2002), Oliner and Sichel (2002), the Ovum Report (2003), Inklaar et al (2003) and Jorgensen et al (2004). A comprehensive literature review with an emphasis on Australia is presented by Anderssen (2004).

The computer was invented in the 1940s, but because of the initial small size of the industry, a noticeable impact on aggregate economic performance (even in the USA) was not evident until the second half of the 1960s. By that time, computers started to assume an important role in data processing and military applications. While the cost of computing was tumbling, the cost of telecommunications was also decreasing at a rapid albeit slower pace, as a result of the introduction of digital signalling and switching equipment, satellite transmission and optical fibre cables. The quality adjusted (hedonic) prices of consumer electronics goods, such as TVs, radios, videos and sound recorders were also falling, but at much slower pace than those of computers.

The falling quality-adjusted prices of ICT equipment are translated in the National Accounts into productivity gains. Some estimates for the productivity effects of falling ICT prices are presented in section 4.3.3. The growth literature refers to these effects as technical change ‘embodied’ in new investment. In addition, there are large

'disembodied' knowledge flows associated with the ICT revolution. The study will examine 'disembodied' technical change in section 6.3.2.

3.2 Quality-adjusted price indexation problems

A number of different approaches have been adopted to quantify the economic impact of the ICT revolution, concentrating particularly on quality-adjusted price indexation issues.

DeLong (2000) cites a USA economic study which found that a computer in 2000 cost one-ten thousandth as much as a computer with the same performance capabilities in 1960. This implies that the quality-adjusted price of a computer at the beginning of a decade was 900 per cent higher than at the end of a decade.

This magnitude of price changes raises serious indexation problems. Even if the performance of digital processing and memory units increased tenfold over a decade, the economic value of the output from the equipment did not increase ten times, due to less efficient application of the equipment as its performance improved exponentially. The decrease in price increased the quantity sold, but computers became less intensively used in terms of working hours and the operating system employed for running them required much more processing time and memory. Moreover, the equipment became employed in applications that would have been uneconomic with more expensive computers; such as Internet communications, video games, CD-ROM reading, e-commerce or factory automation. For example, reading CD-ROMs was technically feasible already 25 years ago, but reading at the same speed as modern personal computers would have required computer hardware costing millions.

Obviously, the 'hedonic' (quality-adjusted) price indexing of ICT equipment raises many difficult issues. Not only is it difficult to estimate accurately constant-price quality-adjusted values for computers sold to consumers, but there are even greater difficulties in estimating the real constant-price value of the ICT capital stock deployed by industry.[16] The study will come back to price indexation issues in section 4.3.

3.3 The ICT revolution in services

Advances in ICT and its applications are often the only technological factors that can be identified as significant contributors to productivity growth in service industries. This applies to the bulk of service industries examined in the present productivity analysis, including wholesale/retail trade, finance/insurance, telecommunications and cultural/recreational services. Only a minority of service industries benefited in recent years from significant technological advances outside ICT. These include transport,

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16 The ABS uses U.S. Bureau of Labour Statistics price indices for computer equipment to estimate quality-adjusted ICT volume measures, taking into account exchange rate fluctuations and time lags between the release of innovations into the USA and Australian markets.

electricity and water supply. Even non-ICT innovations often occurred in conjunction with new ICT applications.

The principal contribution of ICT to productivity growth in services was by advancing the automation of office, banking, shopping and warehouse functions and enabling improved access to information. The new ICT systems opened the way for less labour intensive approaches to various clerical/administrative functions including: data entry, pricing, invoicing, payroll, costing, stock control, financial reporting, job monitoring and project design.

The application of computers in office work in large organisations dates back to the 1960s in developed countries. The more recent advances are manifested in widespread usage of computers, associated devices, advanced telecommunications networks and the Internet by small firms and much more intensive and pervasive application of ICT technologies across all firm sizes. The importance of large mainframe computers has declined while the importance of computer networks (based on personal or small computers) has increased. In recent years there has been a continuing convergence between computers and telecommunication networks, leading to the notion of information and communications technologies (ICT). Some statistics on ICT usage are presented in sections 3.5 and 3.6.

Generally speaking, the trend is toward a 'paperless office', where all transactions are recorded in a digital form and the data are processed through computers and transmitted through digital telecommunication networks. In addition to quicker processing, falling storage costs for digital data means that archived data can be more easily and efficiently retrieved. Financial transactions increasingly rely on computer terminals, while face-to-face contact is decreasing. Electronic cards are gradually replacing paper money.

Bar code scanners and associated systems completely changed billing and data entry in retail and wholesale trade, reducing the demand for sales, warehouse and office personnel, while also supporting just-in-time and other efficiency improving logistics systems. Computer-controlled ticketing and vending machines had a similar effect. New arrangements of e-commerce, involving online ordering, authentication and payments, can lead to a significant reduction in the demand for clerical, warehouse and other administrative personnel involved in preparing orders or processing deliveries.[17] While online shopping (ordering) is not yet widely used by consumers, it is more heavily used in inter-firm transactions.

Whereas in the past computerised administration required highly standardized procedures, new powerful and user-friendly software packages enable a more flexible approach to various trading and administrative functions, while still maintaining a high level of computerisation. In addition, the Internet provides quick access to outside

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[17] Johnston et al (2000) present an interesting study of technological and organisational changes in the Australian wholesale and retail trade industries.

information on topics such as products, prices, suppliers, users, patents, publications, forecasts and futures prices.

All told, the more intensive usage of computers and digital communications had a profound impact on almost all office, administrative and trading jobs. These jobs cover a large proportion of white-collar occupations (apart from highly skilled professional and technical personnel). The statistics on the distribution of occupational categories presented in McLachlan et al (2002, table 4.4) indicate that 61 per cent of the total workforce are employed in skilled and unskilled white-collar occupations. In service industries the proportion of white collar occupations reaches 67 per cent. Almost all these occupations have been markedly affected by the increasing use of computer-related technologies.

The organisation and work flows of firms have changed in order to exploit more effectively cheaper ICT systems and new technological opportunities. The level of inter-firm transactions has increased as a result of reduced transaction costs. Many non-core activities have been outsourced to external suppliers and service providers. Revesz and Lattimore (1997) suggest that this has been one of the prime reasons for the rising importance of small business in the economy.[18]

Other technological advances in electronics also contributed to productivity gains in service industries. Mobile telephones, which became widely used after the late 1980s, led to productivity improvements in mobile service jobs, which require contact with customers and suppliers from different locations. These include construction managers, outdoor repair and maintenance contractors and drivers of taxis and pickup vans. Electronic surveillance and monitoring devices have helped to reduce labour requirements in various security functions. New electronic fire and other safety devices in buildings had a similar effect.

Given that ICT had particularly strong impact on white collar occupations in offices, shops and warehouses, not surprisingly the LP estimates discussed in the next chapter indicate much higher productivity growth in sectors such as finance, insurance, wholesale trade and communications than in construction or road transport, which are dominated by blue collar workers.

This brings up the concept of technological innovation paths (or trajectories), which is used repeatedly in this paper. This concept refers to the widely observed phenomenon of different rates of significant technological innovations occurring between industries and sub-industries. The innovation literature suggests that technological change is, in many instances, path dependent. Thus the future rate and direction of technological change depends on past technological expertise and current technological developments. Consequently, in many industries, it is possible to predict with some confidence the rate

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[18] Increasing intensity of inter-firm transactions in components and sub-assemblies is reflected in the rising importance of intra-industry foreign trade, a subject discussed in PC (2003) and NOIE (2004).

of takeup of new technologies, assuming a given level of on-going investment in R&D, a known technological base, and reasonably steady economic growth.

This path dependency is closely related to the influence of so-called general purpose technologies (GPT) (see Lipsey 2002 and Carlaw 2004). Major GPTs over the last two hundred years were the steam engine, steel making, analytical chemistry, electricity and the internal combustion engine. The two major GPTs that evolved over the last couple of decades are ICT and biotechnology. Sectors that are closely linked to currently developing GPTs tend to exhibit higher productivity growth than the rest. The qualitative review in this section suggests that different technological innovation paths in service industries are closely related to different levels of utilisation of ICT technologies.

3.4 Non-ICT related technological innovations in service industries

While in manufacturing, mining and agriculture a significant portion of technological progress can be attributed to non-ICT innovations (in areas such as biotechnology, material science, bulk material handling and increasing equipment size and sophistication), in many service industries it is difficult to identify significant technological advances outside the ICT area in recent years.

A notable exception is the transport sector. The efficiency of various transport equipment, including planes, ships, trains and trucks, has improved significantly both in terms of labour requirements and fuel consumption. Some of these improvements can be attributed to the incorporation of small computers to control fuel injection and ignition in engines. Increasing usage of containerised cargo in sea, rail and road transport and the growing size of transport equipment has also reduced freight costs. Other advances are related to easier navigation and control of ships and planes, largely based on ICT technologies.

The significant technological improvements in sea and air transport are illustrated in statistics presented in PC (2003) on the freight costs of Australian imports. Table 6.10 in PC (2003) reports that the percentage of sea freight and insurance costs from the free-on–board (FOB) value of imports decreased from 8.5 per cent in 1988–89 to 5.21 per cent in 2001–02. The percentage of air freight and insurance costs on goods carried by air transport decreased from 7.42 per cent in 1988–89 to 3.86 per cent in 2001–02. The large productivity improvements in railways (see table 4.1 and PC [1999]) were partly driven by technological improvements in railway equipment as well as in signalling, coordination and track maintenance.

The electricity supply industry benefited from non-ICT technical innovations over the last twenty years. Continuing technological improvements occurred in power generation and transmission. Apart from improvements in generators and transformers, productivity also improved due to computerised control of the electricity grid through digital communications. Improved automation and remote control through computers

and digital communications also occurred in service industries relying on pipelines and pumps, such as water and gas supply. In addition, water treatment benefited from new filtering and purification technologies.

All told, with the exception of transport, electricity and water supply, it is difficult to identify service industries where non-ICT innovations were of comparable importance to ICT innovations over the last couple of decades.[19] This study did not collect sufficient information to gauge the relative importance of ICT and non-ICT related technological innovations in transport, electricity and water supply in recent years. Commenting on this issue would require extensive consultation with technical experts. This matter is not followed up in the present study.

3.5 Capital expenditure on ICT equipment

As part of the National Accounts series, the ABS publishes spreadsheets on capital stocks and gross fixed capital formation (GFCF) in both current prices and quality-adjusted volume terms. This information covers the nine ANZSIC division service industries used in the productivity analysis. GFCF and capital stock data for each industry is dissected as follows:

- building and structures
- software
- computers
- electronic and electrical equipment
- industrial machinery and equipment
- road vehicles
- other transport equipment
- other plant and equipment

The availability of investment and capital stock data on software, computers and electronic/electrical equipment at the industry level opens the way for estimating the ICT intensity of individual industries. Both the value of ICT capital stock and the value of ICT-related GFCF can be used as indicators of ICT intensity. In the following discussion GFCF is referred to as investment. The level of annual investment in ICT equipment provides an indication on the level of ICT expenditure in each industry. For this reason, the study uses ICT investment (GFCF) rather than ICT capital as a proxy for the ICT intensity of industries.

By definition, ICT incorporates computers and software used by industry. The situation is more ambiguous in respect to the category of electronic/electrical equipment.

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[19] The health industry, which benefited from many non-ICT innovations, is not included in the present productivity analysis.

Electronic equipment other than computers used in industry covers mainly telecommunications equipment, which by definition belongs to ICT. However, electrical equipment used by industry includes energy related products such as cables, motors, airconditioners, transformers and switchgear, which do not belong to ICT as commonly defined. Unfortunately, the ABS could not provide separate information on the capital stock of electronic and electrical equipment included under the combined category. In order to incorporate telecommunications and other electronic equipment into the productivity analysis, the study adopted a definition of ICT capital that includes the entire category of electronic/electrical equipment. However, in some instances the focus is on information technology (IT) capital, which comprises only of computers and software.

Using the combined electronic/electrical category to define a component of ICT in the productivity analysis is supported by the fact that a much higher proportion of electrical equipment is subject to computerised controls than mechanical equipment. Remote control of electrical equipment through computers and digital communications is widespread in the electricity industry, which recorded exceptionally high productivity growth.

There are a number of measures of ICT (or IT) intensity that can be derived from the ABS investment-capital stock data. Table 3.1 compares four such measures between 1984–85 and 2001–02. The indices are described in the table. These estimates are based on the combined totals of service industries covered in the productivity analysis.

Table 3.1 Indicators of the use of IT and ICT capital in selected service industries

Aggregate estimates based on GFCF and capital stock data

Ratio of	*1984–85*	*2001–02*
	%	%
Computer and software (IT) investment to VA[a]	1.85	4.30
ICT investment to VA[a]	4.16	5.79
Computer and software (IT) share in total capital stocks[b]	0.19[c]	5.31
ICT share in total capital stocks[b]	4.72	16.13

[a] In current prices. Investment stands for GFCF. [b] in constant prices.

[c] The very low share of IT in capital stocks in 1984–85 is due to the low valuation of 1984-85 vintage IT equipment in terms of 2001–02 quality adjusted prices.

Source: ABS National Accounts investment and capital stocks data.

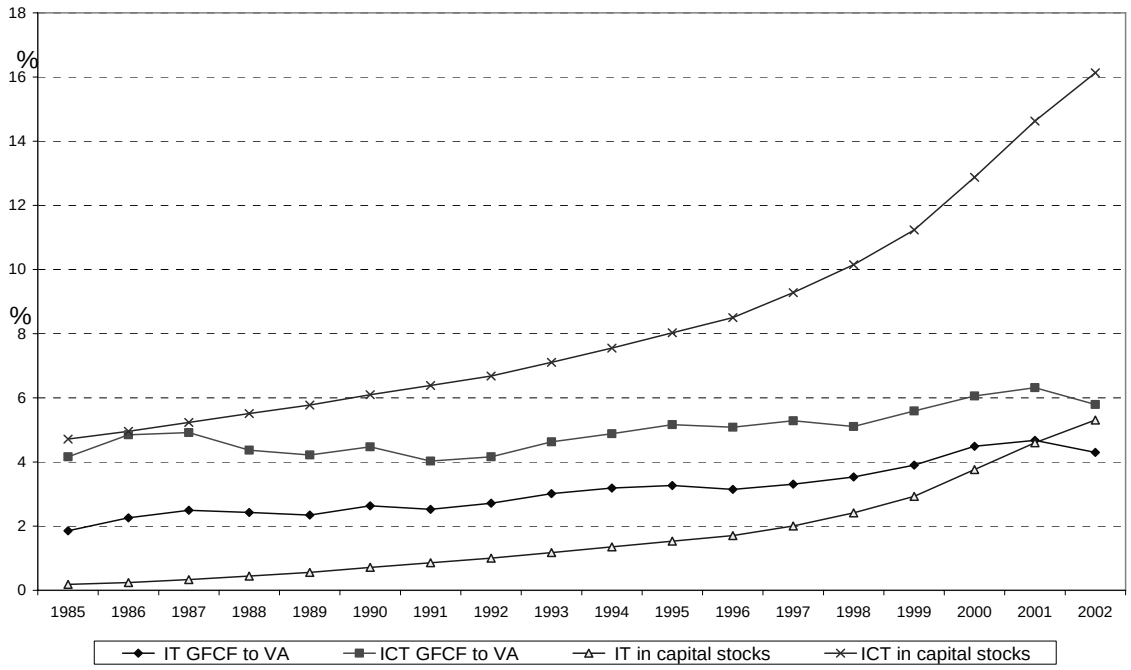
In the ratio of gross fixed capital formation GFCF to value-added (VA), both indicators are measured in current prices. By contrast, in the ratio of ICT capital stocks to total capital stocks, both indicators are measured in volume terms. The aim is to show two sets of indicators, one in current and the other in constant price (volume) terms.

All indicators show a marked increase between 1984–85 and 2001–02, reflecting the rapidly growing application of IT and ICT technologies in service industries. The

increase is particularly large in the two bottom indicators based on volumes, because of the large increase in the value of IT and ICT capital stocks in terms of quality-adjusted constant prices. Notice that the share of the volume of IT capital in total capital increased more than 27 times over 17 years. Much of this increase seems to be related to the large increase over time in the quality-adjusted constant price valuation of the stock of computer equipment.

Figure 3.1 illustrates graphically the trend over time of the IT and ICT capital indicators presented in table 3.1. No matter which IT or ICT-related investment or capital indicator one looks at, they all point to the rapidly growing importance of ICT capital in service industries.

Figure 3.1 Trends in IT and ICT capital usage by service industries



Source: ABS National Accounts investment and capital stocks data.

3.6 Surveys of firms

3.6.1 Survey of the business use of information technology

Since 1994 the ABS has conducted an annual survey concerning business use of information technologies. This survey presents some estimates on ICT expenditure. This report did not use these data because it was decided to rely in expenditure data on the GFCF estimates mentioned in the previous section. The advantage of the GFCF data is that it goes back to 1984–85 and includes also quality-adjusted volume indices.

Table 3.2 Computer usage by firm size in June 1994—all sectors

Employment size	Firms with computers	Proportion of computer users in the workforce
	%	%
1–19	46.1	25.8
20–49	85.9	23.2
50–99	94.6	26.4
100+	99.2	36.3
Total	49.4	30.5

Source: ABS Cat. No. 8129.0 for 1993-94.

The information that appears particularly useful in the Business Use of IT survey pertains to computer usage by firm size. Table 3.2 shows relevant data in June 1994. By that time almost all firms employing over 50 workers were using computers. However, among small firms with less than 20 employees, less than half were using computers. But as shown in the second column, in terms of the proportion of computer users in the workforce, small firms were not lagging far behind large firms in aggregate terms.

Table 3.3 shows computer usage by firm size in 2001–02.

Table 3.3 Computer usage by firm size in 2001–02—all sectors

		Business with	
Employment size	*Computer*	*Internet access*	*Web presence*
	%	%	%
1–19	79	65	15
20–49	91	80	34
50–99	98	93	55
100+	100	99	81
Total	84	72	24

Source: ABS Cat. No. 8129.0 for 2001-02.

By 2001–02, 79 per cent of firms employing less than 20 persons were using computer(s). However, intensity of usage varied by firm size, as reflected by the lower proportion of small firms with Internet access and an even lower proportion with web presence.[20] The reluctance of many small enterprises to use computers beyond basic office applications is related to factors such as poor suitability for business operations, security concerns and skill requirements.

3.6.2 Applications of firm-based surveys

Although this productivity study does not use any data from the Business Use of IT survey, it should be noted that this survey has some promising applications for analysing the effect of ICT technologies on productivity growth.

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[20] Similar findings are reported in the Yellow Pages (2003) e-business report on the online experiences of small and medium sized enterprises.

A recent publication by ABS staff (Rawnsley et al 2003) linked Business Use of IT survey data from 1999–2000 with financial data on the same firms from the ABS Business Economic Activity survey and business taxation records. Using the linked database, they found that higher average wage rates appear to be positively associated with computer and Internet use. This suggests that ICT and highly skilled workers may be complementary to each other. They also found that less profitable firms were less likely to use computer technologies than the rest. Similar findings are reported by Gretton et al (2004), based on data from the ABS Business Longitudinal Survey of a large sample of firms that was conducted between 1994 and 1998.

The study by Rawnsley et al (2003) used linked data from one year only. A similar linked database spanning several years could be used to investigate the links between productivity growth and ICT usage at the firm level using thousands of observations. By contrast, the single-period cross-sectional regressions presented in this paper are based on 16 observations from 16 highly aggregated industries.

Having said that, it should be noted that firm level studies highlight different aspects of the links between ICT use and productivity growth than National Accounts based sectoral studies. LP growth at the firm level can be measured in terms of changes in value-added per person adjusted for inflation. This is a different measure from the one based on National Accounts data, where constant price value-added is adjusted for qualitative changes in output and quality-adjusted price indexation is also applied to capital inputs.

Given the competitive pressures faced by firms, the inflation adjusted average value-added of firms does not necessarily move in tandem with hedonic price indexed sectoral value-added used in macro studies. This means that firm-based studies often yield different estimates regarding the effect of ICT on productivity growth than sectoral macro studies (OECD 2004). Firm-based studies are well suited to highlight the complementarities between ICT use and firm-specific characteristics in respect to skills, entrepreneurship and innovativeness. Macro studies (such as the present one) are better suited to identifying the impact of ICT on aggregate economic performance.

4. Estimating productivity growth

This chapter examines two sets of estimates of productivity growth in service industries:

- labour productivity (LP) growth (based on changes in value-added per hour); and
- MFP growth (based on Productivity Commission estimates).

Attention is given to methodological problems involved in estimating these items.

4.1 Labour productivity growth

Labour productivity (LP) is defined in this study as (quality-adjusted constant price) volume of value-added divided by total working hours. There is sufficient information to calculate LP growth rates for all 16 service industries covered in the productivity analysis. Value-added volume indices are published in the National Accounts for nine 'market sector' ANZSIC division service industries. The Department obtained unpublished information from the ABS for another seven service industries at a more disaggregated level. Summary of relevant estimates is presented in table 2.2.

The ABS estimates of value-added volume indices for 'market sector' service industries are based on various output indicators. In industries such as electricity, gas and water supply, telecommunications, construction and transport, physical measures are combined with financial indicators to estimate changes in the real value of output over time.[21] In wholesale and retail trade the output estimates are based on inflation-adjusted sales. In finance and insurance the estimated volume of output is based on financial service charges, premiums and capital income. In accommodation and restaurants the estimates are based on tourist guest-nights and inflation adjusted turnover estimates for cafes and restaurants. In cultural/recreational services the output indicators include the revenue of commercial TV and radio stations, expenditure on government supplied cultural/recreational services (broadcasting, libraries, museums, parks) and estimates from household surveys concerning expenditure on gambling and entertainment (ABS 2000, chapter 24).

The estimation of productivity growth in services is notoriously difficult. Commenting on productivity growth in the USA, the president of the Federal Reserve Bank of St. Louis (Poole 1999) raised the question whether the measurement of productivity is distorted. He quoted one of the pioneers of productivity research, Griliches, who argued that the part of the USA economy he calls 'reasonably measurable' has declined from about half to less than 30 per cent since World War II. The problem is that much of the economy produces things that are extremely difficult to measure, and the share of this

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[21] In construction physical measures include floor space and in transport passenger/km and freight/km.

sector—services, broadly speaking—keeps growing. Griliches' bottom line is that outside of sectors like agriculture and manufacturing, where it is more or less possible to count things in order to measure output, one should be extremely suspicious of productivity numbers. This qualification also applies to Australian national accounts based productivity estimates.

To work out the LP estimates, this study uses the ABS labour force survey (Catalogue No. 6203.0), which presents detailed estimates on employment and working hours for all 16 service industries covered.[22] Relevant employment estimates are presented in table 2.3. Total working hours by industry are available from the SuperTable database of the labour force survey.

Using the information sources for tables 2.2 and 2.3, this study calculates value-added per hour (in 2001–02 constant prices) for 16 service industries over the period from 1984–85 to 2001–02. The changes over time in value-added per hour yield average annual compound growth rates. Table 4.1 shows the estimates for the entire study period.

Table 4.1 Labour productivity growth in service industries

	VA per hour[a] 1984–85	*VA per hour[a] 2001–02*	*Change 1984–85 to 2001–02*	*Annual growth rate*
	$	$	%	%
Electricity and gas supply	112.4	313.0	178.4	6.21
Water supply and sewerage	111.9	247.2	120.9	4.77
Construction	66.6	70.8	6.3	0.36
Wholesale trade	63.0	98.1	55.7	2.64
Food retailing	42.7	40.6	-4.9	-0.29
Household good retailing	35.1	48.0	36.5	1.85
Motor vehicle retailing/service	30.0	32.0	6.6	0.37
Accommodation and restaurants	49.9	50.9	2.0	0.12
Road transport	50.4	61.0	21.1	1.13
Air transport/travel	85.2	139.8	64.0	2.95
Rail, water and other transport	30.2	83.1	174.9	6.13
Storage and transport facilities	148.6	191.2	28.6	1.49
Communications	47.9	145.5	203.5	6.75
Finance	82.9	170.8	105.9	4.34
Insurance	230.6	319.1	38.4	1.93
Cultural and recreational	96.8	83.2	-14.1	-0.89
Total 'market sector' services	**62.6**	**84.3**	**45.2**	**2.24**

[a] In 2001–02 constant prices.

Source: ABS Cat No. 5206.0, ABS Cat. No. 6203.0 and unpublished ABS data.

[22] Note, the labour force data are based on household surveys whereas the value-added data are based on enterprise surveys. Combining different data sources can lead to some errors in productivity estimates.

Some correlations and regressions use multi-period panel data, where the 17 year study period is subdivided into two or four sub-periods.[23] LP growth rates for two sub-periods are shown in table B.1 in the appendix. For the purpose of statistical analysis all data pertaining to changes over time are expressed in terms of average annual percentage changes and the same applies to productivity growth.

4.2 Some observations on sectoral LP growth rates

The figures in table 4.1 indicate wide disparities in sectoral LP growth rates. Capital intensive industries, such as electricity, gas and water supply, communications, air, water and rail transport have experienced well above average LP growth. To a lesser extent, the same applies to less capital intensive industries that are heavily dependent on ICT technologies, such as finance and wholesale trade. These observations suggest that productivity growth rates are closely related to technological factors (such as capital and/or ICT intensity). This in turn points to different technological innovation paths in different service industries. This proposition will be formally tested using regressions in chapter 6.

There are two negative growth estimates in table 4.1—one for food retailing and the other for cultural/recreational services. Both figures are somewhat questionable in light of recent technological developments.[24] The food retailing industry has benefited in the last twenty years from the introduction of electronic bar code scanners and computerised stock control and logistics. The cultural/recreational sector benefited from a number of technological advances in TV transmission, broadcasting as well as picture and sound recording. Hence judging by technological developments alone, one would expect positive productivity growth in both sectors.

Other factors might have offset the impact of technological advances. In particular, the influx of low paid casual or self-employed persons into 'low entry barrier' segments of labour intensive industries might have reduced value-added per person and hence productivity growth. A similar inflow of less productive labour may explain the low productivity growth recorded in the accommodation and restaurants sector. Increased regulatory burden could have been another cause.

Yet these are speculative explanations. In the absence of detailed information on how the ABS estimated the value-added volume indices, this study does not attempt to interpret figures that appear anomalous. As noted earlier, estimating the real volume of value-added (or output) in service industries is notoriously difficult (OECD 2004, Poole

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[23] In the two period analyses the periods are 1984–85 to 1993–94 and 1993–94 to 2001–02. In the four period analyses the periods are: 1984–85 to 1989–90, 1989–90 to 1993–94, 1993–94 to 1997–98 and 1997–98 to 2001–02.

[24] A possible reason for these dubious results is that the LP estimates are based on information from two different type of surveys — the value-added estimates from an enterprise survey, the labour input estimates from a household survey.

1999, Lawrence and Diewert 1999). Because of lack of direct information on this subject this study uses the ABS estimates as given.[25]

The low LP growth recorded in labour intensive industries, such as retail trade, hotels and restaurants, construction and cultural/recreational services, is somewhat surprising. One of the major objectives of reforms in the industrial relations front is to improve work incentives. There is extensive anecdotal evidence to indicate that as a result of these reforms organisational arrangements and workplace relations have changed in many enterprises in a manner that is conducive to higher productivity (Productivity Commission 1999).

On the quantitative side, there is some statistical evidence that point to improved work incentives. First, average working hours of full-time employees increased significantly between 1985 and 2002. According to statistics presented in Productivity Commission (2003, table 5.6) average weekly hours worked by male full-time employees increased from 41.3 in 1984–85 to 43.7 in 2001–02. The corresponding figures for females were 37.5 hours in 1984–85 increasing to 39.4 hours in 2001–02.[26] Second, as discussed in section 5.5.3, the number of days lost due to industrial disputes decreased markedly between 1985 and 2002. Third, according to Quiggin (2000) in recent years there has been some increase in unpaid overtime work due to the stronger bargaining position of employers.

These indications of improved work incentives do not accord with the very low productivity growth rates recorded in labour intensive industries. This applies both to measures of LP growth and multifactor productivity (MFP) growth that will be discussed later. As indicated earlier, there might have been offsetting factors, such as the inflow of less productive labour, which halted productivity growth in labour intensive industries. Quality-adjusted constant price indexation problems could be another reason for the recorded low productivity gains.[27] These unexpected findings warrant further research.

4.3 MFP growth and capital deepening

4.3.1 The analytical framework

As noted in section 1.1.2, the application of hedonic price indexing to evaluate changes in capital stocks under rapidly falling ICT prices raises some difficult measurement and methodological issues. This section explores these issues in some depth, in order to

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[25] Diewert and Lawrence (2004) express some doubts about ABS productivity estimates, particularly in relation to MFP. This controversial subject is not discussed in the present paper.

[26] Note, the increase in average weekly working hours does not distort our productivity estimates, which are based on working hours rather than the number of people employed.

[27] These questionable findings prompted one referee to conclude that the ABS needs to devote more resources to (quality-adjusted constant price) volume estimates in service industries.

provide a better understanding of the meaning of MFP growth and the difficulties in estimating MFP growth.

The basic economic growth accounting equation has the form:

$$Y(t) = A(t)*f(K(t), L(t)) \quad (4.1)$$

where Y(t) is real output in year t, K is net capital stocks and L is employment.

f represents a constant return to scale aggregate production function, where the factors of production are K and L. A(t) is the multifactor productivity (MFP) term, representing the combined effect of technological progress, cyclical capacity utilisation and various economic-institutional factors on output. All terms in eq. (4.1), including A(t), are time dependent.

As explained in appendix A, from eq. (4.1) one can derive the definition of MFP growth.[28] It is LP growth minus the effect of change in the capital-labour ratio. In symbolic terms:

$$\Delta A = \Delta Y_L - S_K*\Delta K_L \quad (4.2)$$

where ΔA is the MFP growth rate, ΔY_L is the LP growth rate, ΔK_L denotes the rate of change in the capital-labour ratio (capital deepening) and S_K is the share of capital income from total income. The difficulties in applying eq. (4.2) lie in estimating the changing value of output and capital stocks.

Formula (4.2) rests on the assumption that labour and capital are homogeneous inputs. Provided there is adequate information at a more detailed level, this assumption can be relaxed without much difficulty. Most of the growth accounting literature that deals with the effect of ICT on productivity growth splits up the capital deepening term into at least two parts — ICT capital and other capital (see Colecchia and Schreyer 2001, Parham et al 2001 and Simon and Wardrop 2002). Given such splitting, eq (4.2) becomes:

$$\Delta A = \Delta Y_L - S^I_K*\Delta K^I_L - S^O_K*\Delta K^O_L \quad (4.3)$$

where S^I_K represents the share of ICT capital income in total income (capital plus labour) and S^O_K the share of other capital income. By the same token, ΔK^I_L represents ICT capital deepening while ΔK^O_L denotes other capital deepening.

4.3.2 The MFP estimates used

Table 4.2 shows the MFP growth and capital deepening estimates used in the correlation and regression analysis.

The figures in the first two columns are based on Productivity Commission (2004) estimates for nine ANZSIC division service sectors. From eq. (4.2), MFP growth equals

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[28] Subject to the assumption of constant return to scale production and perfect market clearing conditions.

LP growth (table 4.1) minus the effect of the increase in the capital-labour ratio (shown in the second column of table 4.2).

Table 4.2 Multifactor productivity growth and capital deepening

	Change in MFP per PC 1984–85 to 2001–02	*Change in capital-labour ratio per PC 1984–85 to 2001–02*	*Change in 'modified' capital-labour 1984–85 to 2002–02*
	%	%	%
Electricity, gas & water	52.3	127.9	125.2
Construction	-1.1	40.3	1.4
Wholesale trade	36.0	58.1	48.8
Retail trade	1.4	87.0	-14.5
Accommodation and restaurants	-10.8	77.2	-25.3
Transport and storage	29.2	52.7	78.6
Communications	86.3	181.7	68.9
Finance and insurance	11.8	200.3	14.6
Cultural and recreational	-43.9	178.1	39.1

Source: PC (2004) and ABS capital stock data.

The MFP growth rates in table 4.2 are widely dispersed. Capital intensive infrastructure sectors such as EGW and communications recorded high MFP growth rates, while labour intensive industries such as construction, retail trade, accommodation/restaurants and cultural/recreational services recorded low or negative MFP growth. While there are some similarities to the LP growth figures in table 4.1, there are also notable differences. An important point to bear in mind is that in these estimates a large part of technological progress is reflected in rising capital-labour ratios rather than MFP growth.

The third column in table 4.2 shows changes in 'modified' capital-labour ratios, calculated by deflating current price capital stocks by the general GDP price deflator. This is based on ABS National Accounts capital stocks data for nine ANZSIC division service industries (see section 3.5). The published data include estimates on the net value of capital stocks in current prices. This information opens the way for an alternative approach for estimating changes in capital-labour ratios. Instead of using volume measures of capital stocks, which incorporate the (unreported) effect of falling ICT prices, a simple inflation-adjusted valuation of capital is used, based on the current price value of capital stocks converted into constant price terms by the general GDP price deflator.

The inflation adjusted capital stock figures divided by total working hours yielded alternative estimates for changes in capital-labour ratios. The estimates obtained this way represent capital deepening in purely financial terms without 'embodying' the effect technology driven falling ICT prices on capital valuation. The subject of falling quality-adjusted ICT prices is examined in the next section.

4.3.3 Estimating the productivity effect of falling ICT prices

This section takes a closer look on the effect of falling ICT prices on productivity growth. There are two reasons for singling out this item for special attention. First, falling ICT prices are driven by technological change but this factor is 'embodied' into capital deepening rather than MFP growth. Hence, in order to obtain comprehensive estimates on the effect of technological change on productivity growth it is necessary to obtain separate estimates on this item.

Secondly, the effect of falling ICT prices (or other falls in the quality-adjusted prices of imported equipment due to technological progress) represent to a large extent benefits from overseas innovation externalities.[29] In the jargon of growth theory, this is 'free lunch' or 'manna from heaven' for the Australian economy. By contrast, most of technology related MFP growth reflects the contribution to GDP growth of 'disembodied' new knowledge obtained from open publications, domestic innovations, the assimilation of overseas technologies and practical learning-by-doing at the firm level.

Fortunately, there is some limited information that made it possible to estimate the contribution of falling ICT prices to productivity growth, in other words, the impact of technological change 'embodied' into (mainly imported) ICT equipment. Table 4.3 shows relevant information obtained from three sources.

Item 1 in the table shows the annual percentage falls in the quality-adjusted prices of ICT equipment in Australia according to the estimates of Colecchia and Schreyer (2001). Notice that according to these estimates most of the price falls were concentrated in computer hardware.

These figures suggest that there was no overall quality adjusted price fall from 1985 to 2000 in telecommunications equipment.[30] Hence this item need not be included when calculating ICT price falls. Parham et al (2001) excluded telecommunications equipment from their analysis of the contribution of IT capital deepening to LP growth. Given that this study relies on their estimates in regard to the share of IT capital services income from total income, it was decided to exclude telecommunications equipment from the ICT price fall calculations.

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29 Most ICT equipment used in Australia is imported. Domestic production of electronic equipment is also subject to falling quality-adjusted prices as a result of global technological developments (NOIE 2004).

30 In the light of recent technological developments in telecommunications this is a questionable finding, but due to constraints on time and resources it was decided not to pursue this subject further in the present study.

Table 4.3 Calculating the impact of falling ICT prices on productivity growth

	Item	*1985–1990*	*1990–1995*	*1995–2000*	*Average 1985–2002*
		%	%	%	%
Annual price reductions[a]	1				
Computer hardware	1	-10.8	-12.2	-22.2	
Computer software	1	-1.3	-5.9	-7.1	
Telecommunications equipment	1	+5.5	+0.6	-1.5	
Share in value added[b]	2				
Computer hardware	2	1.05	1.55	2.25	
Computer software	2	1.00	1.85	2.45	
Contribution to LP growth	3				
Computer hardware	3	0.11	0.19	0.50	
Computer software	3	0.01	0.11	0.17	
Total IT hardware and software	3	0.13	0.30	0.67	0.40
Bassanini & Scarpetta estimated	4				
'embodied' technical change	4	0.28	0.33	0.35	0.32

[a] Based on Collecchia and Schreyer (2001) table 4; National price index—Australia. [b] Based on Parham et al (2001) table 5.3.

Source: Parham et al (2001), Colecchia and Schreyer (2001), Bassanini & Scarpetta (2002).

Item 2 in table 4.3 shows the share of capital services income from computer hardware and software in total 'market sector' income (value-added). This information is sourced from Parham et al (2001) table 5.3.

Item 3 shows the estimated contribution of computer hardware and software to LP growth. It is obtained simply by multiplying the numbers under item 1 by the corresponding numbers in item 2. The right-hand column shows the average annual contribution of IT to LP growth over the period from 1985 to 2002. This average is calculated on the assumption that the rate of change between 2000 and 2002 remained the same as that recorded between 1995 and 2000.

Finally, item 4 shows the contribution to LP growth of 'embodied' technical change according to the estimates for Australia by Bassanini & Scarpetta (2002). Evidently, their estimates are not far away from those derived in this study. For the purpose of the following analysis a compromise estimate was adopted, based on the average between the two. This implies that falling ICT prices contributed 0.36 per cent per annum to aggregate LP growth over the study period.

Yet this estimate relates to the entire market sector. Based on the ICT intensity information (see table 3.1), it is estimated that the ratio of computer hardware and software (IT) investment to value-added was 26 per cent higher in service industries than in the entire market sector. The reason is the lower IT intensity of manufacturing,

mining and agriculture. To obtain an estimate for the productivity contribution of ICT price falls 'embodied' into capital deepening in service industries, the study multiplied the 0.36 per cent estimate for the market sector by 1.26, which yields the final estimate of 0.45 per cent per annum.

Having obtained an estimate for the productivity effect of falling ICT prices, a more detailed decomposition of LP growth can be carried out. Based on data from PC (2004) the average LP growth rate in service industries from 1984–85 to 2001–02 was made up as follows:

- The effect of capital deepening 1.47%
- MFP growth 0.77%
- Annual LP growth rate 2.24%

Earlier calculations suggest that 0.45 per cent included in the effect of capital deepening can be attributed to technology driven decreases in ICT prices 'embodied' in new ICT investment. Excluding this technological factor, the impact of 'real' financial capital deepening amounted to 1.02 (= 1.47 – 0.45) per cent per annum.

In order to explain the contribution of various factors to LP growth apart from capital spending, this study looks at the combined effect of 'embodied' technological change plus MFP growth. This amounts to 1.22 (= 0.77 + 0.45) per cent per annum. This portion of LP growth represents what is referred to in this report as non-capital spending related LP growth. By definition, it is not the same as MFP growth. The relative contribution of technological and institutional factors to this portion of LP growth will be assessed in chapter 6. In fact, this decomposition exercise is the focal point of the report.

On the basis of information from Parham et al (2001) and the ABS National Accounts data on investment and capital stocks, it appears that ICT contributed 0.86 percentage point per annum to the total annual capital deepening effect of 1.47 per cent per annum. This implies that 0.41 (= 0.86 – 0.45) percentage point of the ICT capital deepening effect was due to increased financial spending on ICT hardware and software. This is an interesting piece of information, but one that is not needed for the purpose of decomposing the effects of institutional and technological factors to productivity growth after discounting the impact of increased capital spending per worker.

4.3.4 Different estimates of the effect of ICT capital deepening

There are a number of different Australian estimates on the effect of ICT capital deepening on LP growth. These estimates will be reviewed here in order to illustrate the difficulties and uncertainties involved.

According to Parham et al (2001, table 5.4), computers and software (excluding telecommunications equipment) added 1.1 per cent to annual output growth in the 1990s from the total of 1.7 per cent growth due to capital deepening. By contrast, according to

Colecchia and Schreyer (2001, table 6) the total annual contribution of ICT equipment (including telecommunications equipment) to Australia's output growth was 0.63 per cent a year between 1989–90 and 1999–2000 from a total of 1.55 per cent annual growth due to increase in capital services. When Colecchia and Schreyer (2001) use 'harmonised' prices instead of 'national' prices, they estimate the annual contribution of ICT over the 1990s at 0.58 per cent from a total annual contribution of 1.5 per cent from capital services.[31] Evidently, Parham et al (2001) indicate a significantly higher contribution of ICT capital deepening to national productivity growth than the estimates of Colecchia and Schreyer (2001). Simon and Wardrop (2002) compare yet other divergent estimates about the contribution of ICT capital deepening to Australia's productivity growth.[32]

Using the sources of information and methodology outlined in section 4.3.3, it appears that computer equipment capital deepening contributed 0.56 per cent per annum to LP growth in the 1990s. By comparison, Parham et al (2001, table 5.7) estimated that computer hardware contributed around 0.5 per cent to LP growth.

These differences highlight the fact that all estimates of capital deepening and MFP growth, based on 'hedonic' price indexation of ICT equipment, are not perfectly accurate. There is no precise methodology to determine the quality-adjusted price indexation of ICT equipment when prices are tumbling and consequently the equipment is being put into use in previously uneconomic applications.

There are a number of possible approaches to mitigate this measurement problem. One is to place more emphasis in productivity analysis on LP growth rather than MFP growth. In line with this approach, this report supplements the regression-based analysis of MFP growth by a similar analysis of LP growth. Another approach is to use to inflation adjusted capital stock estimates instead of 'hedonic' price indexed capital stocks.[33] Such estimates represent capital deepening in purely financial terms, excluding the effect of 'embodied' technological change.

4.4 Allocation to sub-sectors

The data in tables 4.1 and 4.2 cover nine first division ANZSIC sectors. In order to extend these estimates to 16 industries, the report applies pro-rata allocations to MFP growth and capital deepening in direct proportion to recorded LP growth rates in 16 industries. The rationale behind these calculations is that MFP growth and capital deepening are causally related and positively correlated with LP growth.

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31 The distinction between capital stocks and capital services is discussed in section A.4 in the appendix and in Schreyer (2003).

32 Diewert and Lawrence (2004) present other Australian estimates of capital services and MFP growth at the sectoral level.

33 Inflation adjustment can be carried out using the GDP price deflator.

There are four major sectors that can be divided into sub-sectors. Due to lack of information, the five other major service sectors cannot be sub-divided. Table 4.4 shows the coefficients used to multiply cumulative MFP growth and cumulative capital deepening of four major sectors in order to obtain estimates for their subsectors. The table presents the coefficients applied to the cumulative figures from 1984–85 to the end year of the four sub-periods used in the multi-period analysis.[34]

Table 4.4 Allocation coefficients to sub-industries

	1984–85 to 1989–90	1984–85 to 1993–94	1984–5 to 1997–98	1984–85 to 2001–02
Electricity, gas and water				
Electricity and gas supply;	1.14	1.07	1.14	1.11
Water supply, sewerage and drainage	0.86	0.93	0.86	0.89
Retail trade				
Food retailing;	0.99	0.98	0.96	0.84
Personal and household good retailing	1.04	1.09	1.08	1.21
Motor vehicle retailing and services	0.96	0.92	0.96	0.95
Transport				
Road transport	0.97	0.73	0.68	0.70
Air transport/travel	0.78	1.20	1.09	0.95
Rail, water and other transport	1.50	1.39	1.53	1.60
Storage and transport facilities	0.75	0.67	0.71	0.75
Finance and insurance				
Finance	1.09	1.10	1.02	1.20
Insurance	0.91	0.90	0.98	0.80

Source: Allocations based on LP growth rates in table 4.1.

Table B.2 in the appendix present the annual MFP growth rates for 16 industries used in the statistical analysis. In order to save space, the percentages reported are restricted to those used in the one and two-period regressions, but not in the four-period regressions.[35] Tables B.3 and B.4 show annual changes in capital-labour ratios. Table B.3 is based on Productivity Commission (2004) estimates; table B.4 on this study's estimates on inflation adjusted changes in capital stocks. These capital deepening estimates are used as explanatory variables in regressions where LP growth is the dependent variable.

[34] The four sub-periods are: 1984–85 to 1989–90, 1989–90 to 1993–94, 1993–94 to 1997–98 and 1997–98 to 2001–02.

[35] The unreported decomposition results from four-period regressions are in line with those from single-period and two-period regressions.

5. Explanatory variables

5.1 The broad factors driving growth

The LP and MFP growth estimates presented in chapter 4 enable testing statistical relationships between productivity growth and other observable variables that are likely to contribute to productivity improvements. As indicated in chapter 3, based on theoretical considerations there are two broad factors driving MFP growth in the long run:

- technological progress
- changes in the economic environment

A number of observable indicators can be used to quantify technological factors and changes in the institutional-economic environment of Australian service industries. Four technological variables are used in the statistical analysis:

- ratio of annual ICT investment to industry value-added;
- ICT investment per working hour;
- the value of total capital stocks per working hour (capital intensity); and
- sectoral LP growth rates in other OECD countries. These provide some indication about international technological innovation paths.

The institutional-economic variables used in the statistical analysis are divided into two groups—education variables and other institutional variables. There is detailed information for all 16 industries about the education level of the workforce between 1984 and 2003. This makes it possible to establish four education variables:

- share of persons with university degrees in the workforce;
- share of persons with post-school qualifications (from universities or technical colleges) in the workforce;
- change over time in the share of persons with university degrees in the workforce; and
- change over time in the share of persons with post-school qualifications in the workforce.

In addition, another four economic-institutional variables are used:

- reduction in the number of days lost due to industrial disputes;
- decrease in the share of union members in the workforce;

- reduction in the proportion of workers covered under general award pay conditions; and
- a dummy variable marking infrastructure sectors that were subject to significant industry-specific competition enhancing measures.

5.2 Technological variables

5.2.1 Capital and investment based indicators

Three out of four technological variables used in this study are derived from ABS National Accounts time-series tables on capital stocks and gross fixed capital formation (GFCF) in both current and constant prices. This information covers nine ANZSIC division service industries. The investment and capital stock data for each sector includes three ICT categories:

- computers
- software
- electronic and electrical equipment

The availability of ICT-related investment and capital stock data at the industry level opened the way for estimating the ICT intensity of individual industries. In these indicators ICT is defined to cover computers, software and electronic/electrical equipment (see section 3.5). It is possible to derive more than three technological indicators from the ABS investment/capital data, but these are unlikely to add much benefit to the statistical analysis, given the strong positive correlations between the indicators obtained. Change in the ICT capital-labour ratio is not used as a separate explanatory variable, because it forms part of the change in the overall capital-labour ratio, which is an explanatory variable in LP regressions.[36]

Two technological indicators used in the previous study on productivity growth in manufacturing (NOIE 2004) were not employed in the present study. One is R&D intensity (that is, the ratio of business R&D expenditure to value-added). There is some data on business R&D expenditure in service industries (ABS Cat. No. 8104.0). Much of this R&D is devoted to software development.[37] Most of business R&D in services is classified by industry to 'property and business services' and 'scientific research'. These categories do not belong to the industrial groups covered in the present productivity analysis. Because of these classification problems, business R&D intensity

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[36] Changes in the ICT capital-labour ratio and the technological change component 'embodied' into it were discussed in section 4.3.2 and 4.3.3.

[37] Only packaged software sold on the open market is eligible for the 125 per cent R&D tax concession. Customised software developed for internal applications is usually not regarded as R&D.

in services does not appear to be a particularly good proxy for representing the level of innovative effort in individual industries.[38]

Secondly, unlike NOIE (2004), this study does use ICT intensity indicators based on data from input-output tables on purchases from domestic suppliers of electronic equipment, telecommunications and scientific/engineering services. Because the ABS investment-capital stocks data also includes imported equipment and software, it provides more reliable indication about the ICT intensity of industries than input-output coefficients. But given that input-output coefficients cover all the 16 service industries these coefficients were applied to allocate ICT intensity indicators from four ANZSIC division service sectors to their sub-industries, as will be explained later.[39]

Note that unlike most other explanatory variables used in this study, the ICT and capital intensity indicators represent static average ratios rather than changes over time. The purpose of these intensity indicators is to identify different predispositions of sectors to technical change, in other words, to identify different technological innovation paths.

5.2.2 Ratio of ICT investment to value-added

One of the technological indicators used in the productivity analysis is the ratio between current price ICT investment (GFCF) and current price value-added. Given that ICT investment is closely related to ICT expenditure, this ratio is a fairly good indicator of the ICT intensity of an industry.

The data on current price ICT investment (GFCF) and current price value-added cover only nine first division ANZSIC industries. The allocation from EGW, retail trade, transport and finance/insurance to their respective sub-industries is based on information covering all 16 industries from two sources:

- ABS input-output coefficients of domestic purchases of electronic inputs and telecommunication services; and
- capital intensity estimates discussed in section 5.2.4.

Table 5.1 presents the estimated ratios of ICT investment to value-added of 16 industries. The average ratio, shown in the third column, was applied not only in single period regressions but also in multi-period regressions. Given that the purpose of this ratio is to represent the ICT intensity of individual industries, there is no good reason for changing this intensity indicator between periods.

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[38] A portion of business R&D in services is so-called ‘syndicated’ R&D. It is performed by service enterprises for external customers. Some of it is used to support operations in manufacturing and mining.

[39] The four major sectors are: EGW, retail trade, transport and finance/insurance.

Table 5.1 Ratio of ICT gross fixed capital formation (GFCF) to value-added in current prices[a]

	1984–85	*2001–02*	*Average 1984–85 to 2001–02*
	%	%	%
Electricity and gas supply	6.48	10.22	7.94
Water supply and sewerage	4.24	5.94	4.80
Construction	1.73	2.21	1.92
Wholesale trade	1.55	4.20	3.17
Food retailing	2.83	4.11	3.75
Household good retailing	2.07	3.51	3.01
Motor vehicle retailing/service	1.41	2.50	2.28
Accommodation and restaurants	2.68	2.78	2.74
Road transport	2.32	2.26	2.24
Air transport/travel	4.49	4.34	6.05
Rail, water and other transport	5.69	5.50	5.65
Storage and transport facilities	5.77	5.60	5.69
Communications	5.25	13.79	9.98
Finance	6.47	8.03	7.00
Insurance	6.70	8.33	7.25
Cultural and recreational	2.36	4.20	3.65

[a] ICT covers computer equipment, software and electronic/electrical equipment (see section 3.5).

Source: ABS Cat. No. 5206.0. and ABS National Accounts investment-capital stocks data.

In the multi-period analyses, explanatory variables that vary between sub-periods are restricted to changes over time, such as change in the capital-labour ratio, change in education standards, change in the proportion of union members in the workforce, OECD productivity growth rates, or reduction in days lost due to industrial disputes. On the other hand, all static intensity indicators—such as ICT investment to value-added, ICT investment per working hour, capital intensity, the share of university graduates in the workforce or the share of those with post-school qualifications—are represented by the average ratio over the period from 1984–85 to 2001–02, with no change in values between sub-periods.

5.2.3 ICT investment per working hour

Another ICT intensity indicator is the level of ICT investment per working hour. Note, in the present study working hours are used to measure labour input.

The volume measure of ICT gross fixed capital formation (GFCF) was used in the numerator, in order to obtain a real rather than nominal indicator of ICT investment. Total working hours were used in the denominator. The allocation to sub-industries of four first division ANZSIC industries was carried out using the same methodology described in the previous section. The estimated ratios for 16 service industries are presented in table 5.2. Since this is a static intensity indicator, the average ratio between

1984–85 and 2001–02 was applied unchanged in sub-periods in the context of multi-period regressions or correlations.

Table 5.2 Level of ICT GFCF per working hour[a]
in 2001–02 constant prices

	1984–85	*2001–02*	*Average 1984–5 to 2001–02*
	$	$	$
Electricity and gas supply	10.17	31.78	23.09
Water supply and sewerage	6.81	23.80	18.26
Construction	0.41	1.37	1.25
Wholesale trade	0.69	4.39	3.09
Food retailing	0.53	1.76	1.56
Household good retailing	0.45	2.11	1.67
Motor vehicle retailing/service	0.31	1.13	0.95
Accommodation and restaurants	0.57	1.63	1.43
Road transport	0.52	1.42	1.44
Air transport/travel	1.87	5.95	6.52
Rail, water and other transport	1.02	4.75	4.21
Storage and transport facilities	2.69	7.29	7.28
Communications	1.64	21.05	15.08
Finance	1.11	13.56	8.67
Insurance	2.97	24.22	16.52
Cultural and recreational	1.49	4.61	4.08

[a] ICT covers computer equipment, software and electronic/electrical equipment (see section 3.5).

Source: ABS Cat. No. 5206.0 and ABS National Accounts investment-capital stocks data.

5.2.4 Capital intensity

The third technological indicator derived from the National Accounts investment-capital data is capital intensity. It is defined as the ratio of total capital stocks (volume measure) to working hours.

To obtain estimates for 16 industries, data was allocated to sub-sectors of four first-division ANZSIC service sectors using value-added per working hour, shown in the first two columns of table 4.1. Value-added per hour seems to be a fairly good proxy for capital intensity. This assumption is supported by comparisons with detailed USA sectoral capital intensity data in Stiroh (2001). Table 5.3 presents the results for 16 service industries. The average capital intensity figures in the third column were applied in all sub-periods in multi-period analysis.

Notice that capital intensity is particularly high in infrastructure sectors such as EGW, air and rail transport, transport facilities (ports and airports) and communications. As shown in table 4.1, all these sectors recorded well above average LP growth rates.

Table 5.3 Value of total capital stocks per working hour
in 2001–02 constant prices

	1984–85	*2001-02*	*Average 1984–85 to 2001-02*
	$	$	$
Electricity and gas supply	623	1579	1148
Water supply and sewerage	620	1247	913
Construction	60	61	61
Wholesale trade	93	111	101
Food retailing	58	59	59
Household good retailing	47	69	55
Motor vehicle retailing/service	40	46	41
Accommodation and restaurants	114	143	133
Road transport	152	156	153
Air transport/travel	358	457	423
Rail, water and other transport	115	243	194
Storage and transport facilities	305	339	321
Communications	318	560	463
Finance	126	210	165
Insurance	250	313	297
Cultural and recreational	105	148	123

Source: ABS Cat. No. 5206.0 and ABS National Accounts investment-capital stocks data.

5.3 Labour productivity growth in OECD countries

Productivity growth rates in other OECD countries provide some indication about international technological innovation paths. Data are available from some OECD countries on constant-price value-added in major service industries between 1984 and 2001 and there is corresponding data on sectoral employment.

This information makes it possible to construct a weighted average LP index series for a group of seven OECD countries. The results are presented in table 5.4. The countries used and the relative weights given to them in constructing these estimates are:[40]

USA	0.40
Canada	0.10
France	0.15
Denmark	0.05
Finland	0.05
Italy	0.15
Spain	0.10
Total	1.00

[40] The weights are not directly proportional to country size, because observations for small countries contain significant information relevant to Australia.

These countries gave sufficient information on constant-price value-added of broad service sectors to calculate productivity changes according to the OECD industrial classification, which is close to first division ANZSIC.[41] Average annual growth rates between 1984 and 2001 of service sectors in the seven countries are presented in appendix C. Table 5.4 shows the weighted average results.

Table 5.4 Average annual LP growth rates in seven OECD countries

Based on constant price value-added per person—1984 to 2001

	1984 to 2001	*1984 to 1993*	*1993 to 2001*
	%	%	%
Electricity, gas and water supply	2.73	2.50	2.99
Construction	0.34	0.74	-0.11
Wholesale and retail trade; repairs	2.26	1.74	2.84
Hotels and restaurants	-0.02	-0.07	0.04
Transport and storage	1.82	2.02	1.58
Post and telecommunications	5.41	5.23	5.62
Financial except insurance	1.84	1.14	2.64
Insurance	1.53	1.17	1.93
Other community, social and personal services[a]	-0.29	-0.19	-0.41

[a] This OECD category includes cultural and recreational services, which are not reported separately in the OECD STAN database. This category is used in the present statistical analysis to represent OECD cultural and recreational services.

Source: Appendix C, OECD (2003).

Comparing table 5.4 with table 4.1 reveals some strong similarities with the Australian results. In the selected OECD countries the strongest gains in LP occurred in infrastructure sectors, such as EGW and communications.[42] Below average productivity growth was recorded in construction, hotels and restaurants and 'other social/personal' services. Similar trends were evident in Australia.

The reason for the strong positive correlation between Australian and OECD productivity growth rates is not difficult to see. In the long run, productivity growth in Australia is driven by similar technological developments that drive productivity growth in other advanced industrialised countries.[43] Therefore, the similarity in long-term productivity growth trends at the sectoral level is hardly surprising.

Given that there was no adequate information from abroad to allocate from main sectors into sub-industries, the study adopted the estimated productivity growth rates of three

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[41] The United Kingdom and Japan had to be excluded due to lack of sufficient data and Germany because of data consistency problems following unification. Korea was excluded for being a non-typical case, representing a 'catching up' economy.

[42] An exception is Canada, which recorded low productivity growth in electricity, gas and water (EGW), as shown in appendix C.

[43] This is the reason that sectoral productivity growth rates in other OECD countries are classified as a technological variable.

main sectors (that is, EGW, retail trade and transport) without change to their sub-industries. Table D.1 in the appendix shows the OECD data used in the regressions and correlations.

5.4 Rising education standards

Based on the theory of human capital, the rising education level of the workforce may be an important contributing factor to productivity growth. This section reviews ABS data on the educational attainment of the workforce in individual service industries. These estimates relate to the highest educational attainment, regardless of whether the worker is using this education on the job or otherwise.

Table 5.5 presents data on the proportion of university graduates in the workforce of the 16 service industries examined.

Table 5.5 Share of university graduates in the workforce

	1984	*2003*	*Average 1984 to 2003*
	%	%	%
Electricity and gas supply	8.1	16.4	12.0
Water supply and sewerage	9.0	36.5	21.5
Construction	2.4	5.5	3.7
Wholesale trade	5.6	13.2	9.0
Food retailing	2.8	5.6	3.7
Household good retailing	2.8	11.4	7.0
Motor vehicle retailing/service	2.8	3.6	2.9
Accommodation and restaurants	3.0	8.4	5.6
Road transport	1.0	5.2	3.4
Air transport/travel	9.8	14.0	11.3
Rail, water and other transport	3.1	11.0	5.9
Storage and transport facilities	4.8	13.2	10.0
Communications	3.7	15.8	10.4
Finance	7.3	40.1	20.5
Insurance	8.8	29.8	16.4
Cultural and recreational	10.6	25.9	16.5

Source: ABS Cat. No. 6227.0 and unpublished data at the two-digit ANZSIC level.

Notice from these figures that in some service industries (such as water supply, household good retailing, transport facilities, finance and insurance) the share of university graduates in the workforce more than tripled between 1984 and 2003. In most other service industries the proportion more than doubled. As indicated in NOIE (2004), a similar increase in the share of university graduates was also recorded in manufacturing and other sectors of the economy.

The figures in the third column represent the average share of university graduates between 1984 and 2003.[44] This average ratio was used in the regressions and correlations. Like other static intensity indicators (such as ICT intensity or capital intensity) it remained unchanged between sub-periods in the context of multi-period statistical analyses.

Table 5.6 shows the share in the workforce of persons with post-school qualifications, either from universities or technical colleges. Evidently, this is another indicator of the education level of the workforce. It should be noted that many workers without post-school qualification have finished high school, whereas others with vocational qualifications did not complete high school. But what matters in the context of productivity analysis is not length of schooling by itself, but the fact that vocational staff received more technical training than those who did not pursue further training after high school. The purpose of the static education intensity indicators is to identify possible sectoral differences in predisposition to productivity growth due to differences in the level of schooling.

Table 5.6 Share in the workforce of persons with post-school qualifications

	1984	*2003*	*Average 1984–2003*
	%	%	%
Electricity and gas supply	60.9	70.3	66.5
Water supply and sewerage	38.3	77.2	56.6
Construction	54.1	59.8	56.9
Wholesale trade	38.2	48.9	42.4
Food retailing	29.7	26.0	24.9
Household good retailing	29.7	37.9	32.1
Motor vehicle retailing/service	29.7	53.4	43.8
Accommodation and restaurants	30.0	40.6	34.2
Road transport	30.5	39.3	32.9
Air transport/travel	60.6	62.1	59.2
Rail, water and other transport	36.9	49.2	41.8
Storage and transport facilities	42.1	55.2	48.4
Communications	37.9	51.9	44.4
Finance	25.1	66.7	42.9
Insurance	43.4	52.7	46.9
Cultural and recreational	44.6	54.9	48.1

Source: ABS Cat. No. 6227.0 and unpublished data at the two digit ANZSIC level.

[44] The ABS supplied detailed education data at the two-digit ANZSIC level for three years—1984, 1994 and 2003. The time frame of these data extends slightly beyond the study period, which is from 1984–85 to 2001–02. Stretching the period of education variables from 17 to 19 years probably had little effect on the average ratio and annual change estimates.

Using the data on the share of skilled persons in the workforce of individual industries, opened the way for constructing two explanatory variables based on changes over time:

- change in the share of university trained workers (in terms of annualised change between 1984 and 2003 and sub-periods): and
- change in the share of workers with post-school qualifications (in terms of annualised change between 1984 and 2003 and sub-periods).

Annualised changes between 1984 and 2003 are calculated by taking the difference between shares in 2003 and 1984 and dividing it by 19 (years). The same type of calculation is performed in the sub-periods. Tables D.2 and D.3 in the appendix show the data on changes in education levels used in the regressions and correlations.

Education variables are categorised as economic factors in this paper. However, as show in table E.1 in the appendix, they are moderately correlated with technological variables, that is, ICT intensity, capital intensity and OECD productivity growth rates. Education and technological variables are interrelated because the technological requirements of individual industries influence the demand for skilled labour. Yet, a better-educated labour force can by itself spur productivity growth, and this is the reason that education variables were used as a separate group of explanatory variables in the regressions.

5.5 Indicators of workplace relations

A number of variables are used to indicate changes in industrial relations and workplace arrangements. Improving labour market flexibility and bringing remuneration closer in line with productivity are among the central objectives of microeconomic reforms. The purpose of these reforms is to spur productivity growth. While the indicators presented in this section can not measure directly reduction in labour market imperfections and improvement in the level competition, they do provide some fairly strong indications about changes in labour market conditions.

As shown in table 5.11, the decrease in union membership and award coverage are positively and significantly correlated with labour productivity growth. But given that there are other variables that are correlated even stronger, it is rather difficult to disentangle the impact of industrial relation reforms from the impact of technological and education variables. In a more detailed discussion on this subject, Sloan (1998) examines the interaction between industrial relations and other regulatory reforms and the problems in identifying their effects on macroeconomic performance.

5.5.1 Reduction in union membership

One of the most notable developments in the industrial relations front over the last two decades has been the marked decline in the proportion of union members in the workforce. Analysing the reasons for this trend is outside the scope of this paper.

According to a widely accepted view the decline in union membership was partly driven by more deregulated labour market conditions. Hence, the decrease in union membership is an indicator of increasing labour market flexibility, in line with the objectives of microeconomic reforms.

Table 5.7 shows the proportion of union members in the workforce of 16 service industries in 1986 and 2002. The first detailed ABS statistics on union membership at the two-digit ANZSIC level is from August 1986, therefore the statistics used in this paper is from 1986 to 2002.

Table 5.7 Share of union members in the workforce

	1986	*2002*	*Annual decrease 1986–2002*
	%	%	%
Electricity and gas supply	79.8	52.0	1.74
Water supply and sewerage	87.8	40.1	2.98
Construction	48.0	27.7	1.27
Wholesale trade	20.9	7.1	0.86
Food retailing	27.6	16.5	0.69
Household good retailing	27.6	16.5	0.69
Motor vehicle retailing/service	27.6	16.5	0.69
Accommodation and restaurants	31.8	11.8	1.25
Road transport	50.8	28.9	1.37
Air transport/travel	82.8	55.5	1.71
Rail, water and other transport	90.6	68.1	1.41
Storage and transport facilities	56.7	24.6	2.01
Communications	80.4	32.9	2.97
Finance	55.2	19.5	2.23
Insurance	40.2	11.5	1.79
Cultural and recreational	34.2	12.9	1.33

Source: ABS Cat. No. 6325.0 before 1995 and Cat. No. 6310.0 after 1995.

For the purpose of regressions and correlations, the annual decrease in the share of union members was used , which is simply the 1986 share minus the 2002 share divided by 16 (years). Notice that according to this definition, the decrease in shares turns out to be a positive number. The reason for adopting this arithmetic definition is to ensure that variables that are expected to make a positive contribution to productivity growth appear as positive numbers. This facilitates the interpretation of correlation and regression results. Table D.4 in the appendix shows the data used in one-period and two-period statistical analyses.

5.5.2 Award pay coverage

Another indicator of increasing labour market flexibility is the decreasing number of workers covered under general award pay conditions versus those covered under

collective (enterprise) agreements or individual bargaining agreements. The option to apply non-award pay conditions was open all the time, but it became widely used only after the mid 1990s, following the introduction of new industrial relations legislation. Note, awards usually stipulate minimum pay rather than actual pay.

The ABS supplied unpublished data at the two-digit ANZSIC level on the share of workers covered under award pay conditions between 1985 and 2002, based on the survey of Employee Earnings and Hours (ABS Cat. No. 6306.0). Table 5.8 presents the figures for 1985 and 2002.

Table 5.8 Proportion of the workforce covered under award pay conditions

	1985	*2002*	*Annual decrease 1985–2002*
	%	%	%
Electricity and gas supply	88.6	1.5	5.13
Water supply and sewerage	79.6	3.0	4.51
Construction	65.3	19.7	2.68
Wholesale trade	62.2	30.3	1.87
Food retailing	76.8	31.6	2.66
Household good retailing	76.8	49.3	1.62
Motor vehicle retailing/service	76.8	59.2	1.03
Accommodation and restaurants	81.6	70.1	0.68
Road transport	76.0	39.7	2.13
Air transport/travel	90.7	2.1	5.21
Rail, water and other transport	83.2	18.0	3.83
Storage and transport facilities	80.2	27.9	3.07
Communications	99.4	3.9	5.62
Finance	62.0	10.2	3.05
Insurance	84.4	0.7	4.92
Cultural and recreational	55.4	14.0	2.44

Source: ABS Cat. No. 6306.0 and unpublished data at the two digit ANZSIC level.

The annualised changes in the third column are calculated by taking the difference between the 1985 and 2002 shares and dividing it by 17 (years). Table D.5 in the appendix presents the data used in regressions and correlations.

It is clear from table 5.8 that there was a sharp decline in award coverage in all industries between 1985 and 2002. Awards have been replaced by collective (enterprise) agreements or individual agreements. Most of the decline in award coverage occurred after 1996.

It is interesting to note that the sharpest falls in award coverage occurred in capital intensive infrastructure sectors such as EGW, air, rail and water transport and communications. Not surprisingly, the decrease in award coverage is positively

correlated with capital intensity as well as ICT intensity (see table E.1). This is an example of strong correlation between technological and institutional variables that is not expected a priori. This type of correlation makes it difficult to disentangle the effect of technological and institutional variables on productivity growth, a subject discussed in more detail later.

5.5.3 Days lost due to industrial disputes

The statistics on the number of days lost due to strike action provides some indication about changes in the industrial relations climate and the disruptions to production caused by industrial disputes. Table 5.9 presents statistics on the number of days lost per employee due to industrial disputes.

Table 5.9 **Number of working days lost per employee due to industrial disputes in a year**

	1985	*2002*	*Annual change 1985–2002*
	days lost	days lost	days annual decrease[a]
Agriculture, forestry and fishing	0.000	0.005	0.000
Mining	3.119	0.085	0.178
Manufacturing	0.260	0.077	0.011
Service industries			
Electricity and gas	0.399	0.121	0.016
Water and sewerage	0.023	0.036	-0.001
Construction	0.376	0.132	0.014
Wholesaling	0.020	0.008	0.001
Retailing	0.001	0.000	0.000
Accommodation and restaurants	0.026	0.008	0.001
Road transport	0.111	0.059	0.003
Air transport	0.058	0.072	-0.001
Rail and water transport	0.935	0.008	0.055
Storage and transport facilities	0.484	0.009	0.028
Communications	0.205	0.003	0.012
Banking and insurance	0.041	0.009	0.002
Cultural and recreational	0.084	0.028	0.003

[a] The third column is the difference between 1985 and 2002 days divided by 17 (years).

Source: ABS Cat. No. 6321.0 and unpublished ABS data at the two digit ANZSIC level.

As shown in table 5.9, capital intensive sectors, such as mining, manufacturing, and infrastructure services appear to be more prone to industrial stoppages than most service industries. Since the early 1980s, the number of days lost per employee due to industrial disputes has dropped markedly in all sectors. In service industries the biggest drops occurred in infrastructure industries, such as electricity, rail and water transport and transport facilities (particularly ports). These sectors were more prone to industrial

disputations in the 1980s. In most other service industries (apart from construction) the decrease in the number of days lost was minute or non-existent.

The relatively small decrease in this indicator in most service industries over the study period may explain the absence of statistically significant positive correlation with productivity growth (see table 5.11). Table D.6 in the appendix shows the data used in correlations and regressions.

5.6 Infrastructure reforms

Apart from education and industrial relation variables, the statistical analysis also included an institutional variable, marking those sectors that were subject to significant industry-specific microeconomic reform measures during the study period. This was done by using a dummy variable (one) to mark the sectors affected, as shown in table 5.10.

Table 5.10 Sectors subject to industry-specific competition measures

Electricity and gas supply	1
Water supply and sewerage	1
Construction	0
Wholesale trade	0
Food retailing	0
Household good retailing	0
Motor vehicle retailing/service	0
Accommodation and restaurants	0
Road transport	0
Air transport/travel	1
Rail, water and other transport	1
Storage and transport facilities	1
Communications	1
Finance	0
Insurance	0
Cultural and recreational	0

The reason for introducing this dummy variable is the very strong LP growth recorded in infrastructure industries (see table 4.1). Given that these industries were subject to specific competition enhancing measures, it was considered useful to identify them separately in some regressions.

The decision about which sectors to mark as significant is based on information from media reports, Productivity Commission publications and a paper on deregulation of services in OECD counties by Nicoletti (2001). A binary variable was used because of the difficulties of quantifying the size of reform. It is easier just to identify sectors where significant reforms have occurred.

Industry-specific competition reforms were heavily concentrated in infrastructure sectors, that is, EGW, transport and communications. There were also some industry specific competition reform measures in other sectors—particularly in banking and retail trade. These sectors were excluded because apparently competition reforms in these areas had a less significant impact than in those sectors more directly under government control.

This is not to say that competition reforms did not have a significant impact on measured productivity growth in finance and to a lesser extent in retailing. Most of the financial reforms were completed before 1984–85, but some lagged effects might have occurred during the study period. These reforms include the flotation of the Australian dollar and opening up of financial markets to foreign competition. Although the scale of entry of foreign banks into Australia was fairly limited, by virtue of increasing the threat of entry this reform could have stimulated competition and productivity growth. The privatisation of the Commonwealth Bank also had some impact on the level of competition. However, the Commonwealth Bank was operating as a commercial enterprise in a competitive environment for many years before it was privatised. In retail trade, the deregulation of shopping hours might have affected productivity growth. It is impossible to estimate the size of these effects from the data used in this study.

In contrast to finance and retailing, in infrastructure reform affected industries there is some 'natural monopoly' element present, usually because of a need for a 'common carrier', such as telecommunications lines, electricity lines, railway tracks, pipelines or because of the requirement for centralised facilities, such as seaports, airports, postal and telecommunication centers. The purpose of microeconomic reforms introduced in these sectors was to raise the commercial orientation of public trading enterprises and stimulate competition by improving the 'contestability' of these markets by private firms. Various techniques were applied to attain these objectives, including:

- privatisation or corporatisation
- deregulation
- franchising operations to private contractors
- making it legally mandatory to provide access for competing enterprises to 'common carriers', such as telecommunication and electricity lines, pipelines and railway tracks
- sub-contracting non-core activities to outside suppliers
- vertical segmentation (unbundling) of activities for the purpose of privatisation or sub-contracting
- ensuring 'competitive neutrality' between government agencies and private service providers
- reducing government subsidies and 'community service obligations'

Various combinations of these measures were applied in different industries. The Productivity Commission has published numerous reports on competition reform measures in individual industries. Reviewing this large literature is outside the scope of this paper.[45]

The crucial point to note here is that these industry-specific competition reforms apparently lifted the productivity performance of certain service industries (such as railways) well above the level that would be expected on grounds of technological progress and general changes in the economic environment.[46]

In MFP regressions the infrastructure dummy usually turned out to be quite significant. However, in LP regressions it was usually less significant. Note that infrastructure reforms affected only a small portion of service industries. In 2001–02, the infrastructure sectors tagged in table 5.10 accounted for 21.8 per cent of value-added and 9.9 per cent of employment in the 16 service industries examined.

5.7 Correlations

Table 5.11 shows the correlation between the two productivity measures and other variables used in the study. Table E.1 in the appendix presents the full set of correlations. These single period correlations are based on weighted observations, with the weights given by the mean value-added of industries over the study period. Generally, all correlations and regressions discussed in this paper are weighted by industry size in order to ensure that more weight is given to observations from larger industries.

A striking feature of table 5.11 is the high percentage of explanatory variables that show correlation above 0.42 with LP and MFP growth rates. This is statistically significant at the five per cent probability level even with 16 observations.

The ICT intensity variables in table 5.11 show strong positive correlation with LP growth and lower but still statistically significant correlations with MFP growth.[47] While these results strongly suggest that technological factors provided much of the impetus for productivity growth, correlation analysis can provide only a partial answer to this question. More definite conclusions will be presented on the basis of regression results in chapter 6. For the time being, note the important observation that MFP growth is significantly correlated with all technological variables but is not significantly correlated with institutional-economic variables, with the exception of the infrastructure dummy and the decrease in award coverage.

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45 The interested reader can find extensive literature on the subject in the Productivity Commission website: *www.pc.gov.au/publications.*

46 For more details on rail reform refer to PC (1999b).

47 By and large, MFP growth shows considerably weaker correlation with explanatory variables than LP growth.

Table 5.11 Correlations based on weighted observations[a]

Single period 1984–85 to 2001–02

	LP growth		*MFP growth*	
Labour productivity	1.000		0.856	#
MFP growth	0.856	#	1.000	
Capital deepening modified	0.774	#	0.644	#
Capital deepening per PC	0.740	#	0.516	*
Capital intensity	0.617	#	0.474	*
ICT investment to VA	0.799	#	0.558	*
ICT investment per hour	0.709	#	0.476	*
OECD labour productivity growth	0.761	#	0.796	#
Decrease in union membership	0.644	#	0.400	
Decrease in award coverage	0.639	#	0.511	*
Dummy for infrastructure industry	0.615	#	0.620	#
Decrease in industrial disputes	0.207		0.315	
Share of university graduates	0.471	*	0.059	
Share of post-school trained	0.212		0.132	
Change in share of university graduates	0.453	*	0.054	
Change in share of post-school qualified	0.466	*	0.151	

[a] Weights based on mean industry value-added figures shown in table E.3. # significant at the 1% probability level. * significant at the 5% probability level.

Table E.1 in the appendix shows strong positive correlations between many of the explanatory variables. Many of these correlations appear quite spurious and are not necessarily related to direct causation. For example, the decrease in union membership and in award pay coverage affected more strongly capital intensive infrastructure industries. These industries also recorded the highest LP and MFP gains. Hence two industrial relation variables are significantly correlated with productivity growth. This raises the question whether the high productivity growth recorded in these sectors was caused by the strong impact of workplace reforms or was it driven more by their technological characteristics (high ICT and capital intensity). It is not easy to answer this question by looking on correlations alone.[48]

The regression analysis employs two methods to reduce collinearities (that is, correlations between explanatory variables). The first is by amalgamating explanatory variables (apart from capital deepening) into three groups—technological, education and institutional factors—by a standardised combination of variables in each group that will be explained in the next section. Some regressions were run with these composite factors rather than individual variables. The other approach is to run parsimonious regressions using one or two variable(s) from each group. Both approaches tend to reduce collinearity problems, as will be discussed in chapter 6.

[48] The low productivity growth rates in labour intensive sectors (discussed in section 4.2) seems to suggest that workplace reforms had little impact on productivity growth in important sectors of the economy.

5.8 Factor groups

In order to reduce collinearity problems, in some regressions explanatory variables were amalgamated into three composite factors: technological, education and other institutional. The makeup of these composite factors in terms of explanatory variables is given as follows:

Technological factor

- ICT investment to value-added
- ICT investment per hour
- capital intensity
- OECD labour productivity growth rates

Education factor

- share of university graduates in the workforce
- share of post-school qualified persons in the workforce
- change in share of university graduates
- change in share of post-school qualified

Other institutional factor

- decrease in the share of union members in the workforce
- decrease in the proportion of the workforce covered under award pay
- decrease in the number of days lost due to industrial disputes
- a dummy variable marking sectors that were subject to significant industry-specific competition reform measures

Each of the three composite factors consists of four explanatory variables, which tend to be positively correlated with each other (see tables E.1 and E.2).

A fairly simple approach was followed in constructing the composite variables. First, the arithmetic mean of each explanatory variable across 16 industries was calculated. Then the observation for each industry was divided by that mean. These yielded four sets of indices, which were added up and divided by four to yield the estimated composite factor sets. The single period calculation in respect to the technological factor is presented in table 5.12.

Tables F.1 and F.2 in the appendix show the single-period calculations for composite education and institutional variables. Table F.3 shows the two-period composite factor sets. The application of composite variables reduced the strong positive correlations between explanatory variables but did not eliminate them entirely (see tables F.4 and

F.5). The correlation between technological and 'other institutional' composite variables is high.

Table 5.12 Components of the technological composite factor

	ICT to VA	*ICT per hour*	*OECD prodty*	*Capital intensity*	*Composite factor*
Electricity and gas supply	1.64	3.21	1.43	3.86	2.54
Water supply and sewerage	0.99	2.54	1.43	3.08	2.01
Construction	0.40	0.17	0.18	0.21	0.24
Wholesale trade	0.66	0.43	1.18	0.34	0.65
Food retailing	0.78	0.22	1.18	0.20	0.59
Household good retailing	0.62	0.23	1.18	0.19	0.56
M/V retailing/service	0.47	0.13	1.18	0.14	0.48
Accommodation and restaurants	0.57	0.20	-0.01	0.45	0.30
Road transport	0.46	0.20	0.95	0.52	0.53
Air transport/travel	1.09	0.91	0.95	1.09	1.01
Rail, water and other transport	1.38	0.59	0.95	0.65	0.89
Storage and transport facilities	1.18	1.01	0.95	1.42	1.14
Communications	2.07	2.10	2.83	1.56	2.14
Finance	1.45	1.21	0.96	0.56	1.04
Insurance	1.50	2.30	0.80	1.34	1.48
Cultural and recreational	0.76	0.57	-0.15	0.42	0.40

Source: Tables 5.1, 5.2, 5.3 and D.1.

5.9 Heavy and light ICT users

Chapter 6 uses regression analysis to estimate the contribution of technological and institutional-economic factors to productivity growth. But before considering this rather complicated approach, it might be worthwhile to examine a much simpler decomposition method that can be used to attack the problem. This follows the methodology outlined in Stiroh (2001).

Stiroh examined LP growth in 61 USA industries (from all sectors) in the 1990s. He segmented the industries into three groups: two ICT producing industries, 26 ICT using industries and 33 other industries that are less heavily dependent on ICT. He found that productivity gains were highly concentrated in ICT-related industries and concluded:

> This decomposition framework shows that the role of ICT-related industries in U.S. productivity growth is quantitatively large and economically important at a macro level. Virtually all of the industry-specific productivity gains are originating in the industries that either produce or use ICT most intensively, while other industries have made little contribution on net. While one can debate the direction of causation, these results clearly show that ICT-related industries are driving the U.S. productivity revival and that other industries are playing an inconsequential role.

It is not difficult to apply Stiroh's methodology to the data used in this paper. Here sixteen industries are considered, excluding ICT producing industries. These industries are segmented into heavy and light ICT users, based on the information on ICT intensities in tables 5.1 and 5.2.

Various definitions can be used to find a demarcation point that will split the population into two nearly equal sized groups. In the first instance $2 ICT investment per working hour was assumed as the demarcation point (table 5.2). Subject to this definition, the heavy users group comprise of EGW, wholesale trade, air, rail/water transport, storage and transport facilities, communications, finance/insurance and cultural/recreational services. The light ICT users group comprises construction, hotels and restaurants, all branches of retail trade and road transport. Summary statistics for the two groups are presented in the top part of table 5.13.

An alternative definition is based on taking a ratio of ICT investment to value-added of four per cent (table 5.1). This definition allocates more industries into the light ICT users group. Subject to this definition, wholesale trade and cultural/recreational services are transferred from heavy to light users and almost 60 per cent of total value-added is allocated to the light ICT users group. The bottom part of table 5.13 shows the corresponding results.

Table 5.13 Comparing labour productivity performance

	Heavy ICT users	*Light ICT users*
Criterion for heavy users: ICT investment per hour > $2	%	%
Share in total value-added (average between 84–5 and 2001–2))	59.2	40.8
Share of contribution to LP growth; 84–5 to 2001–2	92.1	7.9
Mean annual LP growth between 84–5 and 2001–2	3.70	0.60
Criterion for heavy users: ICT investment to value-added > 4%		
Share in total value-added (average between 84–5 and 2001–2))	40.1	59.9
Share of contribution to LP growth; 84–5 to 2001–2	79.2	20.8
Mean annual LP growth between 84–5 and 2001–2	4.43	1.03

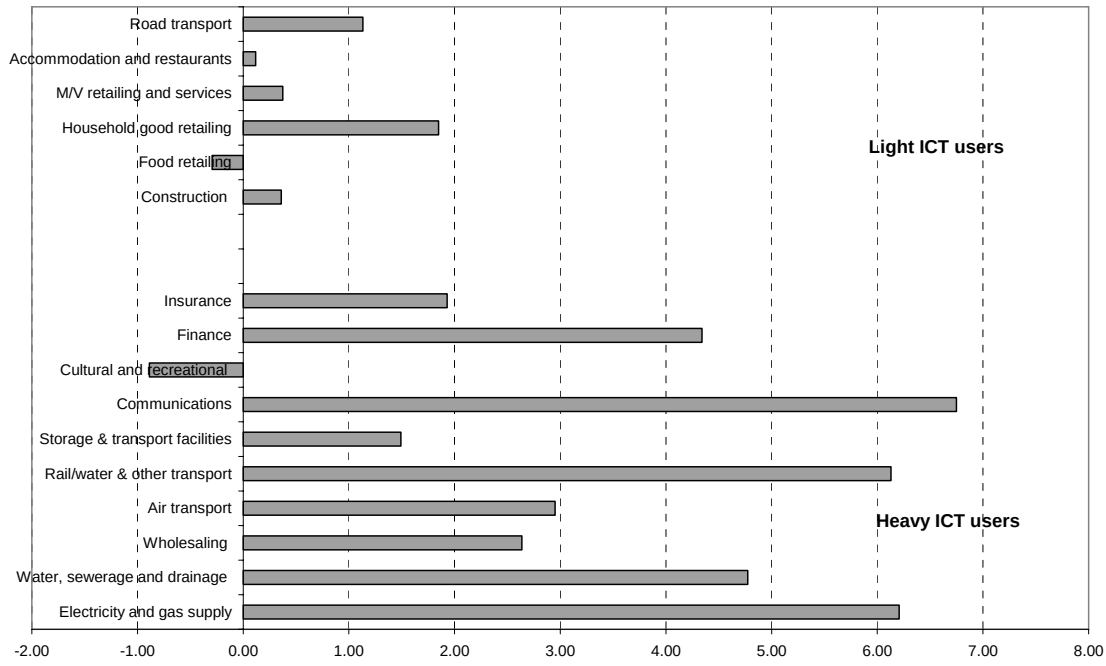
Source: ABS Cat No. 5206.0, ABS Cat. No. 6203.0 and National Accounts investment-capital stocks data.

The average annual LP growth rate of heavy ICT users was over six times larger than that of light ICT user industries under the first grouping and over four times larger under the second grouping. Judging from these figures, Stiroh's conclusion regarding productivity growth in the USA also applies in Australia.

Figure 5.1 illustrates the differences between LP growth rates of low and high ICT intensity service industries divided in accordance with the first grouping.

Figure 5.1 Average annual labour productivity growth rates

In percentage terms over the period from 1984–85 to 2001–02



Source: Table 4.1

6. Regression-based decomposition analysis

In order to infer the relative importance of various factors in driving productivity growth, a number of regressions were run using the explanatory variables discussed in chapter 5. This is a fairly technical approach to assess the impact of different factors, but apart from comparing heavy and light ICT user industries (section 5.9), it is difficult to find a simple quantitative method to tackle this complex issue.

In order to make it easier for readers with little or no knowledge of regression theory to follow the discussion, the analysis is segmented into three parts. Section 6.1 presents some regression results in fairly non-technical terms, in order to familiarise all readers with the type of factor decomposition methodology used. Section 6.2 presents further details about the regressions and methodology. The presentation is moderately technical and readers who are not familiar with regressions may wish to move on to section 6.3. Section 6.3 presents summary and conclusions from the decomposition analysis in non-technical terms.

6.1 Some regression results

The purpose of the regression analysis is to infer the contribution of economic and technological factors to non-capital spending related productivity growth. Notice from the start that both economic and technological factors represent some aspects of change between 1984–85 and 2001–02. The technological factors represent certain industry characteristics that are closely associated with technological progress, imported or locally created. The economic factors describe features related to changes in the economic environment rather than the economic environment itself. Australia has been essentially a market economy since its inception. The interest in the present context is the impact of changes in the economic environment on productivity growth rather than the benefits of the free enterprise system itself.

The regression results are detailed in appendix G. This section portrays two regressions and explains the results in simple terms. An example of regression with high explanatory power (R^2 above 0.8) is presented in table 6.1.[49] In this regression LP growth is the dependent variable, capital deepening and the composite factors outlined in section 5.8 are the independent variables. A number of clarifications are needed to understand the table.

First, the regression is based on single-period data (from 1984–85 to 2001–02) using the estimates presented in tables 4.1, 5.12, B.3, F.1 and F.2. The 16 industry observations

[49] R^2 represents the amount of variance explained by the regression. For example, $R^2 = 0.7$ means that 70 per cent of the variance of the dependent variable was explained by the regression.

used in the regression are weighted by size of industry, proxied by the mean value-added figures in table E.3.

The results from the regressions are decomposed in two ways:

- the portion of variations between productivity growth rates in 16 industries that were accounted for by each explanatory variable, plus the unexplained variance;
- the components of the aggregate productivity growth figure in terms of regression estimates for the explanatory variables, plus the regression constant.

Table 6.1 Regression of LP growth[a]

Based on Productivity Commission estimates of capital deepening

R^2= 0.8198 adj R^2= 0.7543 Degrees of freedom =11	*Coefficients*	*Components of aggregate growth rate*		*Variance explained by*
Independent variables			%	%
Capital deepening	0.429	1.551	70.0	34.8
Technological factors	1.317	1.161	52.3	32.0
Institutional factors	0.816	0.671	30.3	13.5
Education factors	0.126	0.127	5.7	1.7
Unexplained/intercept	-1.293	-1.293	-58.3	18.0
Total		2.217	100.0	100.0
Due to technological factors			59.3	67.8
Due to economic factors			40.7	32.2

[a] Weighted regressions using the weights in table E.3.

In table 6.1 the first column shows the estimated regression coefficients. The second column is the coefficient multiplied by the mean of the respective independent variable. According to regression theory (discussed in section 6.2.2) these terms plus the regression constant add up to the mean annual productivity growth rate of all industries, shown in the total row. The third column presents the components of annual productivity growth as a percentage of the total figure.

The fourth column is based on a different type of decomposition calculations (explained in section 6.2.2). It shows the percentage of total variance explained by each of the independent variables in the regression. The unexplained variance is $1 - R^2$ (R^2 is shown in the top left hand side).

The third and fourth columns provide different, but often similar, indication about the relative importance of each independent variable in explaining aggregate productivity growth. Both methods have an unexplained term. With the components of aggregate growth method, the unexplained term is the regression constant (in other words, the zero intercept). With the variance explanation method it is the unexplained variance (that is, $1 - R^2$).

Numerous regressions with different specifications and combinations of variables were tested. Some of these are presented in appendix G. No attempt was made to identify the most 'appropriate' regression. The aim was more general, that is to show that regressions based on different specifications and independent variables tend to yield a similar pattern of results, when it comes to the relative contribution of technological and economic factors to productivity growth. This issue is addressed in the two bottom lines of the regression tables. These lines decompose the impact of two factor groups in a manner that adds up to 100 per cent. This is done by adding up the effects of factors other than capital deepening and the unexplained/intercept term. The net effect is then divided between technological and economic factors. In table 6.1 the combined institutional and education composite variables represent the economic factor (for more details see section 6.2.2).

The figures in table 6.1 suggest that, after discounting the impact of change in capital per worker, technological factors were responsible for at least 59 per cent of productivity growth in service industries while changes in the economic environment accounted for less than 41 per cent.

Table 6.2 shows results from another regression. In this regression the dependent variable is MFP growth instead of LP growth. Since capital deepening is an integral component of MFP (see eq. 4.2), it is not used here as an independent variable. According to the results in table 6.2, technological variables drive at least 83 per cent of MFP growth.

Table 6.2 Regression of MFP growth[a]

R^2 = 0.4742 adj R^2= 0.3428 Degrees of freedom =12	*Coefficients*	*Components of aggregate growth rate*		*Variance explained by*
Independent variables			%	%
Technological factors	1.412	1.245	165.4	39.3
Institutional factors	0.424	0.349	46.3	9.9
Education factors	-0.425	-0.427	-56.8	-1.8
Unexplained/intercept	-0.414	-0.414	-55.0	52.6
Total		0.752	100.0	100.0
Due to technological factors			106.7	83.0
Due to economic factors			-6.7	17.0

[a] Weighted regressions using the weights in table E.3.

Notice that R^2 of the MFP regression is much lower than that of the LP regression in table 6.1. Generally, MFP regressions have lower explanatory power than LP regressions, as shown in appendix G. Nonetheless, much of the forthcoming decomposition analysis relies on the results from MFP regression. The reason is that much of LP growth can be decomposed without regressions using growth accounting techniques, as explained in section 4.3.3. On the other hand, MFP is a residual term that has be decomposed by other means, such as regression analysis. In the following discussion LP regressions are only used as supplementary tools, to confirm the

plausibility of decomposition estimates obtained by combining growth accounting with regression-based decomposition of the drivers of MFP growth.

6.2 Further explanations about regressions and decomposition

6.2.1 The general framework

The regression analysis employed in this study is not time-series econometric analysis using panel data. It is based on a much simpler cross-sectional OLS approach, which explores patterns rather than attempts to identify the 'best' or 'most appropriate' functional relationship from the data available. Although some multi-period regressions were also tested, the main concern here is with cross-sectional data related to a single period (1984–85 to 2001–02). Given the exploratory nature of this cross-sectional exercise, the discussion does not deal with diagnostic tools that are used in time-series analysis, such as stationarity, heteroscedasticity or autocorrelation.

The single period cross-sectional regressions employed in this study are based on 16 observations (for 16 industries). In order to retain sufficient degrees of freedom, the explanatory variables were applied in a parsimonious manner, with no more than four independent variables in each single-period regression.

Two methods were applied in order to minimise collinearity problems in the regressions. First, by using composite factors as explanatory variables. The construction of composite factors was explained in section 5.8. The two regressions presented earlier are based on composite variables. In addition, numerous regressions were run based on various combinations of individual explanatory variables. These are presented in appendix G. In this type of regression usually only one variable from each factor group was used in single-period regressions, in order to reduce collinearity problems and maintain sufficient degrees of freedom. However, more than one variable from each group was used in some multi-period regressions, where conserving degrees of freedom is a less important consideration.

The change in the capital-labour ratio (capital deepening) was incorporated into all LP growth regressions. This is because of the theoretical importance of this variable in explaining LP growth, as discussed in appendix A. The main interest in this paper is not on the effect of capital deepening but on the relative contribution of technological versus economic factors to productivity growth. Including the change in the capital-labour ratio among the independent variables made it possible to isolate in the LP regressions the effect of capital deepening.

LP growth regressions where capital deepening appears as one of the explanatory variables represents an unconstrained approach to estimating the parameters of the aggregate production function (see appendix A). In this case, the regression coefficient associated with changes in the capital-labour ratio (capital deepening) represents the output elasticity of capital. By contrast, in MFP calculations the capital elasticity coefficient is given by the share of capital income from total income (see eq. 4.2).

Combining observations from different industries to estimate a single production function raises some methodological difficulties, because arguably the production functions of different industries are not the same. However, these differences are related mainly to different technological innovation paths rather than differences in capital output elasticities. Hence the econometric production function approach offers a reasonable method to separate out the effect of capital deepening on productivity growth.

On a different subject, the top left hand panel in the regression tables shows in addition to R^2 also R^2 adjusted. It is defined as follows (Shazam 2001):

$$R^2 \ adjusted = 1 - \left(1 - R^2\right)\frac{N-1}{N-K}$$

where N represents the number of observations and K is the number of independent variables plus one. R^2 adjusted provides a better indication about the true explanatory power of the regression than R^2, particularly when the number of observations is small, as in the present regressions.

In all the regressions reported in this paper observations are weighted by industry size (represented by average value-added over the study period from table E.3). Weighted regressions yield more reliable estimates than regressions where each industry is counted the same. The mean of service industries productivity growth rate in the weighted regression is close to the aggregate productivity growth rate actually observed, whereas a different (higher) mean is obtained in unweighted regressions.

6.2.2 Decomposing contributions to productivity growth

As noted earlier, the results from the regressions were decomposed in two ways — the proportion of variance explained and the components of aggregate productivity growth.

Decomposing the variance explained between the independent variables is based on a well known theorem in regression theory. This theorem states that the variations explained by any ordinary least square (OLS) regression can be decomposed between the independent variables, by multiplying the standardised regression coefficients by the correlation of the independent variable with the dependent variable.[50] The sum total of these terms adds up to total explained variance. In the absence of significant collinearities, the individual terms can be interpreted to represent the contribution of each variable to explain total variance (Aigner 1971). If there are strong correlations between the independent variables, such interpretation may not be justified. Given the efforts made in this study to minimise collinearities, the standardised regression coefficients based approach provides a reasonable indication about the contribution of

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50 The SHAZAM econometric package that was used calculates standardised regression coefficients.

each independent variable to explain variations in the dependent variable (productivity growth).

The second decomposition approach, referred to here as the components of aggregate productivity growth, is also grounded in regression theory. One of the defining equations of OLS regressions is the condition that the OLS coefficients multiplied by the means of the respective independent variables plus the regression constant must add up to the mean of the dependent variable (Aigner 1971). Provided the explanatory power of the regression model is reasonably high (say, R^2 is above 0.6) the coefficient multiplied by mean terms can be regarded to represent an approximation to the contribution of each independent variable to explain the difference between the mean of the dependent variable and the regression constant. Such interpretation is justified only in the absence of strong collinearities and provided there are good reasons to believe that the independent variables represent truly causative factors.

The two bottom lines in the regression tables show the relative importance of technological versus economic factors to non-capital related productivity growth. These figures were calculated so as to take out unexplained terms (that is, the regression constant or the unexplained variance) and the effect of capital deepening. This is done by summing up the figures related to explanatory variables (excluding capital deepening) and finding out the proportion in this total of technological and economic factors. Economic factors are defined here to cover all education and institutional variables.

6.2.3 Regressions without a constant term

As mentioned earlier, the components of aggregate growth provide a useful indication about the contribution of various factors to productivity growth. However, there are some methodological difficulties with this approach.

When the regression constant (intercept) represents a high proportion of the mean value of the dependent variable, then the independent variables 'explain' little of the mean of the dependent variable and this decomposition approach loses its value.[51] On the other hand, when the intercept turns out to be highly negative (say, above 100 per cent of minus the mean productivity growth rate) then sometimes large disparities emerge between estimates based on the makeup of the mean and those based on variance explained. This issue is discussed in some detail in section H.3 in the appendix.

The difficulty in relation to decomposition posed by the regression constant (zero intercept) can be overcome by running regressions where the zero intercept is suppressed. However this approach poses other difficulties, particularly on the mathematical side. Regressions without a constant term tend to yield lower R^2 ratios than conventional OLS regressions. Because some OLS conditions are violated, such

[51] In productivity analysis it completely loses its explanatory value when the regression constant is higher than the mean of the dependent variable.

regressions do not always yield an R^2 ratio between zero and one (Aigner 1971). The sum of the standardised regression coefficients multiplied by the correlation of the independent variable with the dependent variable is not equal to $1-R^2$. Also, the regression coefficients multiplied by the means of the respective independent variables do not add up to the mean of the dependent variable. But, as shown in the results presented in appendix G, these deviations are usually small.

Notwithstanding the imperfect mathematical rigour of this approach, given the occasional difficulties posed by the intercept, it was decided to examine also relative contributions using regressions where the intercept is suppressed. The third and forth columns in the regression tables in appendix G show estimated contributions based on no-constant regressions. The results from the makeup of the mean and variance explained decomposition methods tend to be closer in no-constant regressions than in conventional OLS regressions.

6.2.4 Regressions with individual explanatory variables

The two regression examples presented in tables 6.1 and 6.2 are based on composite factors. In addition, the study experimented with numerous regressions based on various combinations of individual explanatory variables.

As noted earlier, in order to reduce collinearity problems, usually only one explanatory variable from each factor group was used in single-period regressions and only one or two in multi-period regressions. Given 13 explanatory variables, with only three or four used in each single-period regression, this is a small sample from all possible combinations. All the non-composite variable regressions reported in the appendix are single-period regressions. Multi-period regressions with non-composite variables are not reported in this paper. The reasons will be clarified in the next section.

In both composite and individual variable regressions three types of specifications were used:

- LP growth is the dependent variable—the Productivity Commission capital deepening estimate (table 4.2) is an explanatory variables.
- LP growth is the dependent variable—the modified capital deepening estimate (table 4.2) is an explanatory variable.
- The MFP growth estimate (table 4.2) is the dependent variable.

Most of the individual variable regressions indicate that a substantially higher proportion of productivity growth is due to technological factors than to changes in the economic environment. This is in line with the results obtained from single-period composite variable regressions (tables 6.1, 6.2 and G.19).

6.2.5 Multi-period regressions

Another set of regressions presented in appendix G is based on panel rather than cross-sectional data. Initially it was thought that the time-series information available on most variables would lead to better regression estimates based on many more observations. To utilise this information, it was decided to split the entire study period (1984–85 to 2000–01) into sub-periods. In the two-period models the sub-periods are 1984–85 to 1993–94 and 1993–94 to 2001–02. In the four-period models the sub-periods are 1984–85 to 1989–90, 1989–90 to 1993–94, 1993–94 to 1997–98 and 1997–98 to 2001–02. Multi-period regressions are presented in tables G.16, G.17, G.24, G.25, G.26 and G.27 in the appendix.

The two-period regressions are based on 32 observations and the four-period ones on 64 observations, compared with 16 observations in single-period regressions. While there are more degrees of freedom, it turned out that the multi-period regressions yielded substantially lower explanatory power (measured in terms of R^2 or adjusted R^2) than the single-period regressions. Moreover, the multi-period regressions include dummies to represent different periods. These time-related dummies explain a significant portion of variations, but do not help in decomposing the effects of technological and economic factors.

Even when more explanatory variables were added to these regression (because with 32 or 64 observations conserving degrees of freedom is a less important consideration) the explanatory power of multi-period regressions remained well below those of single-period regressions. The lower R^2 ratios of multi-period regressions appear to be related to poor time synchronisation between changes in the independent variables and changes in productivity growth rates.[52] For this reason, the focus in this report is on single-period cross-sectional analysis rather than time-series analysis.

But, regardless of R^2, the multi-period regressions show a stronger dominance of technological over economic factors than single period regressions. Given the lower explanatory power of multi-period regressions, no particular significance can be attached to this finding.[53] In order to save space, only multi-period regressions with composite explanatory variables are reported.

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[52] Brynjolfsson and Hitt (2003) report a similar finding about the poorer suitability of time-series panel data to explain productivity growth compared with single-period long time span data.

[53] This outcome is partly due to the fact that three out of the four technological variables are intensity indicators that remain the same in every sub-period.

6.3 Conclusions from the regressions

6.3.1 Decomposition based on MFP growth

As noted earlier, the main interest in this paper is in decomposing the drivers of MFP growth. From the growth accounting decomposition results presented in section 4.3.3 (based on Productivity Commission (2004a) data) the estimated composition of average annual labour productivity growth between 1984–85 and 2001–02 is given as follows:

	%
Capital deepening due to financial investment	1.02
Capital deepening due to falling ICT prices	0.45
MFP growth	0.77
LP growth	2.24

The interest here is in decomposing the factors driving productivity growth after taking out the effect of capital spending. That refers to the 1.22 per cent covering the second and third items. Capital deepening due to falling ICT prices is clearly a technological factor. In order to assess the relative contribution of technological and institutional factors to LP growth, all that is left to resolve is the contribution of these factors to MFP growth

The 34 MFP growth regressions results in appendix G.1 indicate that much of MFP growth in service industries can be explained by technological variables. This is particularly clear in regressions where OECD productivity growth rates or the ratio of ICT investment to value-added are used as technological variables. The results are slightly less clear cut when ICT investment per working hour is used as the technological variable, but even in these cases technological factors tend to contribute more than institutional-economic factors.

These results suggest that at least half of MFP growth in service industries was driven by technological factors.[54] Given the relatively low R^2 ratios of the MFP regressions (with the exception of those using OECD sectoral LP growth rates) allowance has to be made for a substantial margin of error. Taking a mean estimate of 50 per cent provides a fairly cautious estimate of the contribution of technological factors to MFP growth. Taking 15 per cent plus or minus around 50 per cent provides a reasonably wide confidence interval. Multiplying the annual MFP growth figure of 0.77 by 35 and 65 per cent yields an upper estimate of 0.50 per cent and a lower estimate of 0.27 per cent for the annual contribution of technological factors to MFP growth. Institutional-economic factors accounts for the remainder of MFP growth. Using these figures combined with the ICT price fall effect yields the final decomposition estimates presented in table 6.3.

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[54] Some overseas studies also found significant positive correlation between ICT intensity and MFP growth. These include Bassanini and Scarpetti (2002) cross-country study and Inklaar et al (2003) cross-sectoral study. Recent USA productivity studies, including Oliner and Sichel (2002) and Jorgenson et al (2002), indicate that much of MFP growth in the USA in the 1990s was concentrated in ICT producing industries and in heavy ICT users such as finance.

The two bottom lines in table 6.3 show the portion of growth that can be attributed to technological and institutional factors after discounting the effect of increased capital spending per working hour. These estimates suggest that between 59 and 78 per cent of non-capital spending related productivity growth over the study period can be attributed to technological factors, while institutional-economic changes may explain between 22 and 41 per cent of this growth. These estimates accord with the widely held view among economic historians that MFP growth in the long run reflects mainly technological progress (see appendix A, Aghion and Howitt 1998, BIE 1992 and BIE 1994). The comparison of LP growth rates of ICT using industries in section 5.9 (table 5.12), also supports the conclusion that technological progress (related mainly to advances in ICT) was the principal driver of productivity growth in service industries.

Table 6.3 The drivers of labour productivity growth —1984–85 to 2001–02

LP growth attributed to	*Lower estimate*		*Upper estimate*	
	Annual contribution	*Share*	*Annual contribution*	*Share*
	%	%	%	%
Increased capital spending per worker	1.02	46	1.02	46
Falling ICT prices	0.45	20	0.45	20
MFP growth due to technical change	0.27	12	0.50	22
MFP growth due to institutional change	0.50	22	0.27	12
Annual LP growth	2.24	100	2.24	100
Technological factors[a]	0.72	59	0.95	78
Institutional-economic factors[a]	0.50	41	0.27	22

[a] After discounting the effect of increased capital spending per worker.

The twenty LP growth regressions presented in appendix G.2 support the conclusion that technological progress was the main contributor to LP growth after discounting the effect of increased capital spending per worker. The LP regressions tend to have higher explanatory power (in terms of R^2) than MFP regressions. The big advantage of MFP cum growth accounting approach is that it reveals more about the drivers of productivity growth than LP regressions. LP regressions provide no estimate on the split between embodied and disembodied technical change and yield less accurate estimates on the effect of capital deepening.

The MFP cum growth accounting approach ties in with previous Australian growth accounting studies by Parham et al (2001) and Simon and Wardrop (2002). The present study goes further than this earlier research, by providing estimates on the relative importance of the drivers of MFP growth, instead of leaving it as an unexplained residual. Information is also presented on the composition of capital deepening in terms capital spending and embodied technical change.

As for the influence of institutional factors on MFP growth, the interaction between the adoption of new ICT technologies and changes in the economic environment has received some attention in the literature. Pilat (2004) reports that OECD countries with strict

employment protection legislation have invested less in ICT than others. Also, countries with less product market regulations have seen a stronger pick-up in productivity in ICT-using industries between the early and late 1990s. Bassanini and Scarpetta (2002) found that higher administrative burden on new startup firms is negatively correlated with investment in IT. Due to lack of suitable sectoral data, no attempt was made in this report to estimate the indirect effects of competition reforms on productivity, by way of stimulating more investment and the takeup of new ICT technologies.

Probably the present analysis approaches the limit of what can be inferred about the drivers of LP growth from publicly available macroeconomic data. Summing up the proceeding of a conference on Australian productivity growth, Gregory (1998) listed the following obstacles for identifying the effects of microeconomic reforms on productivity:

- The coverage of microeconomic reform relative to the economy as whole may have been quite small (such as tariff reductions and reorganisation of public utilities).
- Microeconomic reforms have been a continuous process over more than three decades, and, in principle, only increases or decreases in the rate of reform should be detectable in terms of faster or slower productivity growth at the macroeconomic level.
- Many other factors impinge on multifactor productivity and their influence may swamp microeconomic reform effects.

Given the identification problems faced by earlier Australian studies, it can be said that the present approach provides some contribution to a better understanding of the components of LP growth, as imprecise as it may be.

6.3.2 Disembodied knowledge

At this stage the reader may wonder what is behind the technology related portion of MFP growth. It is quite a substantial item. Under the higher estimate in table 6.3, the technology driven component of MFP is greater than falling ICT prices related ‘embodied’ technical change.

The MFP component corresponds to what is referred to in the growth literature as ‘disembodied’ knowledge, to distinguish it from innovative knowledge embodied in new equipment. The productivity effects of disembodied knowledge result from a number of factors, including:

- economic applications of new knowledge obtained from open publications on science and technology;
- domestic innovation related externalities that arise as a result of the imitation of innovations by local producers and the leakage of new knowledge to other firms through movement of staff and informal contacts;

- imitation of overseas innovations by domestic enterprises through reverse engineering and imitative-innovative R&D efforts;
- commercial technology transfer through transnational corporations and other licensing agreements;
- learning-by-doing carried out by firms in assimilating new technologies; and
- network externalities captured in production activities.

Given the central importance of ICT in driving technological advances in service industries, in these sectors network externalities and the learning-by-doing aspect of technological adoption appear to be particularly important.

The growing importance of the Internet and digital communications involve network externalities, because the addition of a new user may benefit some existing users who do not have to pay for this benefit. Given that nowadays most medium and large enterprises are already connected to the net, it is possible that network externalities from new connections are approaching a saturation level.

The learning-by-doing aspect of ICT adoption and development is probably of greater and more lasting importance. On this subject, the findings of DeLong and Summers (1992) seem especially pertinent. They found from a cross-country econometric study that investment in new machinery and equipment (such as ICT equipment) tend to contribute more to GDP growth than equal investment in structures or transport equipment. They explain this by the learning-by-doing process associated with investment in modern equipment. There is also a lot of learning and adaptation required with the introduction and development of new ICT systems. This 'intangible' investment in learning helps to raise productivity but it is not reflected in the National Accounts capital expenditure data.

Commenting on the current situation in Australia, Anderssen (2004) notes that continued technological breakthroughs embedded in ICT hardware can only deliver progress if combined with a host of complementary innovations, large and small, in business and society. It is in this 'middle ground' of entrepreneurial opportunity that users and producers together determine the most promising commercial innovations. Here technological competition is driving change, as ICT service firms work with businesses to convert tacit business practice into codified routines that, in turn, become business systems built around Information Systems (IS). This area involves substantial intangible investment in learning and organisational change and is likely to lead to significant learning-by-doing related contributions to GDP growth.

Some statistical evidence supporting Anderssen's observations comes from the Sensis (2004) survey of small and medium sized enterprises, which revealed that many of these firms develop their own software rather than buy packaged software off the shelf, because of the non-availability of suitable software for their specific requirements. The large business R&D expenditures in service industries such as finance, retail and

wholesale trade and business services, also point to the need to develop non-packaged ICT applications for specific business requirements. Lower import prices are not sufficient by themselves to ensure successful takeup of new ICT technologies. Complementary 'intangible' investment in learning, internal software development and organisational change is also required.

6.3.3 Caveats and conclusions

As indicated in the earlier study (NOIE 2004), any decomposition between technological and institutional variables is difficult, because the two groups are inter-related.[55] Indeed, most explanatory variables in the model are interdependent to some extent, but the size of impact is inferred from statistically estimable direct effects, without estimating possible indirect effects, such as more rapid takeup of new technologies as a result of market reforms. Moreover, the estimates could be subject to inaccuracies due to insufficiently strong cross-sectional proxy variables to represent changes in the competitive environment of individual industries.

Nonetheless, even without regression analysis, the observation that Australian sectoral LP growth rates are similar to those recorded in other advanced OECD countries strongly suggests that productivity growth rates were dictated more by different technological innovation paths than by unique changes in the Australian economic environment.

One of the puzzling results is the low productivity growth recorded in labour intensive industries, such as retailing, hotels and restaurants, construction and cultural/recreational services. While these findings support the thesis that productivity growth was driven mainly by technological factors, these unexpectedly low growth rates do not accord with the expectation of improved work incentives as a result of industrial relation reforms and seem to warrant further research.

It is possible that some puzzling results reflect data accuracy problems. In the opinion of one of the referees, a major message of the present study is that the ABS needs to devote more resources to obtaining more accurate estimates of quality-adjusted volume measures for service industries. More reliable volume estimates could improve the monitoring of productivity trends in the most important sector of the economy.

Given the methodological and practical difficulties involved in estimating constant price quality-adjusted volume measures of outputs and capital inputs at the sectoral level, the decomposition results presented in this paper should be treated with caution. The regression-based decomposition approach is also not without its problems, as discussed in section 6.2.3 and appendix H.3. Due to these data quality and methodological

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[55] Some of the methodological problems involved in decomposing the drivers of productivity growth, and the effects of microeconomic reforms in particular, are discussed in Gregory (1998).

problems, the study draws attention to broad contours rather than to specific numerical results.

The general pattern of results from over 50 regressions presented in this paper points to the conclusion that the main drivers of productivity growth in service industries over the last two decades were ICT-related innovations rather than changes in the economic environment. A similar conclusion was reached in the earlier report on productivity growth in manufacturing (NOIE 2004) and in the revised manufacturing decomposition estimates presented in appendix H.4 of this report.

A The theory and measurement of productivity growth

A.1 Key concepts

The following discussion briefly explains some key concepts to readers who are not familiar with economic growth models. To understand the discussion a basic knowledge of calculus is required. The interested reader can find more detailed methodological discussion on the measurement of labour and multifactor productivity in PC (1999), Parham et al (2001) and Carlaw and Lipsey (2003).

The basic economic growth equation has the form:

$$Y(t) = A(t)*f(K(t), L(t)) \quad \text{(A.1)}$$

where

Y(t) is the level of real output (of the economy or an industry) in year t,

K is net capital stock,

L is the level of employment,

f represents a constant return to scale aggregate production function, where the factors of production are K and L.

A(t) is the multifactor productivity (MFP) term, representing the combined effect of technological progress and various economic-institutional factors on output. Note, all the arguments in eq. (A.1) are time dependent.

L is measured in terms of the number of persons employed (or working hours). In this paper working hours are used.

K is estimated by using the 'perpetual inventory' method, which involves accumulating new purchases of capital goods over time and taking away depreciation, using estimated aggregate asset lives. Methodological problems related to 'hedonic' constant price indexation of capital stocks are discussed in section 4.3.

Y is measured by value-added volume indices reported in table 2.2.

A.2 The mathematical framework

Given a first degree homogeneous (constant return to scale) production function and competitive market clearing conditions, mathematical reasoning leads from eq. (A.1) to the following equation (Carlaw and Lipsey 2003):

$$\frac{d\log(A)}{dt} = \frac{d\log(Y)}{dt} - \left[s_K \frac{d\log(K)}{dt} + s_L \frac{d\log(L)}{dt} \right] \quad \text{(A.2)}$$

where dlog/dt represent logarithmic differentials, which are for small changes approximately equal to percentage changes. In 'growth accounting' studies, S_k and S_L represent the share of capital and labour income from total income (the same as total output or value-added). The assumptions of constant return to scale and competitive market clearing conditions ensure that S_k and S_L add up to one. In econometric production function models, S_k and S_L represent output elasticities estimated from regression results and do not necessarily add up to one.[56]

It is evident from eq. (A.2) that the change in multifactor productivity defines the portion of output growth that can not be explained by changes in labour and capital. This residual term is determined mainly by technological progress and changes in economic-institutional factors.[57] These factors are analysed in the text.

After some algebraic rearrangements, eq. (A.2) can be put as:

$$\frac{d\log(A)}{dt} = \left[\frac{d\log(Y)}{dt} - \frac{d\log(L)}{dt}\right] - \left[\boldsymbol{S}_k \frac{d\log(K)}{dt} - \boldsymbol{S}_k \frac{d\log(L)}{dt}\right]$$

$$= \frac{d\log}{dt}\left(\frac{Y}{L}\right) - s_k \frac{d\log}{dt}\left(\frac{K}{L}\right) \qquad \text{(A.3)}$$

where $\frac{d\log}{dt}\left(\frac{Y}{L}\right)$ is the logarithmic change in LP and $\frac{d\log}{dt}\left(\frac{K}{L}\right)$ is the logarithmic change in the capital-labour ratio (capital deepening). Eq. (A.3) indicates that change in MFP is the change in LP minus an adjustment to account for change in the capital-labour ratio. This definition is used in section 4.3.1 eq. (4.2).

A.3 Possible generalisations

On a more general level than the two-factor production framework, output can be defined as:

$$Y(t) = A(x_1 \ldots x_n, t) * f(K_1 \ldots K_h, L_1 \ldots L_m, t) \qquad \text{(A.4)}$$

where f is a first degree homogeneous function.

$x_1 \ldots x_n$ represent n variables determining MFP growth. $K_1 \ldots K_h$ represent h different forms of capital (machinery and equipment, structures, land, transport equipment, ICT equipment, software, etc). $L_1 \ldots L_m$ represent m different forms of labour (skilled, unskilled, tradesmen, farmers, clerks, etc.).

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56 The production function approach is used in regressions where LP growth is the dependent variable and capital deepening is one of the independent variables. The output elasticity of capital deepening is estimated from the regressions.

57 In the short run, changes in capacity utilisation could also have a significant effect on MFP growth. Other potentially influential factors include changes in economies of scale or in the terms of foreign trade.

The focus of attention in this paper is on the x_i variables determining MFP growth, or more precisely, on various proxies for these variables.

A.4 Extensions used in ICT-related studies

The discussion in sections 4.3.3 and 4.3.4 reviews a number of MFP studies, which explored the contribution of ICT to productivity growth. The basic mathematical framework of these MFP calculations is the same as eq. (A.3) but the capital deepening term is disaggregated into several sub-groups. In the OECD study by Colecchia and Schreyer (2001) four capital sub-groups are employed:

- computer equipment
- telecommunications equipment
- software
- other capital

In the Australian studies of Parham et al (2001) and Simon and Wardrop (2002) three capital categories are employed:

- computer equipment
- software
- other capital

With three capital categories, eq. (A.3) assumes the form:

$$\frac{d\log}{dt}\left(\frac{Y}{L}\right) = s_k^c \frac{d\log}{dt}\left(\frac{K^c}{L^c}\right) + s_k^s \frac{d\log}{dt}\left(\frac{K^s}{L^s}\right) + s_k^o \frac{d\log}{dt}\left(\frac{K^o}{L^o}\right) + \frac{d\log(A)}{dt} \qquad \text{(A.5)}$$

where K^c, K^s and K^o represent the (hedonic) constant price values of the capital stocks of computers, software and other capital respectively and L^c L^s and L^o are corresponding labour inputs. s_k^c denotes the share of computer related capital income from total income (labour and capital combined), with s_k^s being the income share of software and s_k^o the income share of other capital goods.

The calculations in these studies are based on changes in the flow of 'capital services'. Changes in the volume of capital services are assumed to be proportional to changes in the (constant price) volume of capital stocks. However, the user cost of capital services is more complicated, defined by the formula:

$$p^i = q^i(r + d^i - \zeta^i) \qquad \text{(A.6)}$$

where p^i represents the rental price (user cost) of the capital service of asset type i, q^i is the net purchase price, r is the average rate of return to capital, d^i is the rate of depreciation of capital asset i and ζ^i is the rate of change in asset price. Computers have

a higher depreciation rate than most other capital assets and negative ζ^i due to falling prices. According to this rental price formula capital income is not directly proportional to capital stocks, which affects the estimates of the S_k shares of various asset categories. Compositional changes in capital stocks over time may lead to different estimates of capital deepening based on changes in capital stocks or changes in capital services. A detailed discussion about capital services is presented by Schreyer (2003).

A.5 Further explanations with growth accounting

The growth accounting framework can be used to explain not only the contribution of ICT capital deepening but also others drivers of LP growth.

Rising education standards is a factor that received most attention in the literature. Unlike other institutional-economic changes, the contribution of higher skills to MFP growth is not too difficult to estimate. Since educational standards and the length of work experience are statistically related to higher wages, it is possible to quantify directly the economic value of changes in skills.

Estimates of quality-adjusted labour supply incorporating changes in the level of skills (in addition to number of persons and working hours) are presented by Barnes and Kennard (2002) for the Australian market sector. They estimate that between 1988–89 and 1993–94 the growth in skills contributed 0.2 of a percentage point to the 0.7 per cent a year growth in MFP in the market sector of the Australian economy. But rising skills contributed only around 0.05 of a percentage point to the 1.7 per cent a year growth in MFP from 1993–94 to 1997–98.[58]

Another driver of MFP growth that perhaps could be estimated in Australia is the effect of microeconomic reforms of infrastructure services (such as electricity, telecommunications, railways, ports, etc.). These reforms were subject to a number of detailed studies by the Productivity Commission and other researchers. Provided the net financial effect of these reforms could be quantified, these estimates could be used to further reduce the unexplained residual of productivity growth lumped under MFP.

There are also other factors that could be estimated to provide a clearer understanding of the drivers of productivity growth. In recent years, price falls of capital inputs due to technological progress were most dramatic in the ICT area. Less spectacular quality-adjusted price falls occurred in some other types of production equipment and perhaps could be estimated.

Provided it was possible to estimate in a reliable manner quality-adjusted capital deepening and compare it with inflation adjusted capital deepening and also estimate reliably the effect of rising skills and of infrastructure reforms, the remaining long-term MFP growth would reflect largely ‘disembodied’ factors. These ‘disembodied’ factors

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58 The ABS has now extended their official productivity analysis to cover quality adjusted labour (see ABS 2003).

include the effects of domestic R&D externalities, the intangible investment associated with learning-by-doing and the impact of general institutional changes affecting labour and product markets.

A.6 A few notes on growth theories

A number of theoretical explanations have been developed about what is driving MFP growth. Generally, most explanations attribute changes in MFP in the long-run to the adoption of more advanced technologies and associated changes in work practices and organisations. In the short-run, cyclical factor and changes in the institutional-economic environment may have an important role to play.

Endogenous growth theories draw attention to the fact that only part of the technological knowledge used by a country (or industry) is available to all through open publications and free trade in capital goods. Some other technological knowledge is not freely accessible but can be acquired through internal R&D or production experience.[59] Moreover, the utilisation of all technological knowledge (both public and tacit) depends on the level of human capital in the economy. R&D and human capital development are assumed to be endogenous control variables in some growth model.

Another strand of growth models emphasise the importance of learning-by-doing in industrial development, given that much of the tacit technological knowledge used by industry is acquired on the job rather than from open information. The interested reader can find good surveys on endogenous growth models and the learning-by-doing aspects of industrial development in Aghion and Howitt (1998), BIE (1992), Industry Commission (1995), Nelson (1990) and DeLong and Summers (1991 and 1992).

It is not clear to what extent these theories are applicable to ICT in services. Secrecy and patent protection of new technologies coupled with limited open trade in dedicated (product specific) machinery and equipment is widespread in manufacturing. In this situation, internal R&D by firms has an important role to play in ensuring that they keep up with the latest technological developments in many (but not all) manufacturing activities. On the other hand, there is fairly open trade in computers and telecommunications equipment and software packages, even if the program code is kept secret. It is not clear whether secrecy is as important in software and ICT services as it is in manufacturing.

Perhaps, further research is warranted to examine to what extent there is a need for domestic capabilities in electronics R&D and production and software development in order to absorb effectively new ICT technologies from abroad.

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59 Internal R&D often involves the development of state-of-the-art product-specific machinery and software that is not sold on the open market. The limited transfer of such machinery and software to non-affiliated enterprises is usually carried out through licensing agreements (see Nelson 1990, BIE 1994 and Caves 1996).

B. Productivity growth data used in the statistical analysis

B.1 Labour productivity growth—average annual growth rates

	1984–85 to 2001–02	*1984–85 to 1993–94*	*1993–94 to 2001–02*
	%	%	%
Electricity and gas supply	6.21	8.17	4.04
Water supply, sewerage and drainage	4.77	6.44	2.93
Construction	0.36	0.36	0.36
Wholesale trade	2.64	0.20	5.45
Food retailing	-0.29	-0.48	-0.09
Personal and household good retailing	1.85	0.72	3.13
Motor vehicle retailing and services	0.37	-1.16	2.13
Accommodation, cafes and restaurants	0.12	-0.95	1.34
Road transport	1.13	-0.41	2.90
Air transport	2.95	5.28	0.39
Rail/water and other transport	6.13	6.98	5.18
Storage and transport facilities	1.49	-1.29	4.71
Communications	6.75	8.15	5.19
Finance	4.34	4.21	4.49
Insurance	1.93	1.94	1.92
Cultural and recreational services	-0.89	-1.58	-0.10

Source: ABS Cat No. 5206.0, ABS Cat. No. 6203.0 and unpublished ABS data at the two-digit ANZSIC level.

Table B.2 Multifactor productivity growth—average annual growth rates

	1984–85 to 2001–02	*1984–85 to 1993-94*	*1993–94 to 2001–02*
	%	%	%
Electricity and gas supply	2.72	4.80	0.43
Water supply, sewerage and drainage	1.97	3.69	0.07
Construction	-0.06	0.04	-0.18
Wholesale trade	1.82	0.02	3.89
Food retailing	-0.03	-2.83	3.22
Personal and household good retailing	0.21	3.50	-3.37
Motor vehicle retailing and services	0.04	-8.28	10.30
Accommodation, cafes and restaurants	-0.67	-1.69	0.49
Road transport	0.68	-0.17	1.65
Air transport	1.88	2.43	1.26
Rail/water and other transport	4.21	3.32	5.23
Storage and transport facilities	0.91	-0.51	2.53
Communications	3.73	4.98	2.33
Finance	0.90	0.88	0.92
Insurance	0.34	0.38	0.30
Cultural and recreational services	-3.34	-3.37	-3.30

Source: PC (2004). Pro-rata allocations to sub-sectors are based on table 4.4.

Table B.3 Changes in capital-labour ratios—average annual change rates

Based on Productivity Commission estimates

	1984–85 to 2001–02	*1984–85 to 1993–94*	*1993–94 to 2001—02*
	%	%	%
Electricity and gas supply	5.64	5.90	5.34
Water supply, sewerage and drainage	4.21	4.21	4.22
Construction	2.01	3.69	0.15
Wholesale trade	2.73	1.99	3.56
Food retailing	2.72	2.90	2.51
Personal and household good retailing	4.92	4.14	5.81
Motor vehicle retailing and services	3.41	2.19	4.79
Accommodation, cafes and restaurants	3.42	3.43	3.41
Road transport	0.42	-0.55	1.52
Air transport	2.23	5.14	-0.95
Rail/water and other transport	5.38	6.84	3.77
Storage and transport facilities	0.78	-1.42	3.31
Communications	6.75	8.15	5.19
Finance	7.81	8.15	7.44
Insurance	5.32	5.80	4.79
Cultural and recreational services	-0.89	-1.58	-0.10

Source: PC (2004). Pro-rata allocations to sub-sectors are based on table 4.4.

Table B.4 Changes in modified capital-labour ratios—average annual change rates

Modified estimates, based on inflation-adjusted ABS capital stocks data

	1984–85 to 2001–02	*1984–85 to 1993–94*	*1993–94 to 2001–02*
	%	%	%
Electricity and gas supply	5.57	5.16	6.02
Water supply, sewerage and drainage	4.14	3.48	4.89
Construction	0.08	2.77	-2.85
Wholesale trade	2.37	1.14	3.76
Food retailing	-1.91	-0.51	-3.46
Personal and household good retailing	0.20	0.69	-0.35
Motor vehicle retailing and services	-1.25	-1.19	-1.31
Accommodation and restaurants	-1.70	-0.46	-3.09
Road transport	1.35	0.14	2.73
Air transport	3.17	5.86	0.23
Rail/water and other transport	6.36	7.57	5.01
Storage and transport facilities	1.71	-0.74	4.54
Communications	3.13	5.65	0.36
Finance	1.87	3.32	0.27
Insurance	-0.48	1.07	-2.21
Cultural and recreational services	1.96	1.39	2.60

Source: ABS Cat. No. 6203.0 and unpublished ABS National Accounts capital stocks data. Pro-rata allocations to sub-sectors are based on table 4.4.

C. Labour productivity growth in seven OECD countries

Table C.1 LP growth in service sectors in selected OECD countries between 1984 and 2001

Average annual growth rates

	USA	*Canada*	*France*
	%	%	%
Electricity, gas and water supply	1.76	-0.10	4.16
Construction	0.06	-0.20	0.90
Wholesale and retail trade; repairs	2.68	2.29	2.13
Hotels and restaurants	0.52	-0.05	-1.64
Transport and storage	1.15	1.26	2.27
Post and telecommunications	4.23	3.55	5.74
Financial except insurance	1.91	2.09	0.02
Insurance	0.67	2.09	0.02
Other community, social and personal services[a]	-0.13	-0.30	-0.91
	Denmark	*Finland*	*Italy*
Electricity, gas and water supply	3.15	5.70	2.30
Construction	0.36	0.70	0.54
Wholesale and retail trade; repairs	1.55	3.51	2.22
Hotels and restaurants	-0.34	1.86	-0.42
Transport and storage	3.38	3.15	1.65
Post and telecommunications	5.27	8.26	8.25
Financial except insurance	1.15	3.92	2.58
Insurance	3.69	4.03	2.58
Other community, social and personal services[a]	0.03	0.39	-0.29
	Spain		
Electricity, gas and water supply	4.46		
Construction	0.56		
Wholesale and retail trade; repairs	0.00		
Hotels and restaurants	-0.42		
Transport and storage	2.72		
Post and telecommunications	3.57		
Financial except insurance	1.64		
Insurance	1.64		
Other community, social and personal services[a]	-0.60		

[a] This OECD category includes cultural and recreational services, which are not reported separately in the OECD STAN database. In the present statistical analysis this category is used to represent OECD cultural and recreational services.

Source: OECD (2003).

D. Explanatory variables related to changes over time

D.1 Labour productivity growth in selected OECD countries

Average annual growth rates

	1984-85 to 2001–02	*1984–85 to 1993–94*	*1993–94 to 2001–02*
	%	%	%
Electricity and gas supply	2.73	2.50	2.99
Water supply, sewerage and drainage	2.73	2.50	2.99
Construction	0.34	0.74	-0.11
Wholesale trade	2.26	1.74	2.84
Food retailing	2.26	1.74	2.84
Personal and household good retailing	2.26	1.74	2.84
Motor vehicle retailing and services	2.26	1.74	2.84
Accommodation, cafes and restaurants	-0.02	-0.07	0.04
Road transport	1.82	2.02	1.58
Air transport	1.82	2.02	1.58
Rail/water and other transport	1.82	2.02	1.58
Storage and transport facilities	1.82	2.02	1.58
Communications	5.41	5.23	5.62
Finance	1.84	1.14	2.64
Insurance	1.53	1.17	1.93
Cultural and recreational services	-0.29	-0.19	-0.41

[a] The selected OECD countries are the USA, Canada, France, Denmark, Finland, Italy and Spain.

Source: OECD (2003).

D.2 Increase in the share of university graduates in the workforce

Expressed in terms of average change in percentage points per year

	1984–85 to 2001–02	*1984–85 to 1993–94*	*1993–94 to 2001–02*
	%	%	%
Electricity and gas supply	0.44	0.34	0.55
Water supply, sewerage and drainage	1.45	0.99	1.95
Construction	0.16	0.08	0.26
Wholesale trade	0.40	0.27	0.55
Food retailing	0.14	-0.02	0.33
Personal and household good retailing	0.45	0.39	0.51
Motor vehicle retailing and services	0.04	-0.04	0.14
Accommodation, cafes and restaurants	0.29	0.24	0.33
Road transport	0.22	0.29	0.14
Air transport	0.22	0.02	0.44
Rail/water and other transport	0.42	0.05	0.83
Storage and transport facilities	0.44	0.71	0.15
Communications	0.64	0.79	0.47
Finance	1.73	0.70	2.87
Insurance	1.10	0.18	2.13
Cultural and recreational services	0.81	0.25	1.42

Source: ABS Cat. No. 6227.0. and unpublished data at the two digit ANZSIC level.

D.3 Increase in the share of persons with post-school qualifications in the workforce

Expressed in terms of average change in percentage points per year

	1984–85 to 2001–02	*1984–85 to 1993–94*	*1993–94 to 2001–02*
	%	%	%
Electricity and gas supply	0.49	0.74	0.23
Water supply, sewerage and drainage	2.05	1.60	2.56
Construction	0.30	0.28	0.32
Wholesale trade	0.56	0.19	0.97
Food retailing	-0.20	-1.07	0.77
Personal and household good retailing	0.43	-0.10	1.03
Motor vehicle retailing and services	1.25	1.88	0.54
Accommodation, cafes and restaurants	0.56	0.18	0.97
Road transport	0.46	-0.17	1.17
Air transport	0.08	-0.56	0.79
Rail/water and other transport	0.65	0.26	1.09
Storage and transport facilities	0.69	0.58	0.81
Communications	0.74	0.56	0.93
Finance	2.19	1.19	3.30
Insurance	0.49	0.10	0.92
Cultural and recreational services	0.54	0.01	1.13

Source: ABS Cat. No. 6227.0 and unpublished data at the two digit ANZSIC level.

D.4 Decrease in the share of union members in the workforce

Expressed in terms of average change in percentage points per year

	1984–85 to 2001–02	*1984–85 to 199–-04*	*1993–94 to 2001-02*
	%	%	%
Electricity and gas supply	1.74	1.04	2.44
Water supply, sewerage and drainage	2.98	3.05	2.92
Construction	1.27	1.33	1.20
Wholesale trade	0.86	0.42	1.30
Food retailing	0.69	1.05	0.33
Personal and household good retailing	0.69	1.05	0.33
Motor vehicle retailing and services	0.69	1.05	0.33
Accommodation, cafes and restaurants	1.25	1.57	0.93
Road transport	1.37	0.84	1.90
Air transport	1.71	1.42	1.99
Rail/water and other transport	1.41	1.38	1.44
Storage and transport facilities	2.01	0.62	3.39
Communications	2.97	1.25	4.68
Finance	2.23	1.52	2.95
Insurance	1.79	1.49	2.09
Cultural and recreational services	1.33	1.12	1.53

Source: ABS Cat. No. 6325.0 before 1995 and Cat. No. 6310.0 after 1995.

Table D.5 Decrease in the share of workforce covered under award pay conditions

Expressed in terms of average change in percentage points per year

	1984–85 to 2001–02	*1984–85 to 1993-94*	*1093–94 to 2001–02*
	%	%	%
Electricity and gas supply	5.13	-0.74	11.73
Water supply, sewerage and drainage	4.51	-1.82	11.62
Construction	2.68	0.20	5.47
Wholesale trade	1.87	1.04	2.81
Food retailing	2.66	-0.05	5.70
Personal and household good retailing	1.62	-0.05	3.49
Motor vehicle retailing and services	1.03	-0.05	2.25
Accommodation, cafes and restaurants	0.68	0.69	0.66
Road transport	2.13	0.87	3.55
Air transport	5.21	0.06	11.01
Rail/water and other transport	3.83	-1.28	9.59
Storage and transport facilities	3.07	1.09	5.31
Communications	5.62	0.04	11.90
Finance	3.05	-1.52	8.19
Insurance	4.92	2.20	7.99
Cultural and recreational services	2.44	-0.14	5.35

Source: ABS Cat. No. 6306.0 and unpublished data at the two digit ANZSIC level.

Table D.6 Decrease in number of working days lost per employee due to industrial disputes in a year

Expressed in terms of annual decrease in the number of days lost

	1984–85 to 2001–02	*1984–85 to 1993–94*	*1993–94 to 2001–02*
	days decrease	days decrease	days decrease
Electricity and gas supply	0.016	0.012	0.021
Water supply, sewerage and drainage	-0.001	-0.026	0.028
Construction	0.014	0.038	-0.012
Wholesale trade	0.001	0.002	-0.001
Food retailing	0.000	-0.001	0.002
Personal and household good retailing	0.000	-0.001	0.002
Motor vehicle retailing and services	0.000	-0.001	0.002
Accommodation, cafes and restaurants	0.001	0.002	0.000
Road transport	0.003	-0.002	0.008
Air transport	-0.001	0.006	-0.008
Rail/water and other transport	0.055	0.089	0.016
Storage and transport facilities	0.028	0.022	0.035
Communications	0.012	0.023	0.000
Finance	0.002	0.004	-0.001
Insurance	0.002	0.004	-0.001
Cultural and recreational services	0.003	0.008	-0.002

Source: ABS Cat. No. 6321.0 and unpublished data at the two digit ANZSIC level.

E Correlations

Table E.1 Correlations based on weighted observations[a]

Single period 1984–85 to 2001–02

	LP growth		*MFP growth*		*Capital deep modified*		*Capital deep per PC*	
LP growth	1.000		0.856	#	0.774	*	0.740	#
MFP growth	0.856	#	1.000		0.644	#	0.516	*
Capital deepn'g modified	0.774	#	0.644	#	1.000		0.222	
Capital deepening per PC	0.740	#	0.516	*	0.222		1.000	
Capital intensity	0.617	#	0.474	*	0.609	#	0.290	
ICT to VA	0.799	#	0.558	*	0.510	*	0.688	#
ICT per hour	0.709	#	0.476	*	0.533	*	0.541	*
OECD prod growth	0.761	#	0.796	#	0.454	*	0.522	*
Union membership	0.644	#	0.400		0.434	*	0.490	*
Award coverage	0.639	#	0.511	*	0.506	*	0.407	
Infrastructure industry	0.615	#	0.620	#	0.661	#	0.135	
Industrial disputes	0.207		0.315		0.398		-0.117	
University trained	0.471	*	0.059		0.389		0.512	*
Post-school trained	0.212		0.132		0.443	*	-0.070	
Change in university grads	0.453	*	0.054		0.237		0.646	#
Change in post-school	0.466	*	0.151		0.270		0.602	#

	Capital intensity		*ICT to value-added*		*ICT per hour*	
LP growth	0.617	#	0.799	#	0.709	#
MFP growth	0.474	*	0.558	*	0.476	*
Capital deepen'g modified	0.609	#	0.510	*	0.533	*
Capital deepening per PC	0.290		0.688	#	0.541	*
Capital intensity	1.000		0.642	#	0.896	#
ICT to VA	0.642	#	1.000		0.848	#
ICT per hour	0.896	#	0.848	#	1.000	
OECD prod growth	0.414		0.646	#	0.499	*
Union membership	0.558	*	0.792	#	0.699	#
Award coverage	0.710	#	0.808	#	0.845	#
Infrastructure industry	0.750	#	0.610	#	0.599	*
Industrial disputes	0.256		0.192		0.112	
University trained	0.375		0.646	#	0.617	#
Post-school trained	0.514	*	0.145		0.428	*
Change in university grads	0.196		0.595	*	0.489	*
Change in post-school	0.113		0.402		0.280	

a The weights are given in table E.3. # significant at the 1% probability level. * significant at the 5% probability level.

Table E.1 cont. Correlations based on weighted observations[a]

Single period 1984–85 to 2001–02

	OECD prod growth		*Union membership*		*Award coverage*		*Infrastructure sector*	
LP growth	0.761	#	0.644	#	0.639	#	0.615	#
MFP growth	0.796	#	0.400		0.511	*	0.620	#
Capital deepen'g modified	0.454	*	0.434	*	0.506	*	0.661	#
Capital deepening per PC	0.522	*	0.490	*	0.407		0.135	
Capital intensity	0.414		0.558	*	0.710	#	0.750	#
ICT to VA	0.646	#	0.792	#	0.808	#	0.610	#
ICT per hour	0.499	*	0.699	#	0.845	#	0.599	*
OECD prod growth	1.000		0.423	*	0.505	*	0.540	*
Union membership	0.423	*	1.000		0.727	#	0.600	*
Award coverage	0.505	*	0.727	#	1.000		0.657	#
Infrastructure industry	0.540	*	0.600	*	0.657	#	1.000	
Industrial disputes	-0.007		0.232		0.298		0.588	*
University trained	0.155		0.618	#	0.434	*	0.136	
Post-school trained	-0.149		0.329		0.490	*	0.391	
Change in university grads	0.139		0.616	#	0.331		-0.022	
Change in post-school	0.162		0.555	*	0.070		0.020	

	Industrial disputes		*University trained*		*Post-school trained*		*Change in post-school*	
LP growth	0.207		0.471	*	0.212		0.466	*
MFP growth	0.315		0.059		0.132		0.151	
Capital deepen'g modified	0.398		0.389		0.443	*	0.270	
Capital deepening per PC	-0.117		0.512	*	-0.070		0.602	#
Capital intensity	0.256		0.375		0.514	*	0.113	
ICT to VA	0.192		0.646	#	0.145		0.402	
ICT per hour	0.112		0.617	#	0.428	*	0.280	
OECD prod growth	-0.007		0.155		-0.149		0.162	
Union membership	0.232		0.618	#	0.329		0.555	*
Award coverage	0.298		0.434	*	0.490	*	0.070	
Infrastructure industry	0.588	*	0.136		0.391		0.020	
Industrial disputes	1.000		-0.216		0.406		-0.145	
University trained	-0.216		1.000		0.146		0.725	#
Post-school trained	0.406		0.146		1.000		0.022	
Change in university grads	-0.226		0.938	#	-0.005		0.836	#
Change in post-school	-0.145		0.725	#	0.022		1.000	

[a] The weights are given in table E.3 # significant at the 1% probability level. * significant at the 5% probability level.

Table E.2 Two-period correlations based on weighted observations[a]

Based on observations for two periods: 1984–85 to 1993–94 and 1993–94 to 2001–02

	LP growth		*MFP growth*		*Capital deep modified*		*Capital deep per PC*	
LP growth	1.000		0.616	#	0.627	#	0.707	#
MFP growth	0.616	#	1.000		0.336	*	0.354	*
Capital deepen'g modified	0.627	#	0.336	*	1.000		0.402	*
Capital deepening per PC	0.707	#	0.354	*	0.402	*	1.000	
Capital intensity	0.492	#	0.246		0.450	#	0.260	
ICT to VA	0.641	#	0.294	*	0.368	*	0.612	#
ICT per hour	0.565	#	0.245		0.388	*	0.481	#
OECD prod growth	0.642	#	0.470	#	0.313	*	0.487	#
Union membership	0.421	*	0.126		0.216		0.319	*
Award coverage	0.143		0.044		-0.164		-0.005	
Infrastructure industry	0.495	#	0.334	*	0.488	#	0.122	
Industrial disputes	0.148		0.107		0.566	#	0.185	
University trained	0.380	*	0.013		0.285	*	0.460	#
Post-school trained	0.160		0.060		0.319	*	-0.073	
Change in university grads	0.269	*	0.024		-0.062		0.358	*
Change in post-school	0.396	*	0.055		0.016		0.398	*

	Capital intensity		*ICT to value-added*		*ICT per hour*	
LP growth	0.492	#	0.641	#	0.565	#
MFP growth	0.246		0.294	*	0.245	
Capital deepen'g modified	0.450	#	0.368	*	0.388	*
Capital deepening per PC	0.260		0.612	#	0.481	#
Capital intensity	1.000		0.642	#	0.896	#
ICT to VA	0.642	#	1.000		0.848	#
ICT per hour	0.896	#	0.848	#	1.000	
OECD prod growth	0.388	*	0.611	#	0.471	#
Union membership	0.390	*	0.554	#	0.489	#
Award coverage	0.277		0.317	*	0.329	*
Infrastructure industry	0.750	#	0.610	#	0.599	#
Industrial disputes	0.182		0.132		0.086	
University trained	0.375	*	0.646	#	0.617	#
Post-school trained	0.514	#	0.145		0.428	#
Change in university grads	0.137		0.429	#	0.353	*
Change in post-school	0.076		0.302	*	0.205	

a The weights are given in table E.3. # significant at the 1% probability level. * significant at the 5% probability level.

Table E.2 cont. Two-period correlations based on weighted observations[a]

Based on observations for two periods: 1984–85 to 1993–94 and 1993–94 to 2001–02

	OECD prod growth		*Union membership*		*Award coverage*		*Infrastructure sector*	
LP growth	0.642	#	0.421	*	0.143		0.495	#
MFP growth	0.470	#	0.126		0.044		0.334	*
Capital deepen'g modified	0.313	*	0.216		-0.164		0.488	#
Capital deepening per PC	0.487	#	0.319	*	-0.005		0.122	
Capital intensity	0.388	*	0.390	*	0.277		0.750	#
ICT to VA	0.611	#	0.554	#	0.317	*	0.610	#
ICT per hour	0.471	*	0.489	#	0.329	*	0.599	#
OECD prod growth	1.000		0.337	*	0.303	*	0.502	#
Union membership	0.337	*	1.000		0.613	#	0.419	*
Award coverage	0.303	*	0.613	#	1.000		0.257	
Infrastructure industry	0.502	#	0.419	*	0.257		1.000	
Industrial disputes	0.074		0.065		-0.180		0.386	*
University trained	0.154		0.431	#	0.173		0.136	
Post-school trained	-0.148		0.230		0.192		0.391	*
Change in university grads	0.226		0.422	#	0.479	#	-0.026	
Change in post-school	0.251		0.453	#	0.406	*	0.007	

	Industrial disputes		*University trained*		*Post-school trained*		*Change in post-school*	
LP growth	0.148		0.380	*	0.160		0.396	*
MFP growth	0.107		0.013		0.060		0.055	
Capital deepn'g modified	0.566	#	0.285	*	0.319	*	0.016	
Capital deepn'g per PC	0.185		0.460	#	-0.073		0.398	*
Capital intensity	0.182		0.375	*	0.514	#	0.076	
ICT to VA	0.132		0.646	#	0.145		0.302	*
ICT per hour	0.086		0.617	#	0.428	#	0.205	
OECD prod growth	0.074		0.154		-0.148		0.251	
Decr union membership	0.065		0.431	#	0.230		0.453	#
Decr award coverage	-0.180		0.173		0.192		0.406	*
Infrastructure industry	0.386	#	0.136		0.391	*	0.007	
Decr industrial disputes	1.000		-0.123		0.249		-0.121	
University trained	-0.123		1.000		0.146		0.551	#
Post-school trained	0.249		0.146		1.000		0.002	
Change in Uni trained	-0.189		0.684	#	-0.003		0.787	#
Change in post-school	-0.121		0.551	#	0.002		1.000	

[a] The weights are given in table E.3. # significant at the 1% probability level. * significant at the 5% probability level.

Table E.3 The weights used in regressions and correlations

Based on average value-added over the period 1984–85 to 2001–02

	$M	*% of total*
Electricity and gas supply	9812	5.0
Water supply, sewerage and drainage	3828	2.0
Construction	31217	16.1
Wholesale trade	27222	14.0
Food retailing	10343	5.3
Personal and household good retailing	12713	6.5
Motor vehicle retailing and services	5583	2.9
Accommodation, cafes and restaurants	11173	5.7
Road transport	8354	4.3
Air transport	3614	1.9
Rail/water and other transport	3037	1.6
Storage and transport facilities	10811	5.6
Communications	11579	6.0
Finance	21929	11.3
Insurance	13269	6.8
Cultural and recreational services	9949	5.1

Source: Table 2.2.

F. Composite factors

Table F.1 Components of the education composite factor

Single period 1984–85 to 2001–02

	Share universi trained	*Share post-school*	*Change universi trained*	*Change post-school*	*Composite factor*
Electricity and gas supply	1.20	1.47	0.78	0.70	1.04
Water supply and sewerage	2.15	1.25	2.59	2.91	2.23
Construction	0.37	1.26	0.29	0.42	0.59
Wholesale trade	0.90	0.94	0.72	0.80	0.84
Food retailing	0.37	0.55	0.26	-0.28	0.22
Household good retailing	0.70	0.71	0.80	0.62	0.71
M/V retailing/service	0.29	0.97	0.07	1.77	0.78
Accommodation and restaurants	0.56	0.76	0.51	0.79	0.65
Road transport	0.34	0.73	0.39	0.66	0.53
Air transport/travel	1.13	1.31	0.39	0.11	0.73
Rail, water and other transport	0.59	0.93	0.74	0.92	0.80
Storage and transport facilities	1.00	1.07	0.80	0.97	0.96
Communications	1.04	0.98	1.14	1.04	1.05
Finance	2.06	0.95	3.09	3.10	2.30
Insurance	1.65	1.04	1.98	0.70	1.34
Cultural and recreational	1.65	1.07	1.44	0.77	1.23

Source: Tables 5.5, 5.6, D.2 and D.3.

Table F.2 Components of the 'other institutional' composite factor

Single period 1984–85 to 2001–02

	Decrease union members	*Decrease award coverage*	*Decrease industrl disputes*	*Infra-structur reform*	*Composite factor*
Electricity and gas supply	1.11	1.63	1.93	2.67	1.83
Water supply and sewerage	1.91	1.43	-0.09	2.67	1.48
Construction	0.81	0.85	1.70	0.00	0.84
Wholesale trade	0.55	0.59	0.08	0.00	0.31
Food retailing	0.44	0.84	0.01	0.00	0.32
Household good retailing	0.44	0.51	0.01	0.00	0.24
M/V retailing/service	0.44	0.33	0.01	0.00	0.19
Accommodation and restaurants	0.80	0.22	0.12	0.00	0.28
Road transport	0.88	0.68	0.37	0.00	0.48
Air transport/travel	1.09	1.65	-0.10	2.67	1.33
Rail, water and other transport	0.90	1.22	6.44	2.67	2.81
Storage and transport facilities	1.29	0.97	3.30	2.67	2.06
Communications	1.90	1.78	1.40	2.67	1.94
Finance	1.43	0.97	0.22	0.00	0.65
Insurance	1.15	1.56	0.22	0.00	0.73
Cultural and recreational	0.85	0.77	0.39	0.00	0.50

Source: Tables 5.10, D.4, D.5 and D.6.

Table F.3 Composite factors used in two-period analysis

Periods from 1984–85 to 1993–94 and from 1993–94 to 2001–02

	Technological	*Education*	*Institutional*
First period			
Electricity and gas supply	2.54	1.45	0.79
Water supply and sewerage	2.01	2.74	-0.16
Construction	0.30	0.66	1.21
Wholesale trade	0.60	0.80	0.61
Food retailing	0.55	-0.54	0.16
Household good retailing	0.51	0.58	0.16
M/V retailing/service	0.43	1.61	0.16
Accommodation and restaurants	0.29	0.64	0.67
Road transport	0.58	0.37	0.54
Air transport/travel	1.06	0.23	1.11
Rail, water and other transport	0.94	0.60	2.34
Storage and transport facilities	1.19	1.47	1.79
Communications	2.18	1.51	1.44
Finance	0.96	2.13	-0.32
Insurance	1.45	0.88	1.42
Cultural and recreational	0.41	0.88	0.34
Second period			
Electricity and gas supply	2.54	0.89	2.40
Water supply and sewerage	2.01	2.03	2.75
Construction	0.18	0.56	-0.19
Wholesale trade	0.70	0.85	0.25
Food retailing	0.64	0.51	0.33
Household good retailing	0.60	0.74	0.25
M/V retailing/service	0.53	0.48	0.20
Accommodation and restaurants	0.31	0.65	0.16
Road transport	0.48	0.58	0.77
Air transport/travel	0.96	0.92	0.96
Rail, water and other transport	0.84	0.88	1.95
Storage and transport facilities	1.09	0.75	2.90
Communications	2.10	0.86	1.74
Finance	1.12	2.38	0.68
Insurance	1.51	1.53	0.55
Cultural and recreational	0.39	1.37	0.30

Source: Tables 5.1, 5.2, 5.3, 5.5, 5.6, 5.10, D.1, D.2, D.3, D.4, D.5 and D.6.

Table F.4 Correlations involving composite factors[a]

Single period 1984–85 to 2001–02

	Technological factor		*Institutional factor*		*Education factor*	
Labour productivity growth	0.822	#	0.570	*	0.516	*
MFP growth	0.653	#	0.555	*	0.113	
Capital deepening based on PC	0.565	*	0.158		0.627	#
Capital deepening modified	0.626	#	0.615	#	0.358	
Technological factor	1.000		0.658	#	0.416	
Institutional factor	0.658	#	1.000		0.119	
Education factor	0.416		0.119		1.000	

[a] Weighted correlations based on mean industry value-added figures from table E.3. # significant at the 1% probability level. * significant at the 5% probability level.

Source: Tables 5.12, F.1 and F.2.

Table F.5 Two-period correlations involving composite factors[a]

First period from 1984–85 to 1993–94, second from 1993–94 to 2001–02

	Technological factor		*Institutional factor*		*Education factor*	
Labour productivity growth	0.671	#	0.228		0.428	#
MFP growth	0.361	*	0.150		0.063	
Capital deepening per PC	0.516	#	0.111		0.489	#
Capital deepening modified	0.461	#	0.475	#	0.221	
Technological factor	1.000		0.520	#	0.439	#
Institutional factor	0.520	#	1.000		-0.017	
Education factor	0.439	#	-0.017		1.000	
Second period dummy	0.010		-0.012		0.022	

[a] Weighted correlations based on mean industry value-added figures from table E.3. # significant at the 1% probability level. * significant at the 5% probability level.

Source: As cited in table F.3.

G. Regression results

All the regressions presented in this appendix are weighted by sector size, based on the mean value-added figures in table E.3.

G.1 Multifactor productivity growth regressions

Table G.1 Regression of MFP growth[a]

R^2 = 0.693 adj R^2= 0.616 Constant suppressed R^2 = 0.601	*OLS regression*		*No constant regression*	
	Makeup of mean[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
OECD LP growth	180.6	53.1	93.5	36.1
Change in share of post-school qlfd	10.2	0.7	-16.8	-1.5
Infrastructure reform	26.9	15.5	23.3	17.7
Unexplained/intercept	-117.6	30.7		47.7
Total	100.0	100.0	100.0	100.0
Due to technological factors	83.0	76.6	93.5	69.1
Due to economic factors	17.0	23.4	6.5	30.9

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.989.

Table G.2 Regression of MFP growth [a]

R^2 = 0.429 adj R^2= 0.286 Constant suppressed R^2 = 0.363	*OLS regression*		*No constant regression*	
	Makeup of mean[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
ICT investment to value-added	294.6	43.2	179.6	32.6
Change in share of university grads	-91.9	-2.2	-80.7	-2.4
Decrease in industrial disputes	9.2	1.9	1.0	0.3
Unexplained/intercept	-111.9	57.1		69.6
Total	100.0	100.0	100.0	100.0
Due to technological factors	139.0	100.7	179.6	107.2
Due to economic factors	-39.0	-0.7	-79.6	-7.2

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.931.

Table G.3 Regression of MFP growth[a]

R^2 = 0.340 adj R^2= 0.175 Constant suppressed R^2 = 0.340	OLS regression		No constant regression	
	Makeup of mean[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
ICT investment per hour	96.8	23.7	92.4	22.4
Share of university graduates	-115.4	-2.1	-112.1	-2.0
Decrease in award coverage	106.2	12.5	119.7	13.9
Unexplained/intercept	12.5	66.0		65.8
Total	100.0	100.0	100.0	100.0
Due to technological factors	110.6	69.6	92.4	65.4
Due to economic factors	-10.6	30.4	7.6	34.6

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.745.

Table G.4 Regression of MFP growth[a]

R^2 = 0.693 adj R^2= 0.581 Constant suppressed R^2 = 0.606	OLS regression		No constant regression	
	Makeup of mean[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
Capital intensity	4.4	1.2	-14.8	-5.3
OECD LP growth	180.7	53.1	97.8	37.2
Change in share of post-school qualified	9.6	0.7	-13.4	-1.2
Infrastructure reform	24.8	14.3	30.4	22.7
Unexplained/intercept	-119.6	30.7		46.6
Total	100.0	100.0	100.0	100.0
Due to technological factors	84.3	78.4	83.0	59.8
Due to economic factors	15.7	21.6	17.0	40.2

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.972.

Table G.5 Regression of MFP growth[a]

R^2 = 0.406 adj R^2= 0.258 Constant suppressed R^2 = 0.406	OLS regression		No constant regression	
	Makeup of mean[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
ICT investment per hour	25.0	6.1	23.0	5.7
Change in share of post-school qualified	24.3	1.7	21.4	1.5
Infrastructure reform	57.0	32.9	55.6	32.8
Unexplained/intercept	-6.2	59.4	0.0	60.0
Total	100.0	100.0	100.0	100.0
Due to technological factors	23.5	15.0	23.0	14.3
Due to economic factors	76.5	85.0	77.0	85.7

a Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.769.

Table G.6 Regression of MFP growth[a]

R^2 = 0.430 adj R^2= 0.287 Constant suppressed R^2 = 0.415	OLS regression		No constant regression	
	Makeup of mean[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
ICT investment to value-added	99.1	14.5	45.8	7.4
Change in share of post-school qualified	8.5	0.6	5.8	0.4
Infrastructure reform	48.3	27.9	48.4	30.9
Unexplained/intercept	-55.9	57.0		61.2
Total	100.0	100.0	100.0	100.0
Due to technological factors	63.6	33.8	45.8	19.2
Due to economic factors	36.4	66.2	54.2	80.8

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.834.

Table G.7 Regression of MFP growth[a]

R^2 = 0.692 adj R^2= 0.580	OLS regression		No constant regression	
Constant suppressed R^2 = 0.670	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
Change in share of university graduates	-1.5	0.0	20.8	0.6
OECD LP growth	184.9	54.3	153.9	49.4
Decrease in union membership	-17.8	-1.6	-115.7	-11.1
Infrastructure reform	28.5	16.4	41.1	25.9
Unexplained/intercept	-94.2	30.8		35.3
Total	100.0	100.0	100.0	100.0
Due to technological factors	95.2	78.5	153.9	76.4
Due to economic factors	4.8	21.5	-53.9	23.6

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.822.

Table G.8 Regression of MFP growth[a]

R^2 = 0.318 adj R^2= 0.148	OLS regression		No constant regression	
Constant suppressed R^2 = 0.309	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
Change in share of university graduates	-81.5	-2.0	-73.5	-1.9
ICT investment per hour	85.4	20.9	87.3	22.9
Decrease in union membership	147.2	13.0	86.2	8.1
Unexplained/intercept	-51.1	68.2		70.9
Total	100.0	100.0	100.0	100.0
Due to technological factors	56.5	65.5	87.3	78.6
Due to economic factors	43.5	34.5	12.7	21.4

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.807.

Table G.9 Regression of MFP growth[a]

R^2 = 0. 0.428 adj R^2= 0.285 Constant suppressed R^2 = 0.372	OLS regression		No constant regression	
	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
Change in share of university grads	-103.9	-2.5	-78.7	-2.3
ICT investment to value-added	287.3	42.1	232.0	40.4
Decrease in union membership	36.0	3.2	-53.4	-5.6
Unexplained/intercept	-119.5	57.2		67.5
Total	100.0	100.0	100.0	100.0
Due to technological factors	130.9	98.5	232.0	124.2
Due to economic factors	-30.9	1.5	-132.0	-24.2

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.894.

Table G.10 Regression of MFP growth[a]

R^2 = 0.244 adj R^2= 0.055 Constant suppressed R^2 = 0.239	OLS regression		No constant regression	
	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
ICT investment per hour	76.2	18.6	78.9	20.4
Change in share of post-school qlfd	-9.9	-0.7	-6.7	-0.5
Decrease in union membership	73.6	6.5	27.8	2.6
Unexplained/intercept	-39.9	75.6		77.5
Total	100.0	100.0	100.0	100.0
Due to technological factors	54.5	76.2	78.9	90.6
Due to economic factors	45.5	23.8	21.1	9.4

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.795.

Table G.11 Regression of MFP growth[a]

R^2 = 0.668 adj R^2= 0.585 Constant suppressed R^2 = 0. 578	OLS regression		No constant regression	
	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
Change in share of university graduates	-37.4	-0.9	-22.9	-0.7
OECD LP growth	204.6	60.1	154.1	56.0
Decrease in union membership	86.3	7.6	-31.2	-3.4
Unexplained/intercept	-153.5	33.2		48.1
Total	100.0	100.0	100.0	100.0
Due to technological factors	80.7	90.0	154.1	107.9
Due to economic factors	19.3	10.0	-54.1	-7.9

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.931.

Table G.12 Regression of MFP growth[a]

R^2 = 0. 663 adj R^2= 0. 579 Constant suppressed R^2 = 0. 559	OLS regression		No constant regression	
	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
OECD LP growth	199.6	58.6	154.5	56.8
Change in share of post-school	7.0	0.5	-16.1	-1.4
Decrease in award coverage	61.2	7.2	-38.5	-5.6
Unexplained/intercept	-167.7	33.7		50.3
Total	100.0	100.0	100.0	100.0
Due to technological factors	74.5	88.4	154.5	114.1
Due to economic factors	25.5	11.6	-54.5	-14.1

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.940.

Table G.13 Regression of MFP growth[a]

R^2 = 0. 430 adj R^2= 0. 223	*OLS regression*		*No constant regression*	
Constant suppressed R^2 = 0. 421	*Makeup of mean*[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
ICT investment to value-added	102.4	15.0	100.6	15.7
Change in share of post-school qlfd	7.8	0.5	-0.4	0.0
Decrease in award coverage	-4.8	-0.6	-50.9	-6.4
Infrastructure reform	48.5	28.0	50.6	31.1
Unexplained/intercept	-54.0	57.0		59.5
Total	100.0	100.0	100.0	100.0
Due to technological factors	66.5	34.9	100.6	38.9
Due to economic factors	33.5	65.1	-0.6	61.1

[a] Mean of dependent variable in OLS is 0.752.; in no-constant regression it is 0.

Table G.14 Regression of MFP growth[a]

R^2 = 0.429 adj R^2= 0.286	*OLS regression*		*No constant regression*	
Constant suppressed R^2 = 0.363	*Makeup of mean*[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
ICT investment to value-added	294.5	43.2	179.6	32.6
Change in share of university grads	-91.9	-2.2	-80.7	-2.4
Decrease in industrial disputes	9.2	1.9	1.0	0.3
Unexplained/intercept	-111.9	57.1		69.6
Total	100.0	100.0	100.0	100.0
Due to technological factors	139.0	100.7	179.6	107.2
Due to economic factors	-39.0	-0.7	-79.6	-7.2

[a] Mean of dependent variable in OLS is 0.752; in no-constant regression it is 0.931.

Table G.15 Regression of MFP growth[a]

R^2 = 0.340 adj R^2= 0.175 Constant suppressed R^2 = 0.340	OLS regression		No constant regression	
	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
ICT investment per working hour	96.8	23.6	92.4	22.4
Share of university graduates	-115.3	-2.1	-112.1	-2.0
Decrease in award coverage	106.1	12.5	119.7	13.9
Unexplained/intercept	12.4	66.0		65.8
Total	100.0	100.0	100.0	100.0
Due to technological factors	110.5	69.5	92.4	65.4
Due to economic factors	-10.5	30.5	7.6	34.6

[a] Mean of dependent variable in OLS is 0.752; in no-constant regression it is 0.745.

Table G.16 Two-period regression of MFP growth[a]

R^2 = 0.173 adj R^2= 0.050 Constant suppressed R^2 = 0.167	OLS regression		No constant regression	
	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
Technological factors	217.5	17.2	191.9	16.9
Institutional factors	-30.3	-1.5	-34.5	-1.9
Education factors	-80.2	-1.0	-94.7	-1.3
Dummy for second period	52.0	2.5	37.3	2.0
Unexplained/intercept	-59.1	82.7		84.3
Total	100.0	100.0	100.0	100.0
Due to technological factors	203.2	116.5	306.0	122.8
Due to economic factors	-103.2	-16.5	-206.0	-22.8

[a] Mean of dependent variable in OLS is 0.801; in no-constant regression it is 0.889.

Table G.17 Four-period regression of MFP growth[a]

R^2 = 0.134 adj R^2= 0.043 Constant suppressed R^2 = 0.129	OLS regression		No constant regression	
	Makeup of mean[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
Technological factors	189.0	8.1	165.9	7.9
Institutional factors	-17.5	-0.5	-22.3	-0.7
Education factors	-75.9	-0.4	-90.1	-0.5
Dummy for second period	18.0	-0.1	6.2	-0.1
Dummy for third period	66.2	6.3	49.9	5.3
Dummy for fourth period	0.2	0.0	-9.6	0.4
Unexplained/intercept	-79.9	86.6		87.7
Total	100.0	100.0	100.0	100.0
Due to technological factors	197.7	112.3	310.3	118.3
Due to economic factors	-97.7	-12.3	-210.3	-18.3

[a] Mean of dependent variable in OLS is 0.844; in no-constant regression it is 0.936.

G.2 Regressions of labour productivity growth

Table G.18 Regression of LP growth[a]

Using Productivity Commission estimates of capital deepening

R^2 = 0.874 adj R^2= 0.811 Constant suppressed R^2 =0.818	OLS regression		No constant regression	
	Makeup of mean[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	58.3	29.0	45.5	25.2
Capital intensity	14.1	10.3	5.7	4.7
OECD LP growth	44.0	24.8	23.7	15.0
Change in share post-school qlfd	17.9	7.7	9.2	4.4
Infrastructure reform	13.1	15.4	15.9	20.8
Unexplained/intercept	-47.4	12.6		29.9
Total	100.0	100.0	100.0	100.0
Due to technological factors	65.2	60.2	54.1	43.8
Due to economic factors	34.8	39.8	45.9	56.2

[a] Mean of dependent variable in OLS is 2.217; in no-constant regression it is 2.470.

Table G.19 Regression of LP growth[a]

Using modified estimates of capital deepening

R^2 = 0.806 adj R^2= 0.736	*OLS regression*		*No constant regression*	
Constant suppressed R^2 = 0.800	*Makeup of mean[a]*	*Variance explained by*	*Makeup of mean[a]*	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	26.5	31.8	28.0	34.6
Technological factors	72.2	44.1	69.2	43.5
Institutional factors	-7.0	-3.1	-13.0	-6.0
Education factors	26.4	7.8	15.8	4.8
Unexplained/intercept	-18.1	19.4		23.0
Total	100.0	100.0	100.0	100.0
Due to technological factors	78.8	90.4	96.1	102.7
Due to economic factors	21.2	9.6	3.9	-2.7

[a] Mean of dependent variable in OLS is 2.217.; in no-constant regression it is 2.283.

Table G.20 Regression of LP growth[a]

Using Productivity Commission estimates of capital deepening

R^2 = 0.723 adj R^2= 0.623	*OLS regression*		*No constant regression*	
Constant suppressed R^2 = 0.663	*Makeup of mean[a]*	*Variance explained by*	*Makeup of mean[a]*	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	59.2	29.5	46.8	25.5
Share of university graduates	-23.2	-6.8	91.7	33.8
ICT investment to value-added	93.0	40.2	-26.3	-8.4
Decrease in union membership	32.2	9.4	-12.1	-3.9
Unexplained/intercept	-61.3	27.7	0.0	53.0
Total	100.0	100.0	100.0	100.0
Due to technological factors	91.1	93.9	172.3	156.8
Due to economic factors	8.9	6.1	-72.3	-56.8

[a] Mean of dependent variable in OLS is 2.217; in no-constant regression it is 2.427.

Table G.21 Regression of LP growth[a]

Using modified estimates of capital deepening

R^2 = 0.887 adj R^2= 0.854 Constant suppressed R^2 = 0.858	OLS regression		No constant regression	
	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
Capital deepening	23.8	28.6	24.8	32.3
Capital intensity	14.0	10.2	8.8	7.0
OECD LP growth	64.6	36.6	46.9	28.8
Change in share of post-school qualified	30.6	13.2	19.5	9.1
Unexplained/intercept	-33.0	11.3		22.8
Total	100.0	100.0	100.0	100.0
Due to technological factors	71.9	78.0	74.1	79.8
Due to economic factors	28.1	22.0	25.9	20.2

[a] Mean of dependent variable in OLS is 2.217; in no-constant regression it is 2.403.

Table G.22 Regression of LP growth[a]

Using modified estimates of capital deepening

R^2 = 0.885 adj R^2= 0.828 Constant suppressed R^2 = 0.863	OLS regression		No constant regression	
	Makeup of mean[a]	Variance explained by	Makeup of mean[a]	Variance explained by
Independent variables	%	%	%	%
Capital deepening	29.8	35.8	25.2	31.6
Change in share of university graduates	20.5	8.3	34.2	14.5
OECD LP growth	65.0	36.9	54.9	32.6
Decrease in union membership	36.1	10.5	-22.0	-6.7
Infrastructure reform	-2.5	-3.0	7.7	9.5
Unexplained/intercept	-48.8	11.5		18.4
Total	100.0	100.0	100.0	100.0
Due to technological factors	54.6	69.9	73.4	65.3
Due to economic factors	45.4	30.1	26.6	34.7

[a] Mean of dependent variable in OLS is 2.217; in no-constant regression it is 2.318.

Table G.23 Regression of LP growth[a]

Using modified estimates of capital deepening

R^2 = 0.885 adj R^2= 0.843	*OLS regression*		*No constant regression*	
Constant suppressed R^2 = 0.855	*Makeup of mean[a]*	*Variance explained by*	*Makeup of mean[a]*	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	28.5	34.2	29.5	23.9
Change in share of university grads	23.7	9.6	24.5	12.1
OECD LP growth	64.2	36.4	54.7	30.3
Decrease in union membership	28.2	8.2	-8.7	-2.1
Unexplained/intercept	-44.6	11.5		35.8
Total	100.0	100.0	100.0	100.0
Due to technological factors	55.3	67.1	77.6	75.2
Due to economic factors	44.7	32.9	22.4	24.8

[a] Mean of dependent variable in OLS is 2.217; in no-constant regression it is 2.363.

Table G.24 Two-period regression of LP growth[a]

Using Productivity Commission estimates of capital deepening

R^2 = 0.689 adj R^2= 0. 629	*OLS regression*		*No constant regression*	
Constant suppressed R^2 = 0.627	*Makeup of mean[a]*	*Variance explained by*	*Makeup of mean[a]*	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	81.3	36.0	61.6	30.7
Technological factors	71.6	30.1	64.2	30.3
Institutional factors	-6.5	-1.4	-14.5	-3.4
Education factors	-4.6	-1.1	-25.1	-6.5
Dummy for second period	27.9	5.2	13.8	2.9
Unexplained/intercept	-69.8	31.1		46.1
Total	100.0	100.0	100.0	100.0
Due to technological factors	118.2	108.7	261.8	148.9
Due to economic factors	-18.2	-8.7	-161.8	-48.9

[a] Mean of dependent variable in OLS is 2.262; in no-constant regression it is 2.537.

Table G.25 Two-period regression of LP growth[a]

Using modified estimates of capital deepening

R^2 = 0.770 adj R^2= 0.726	*OLS regression*		*No constant regression*	
Constant suppressed R^2 = 0.756	*Makeup of mean[a]*	*Variance explained by*	*Makeup of mean[a]*	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	33.8	38.8	32.3	39.5
Technological factors	86.8	36.5	79.0	35.3
Institutional factors	-37.4	-7.9	-39.8	-8.9
Education factors	6.7	1.6	-7.1	-1.7
Dummy for second period	43.4	8.0	35.5	7.0
Unexplained/intercept	-33.3	22.9		28.9
Total	100.0	100.0	100.0	100.0
Due to technological factors	154.6	121.0	246.0	143.3
Due to economic factors	-54.6	-21.0	-146.0	-43.3

[a] Mean of dependent variable in OLS is 2.262.; in no-constant regression it is 2.401.

Table G.26 Four-period regression of LP growth[a]

Using Productivity Commission estimates of capital deepening

R^2 = 0.737 adj R^2= 0.704	*OLS regression*		*No constant regression*	
Constant suppressed R^2 = 0.698	*Makeup of mean[a]*	*Variance explained by*	*Makeup of mean[a]*	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	113.5	53.5	99.5	52.3
Technological factors	56.2	12.3	46.3	11.3
Institutional factors	-3.4	-0.4	-10.1	-1.4
Education factors	-18.1	-2.1	-38.5	-4.9
Dummy for second period	4.9	0.1	-6.2	-0.2
Dummy for third period	31.0	10.6	17.4	6.7
Dummy for fourth period	2.1	-0.3	-8.5	1.5
Unexplained/Intercept	-86.2	26.3		34.7
Total	100.0	100.0	100.0	100.0
Due to technological factors	161.9	125.5	[b]	226.7
Due to economic factors	-61.9	-25.5	[b]	-126.7

[a] Mean of dependent variable in OLS is 2.335; in no-constant regression it is 2.605. [b] Meaningless, given that the contribution of factors adds up to a negative number.

Table G.27 Four-period regression of LP growth[a]

Using modified estimates of capital deepening

R^2 = 0.643 adj R^2= 0.598 Constant suppressed R^2 = 0.629	*OLS regression*		*No constant regression*	
	Makeup of mean[a]	*Variance explained by*	*Makeup of mean*[a]	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	35.1	37.7	33.4	38.3
Technological factors	82.9	18.2	74.2	17.4
Institutional factors	-29.4	-3.7	-32.1	-4.3
Education factors	6.2	0.7	-8.8	-1.1
Dummy for second period	7.2	0.2	0.0	0.0
Dummy for third period	37.9	13.0	29.1	10.6
Dummy for fourth period	11.3	-1.8	4.3	-0.7
Unexplained/Intercept	-51.3	35.7		39.8
Total	100.0	100.0	100.0	100.0
Due to technological factors	138.8	119.3	222.6	144.4
Due to economic factors	-38.8	-19.3	-122.6	-44.4

[a] Mean of dependent variable in OLS is 2.335.; in no-constant regression it is 2.496.

H. Revised manufacturing estimates

The previous report on productivity growth in manufacturing indicated that information would be upgraded on the manufacturing regressions, provided more suitable proxy variables could be found for changes in the competitive environment of individual industries (NOIE 2004, section 5.6.4). In the meantime, data for two such variables has been found. One is time-series sectoral data on union membership, the other is on the award coverage of pay conditions.

This also gives an opportunity to upgrade the estimates concerning the relative importance of technological and institutional factors in driving manufacturing productivity growth. Like in services, the new estimates are based on growth accounting combined with the decomposition of MFP growth.

H.1 The new data

Sections 5.5.1 and 5.5.2 in the text present data for union membership and award coverage in service industries. The same data sources were used to obtain corresponding estimates for manufacturing industries.

Table H.1 Share of union members in the manufacturing workforce—1986 to 2002

	1986	*2002*	*Annual decrease 1986 to 2002*
	%	%	%
Food, beverage and tobacco	58.0	30.9	1.69
Textiles and leather	55.8	24.1	1.98
Clothing and footwear	56.5	20.7	2.24
Wood and paper products	35.1	26.0	0.57
Printing, publishing and recorded media	47.3	21.5	1.61
Simple chemicals	48.0	25.1	1.43
Complex chemicals	48.0	25.1	1.43
Pharmaceuticals	48.0	25.1	1.43
Non-metallic mineral product manufacturing	53.8	38.6	0.95
Iron and steel manufacturing	63.4	36.1	1.71
Non-ferrous metals	63.4	36.1	1.71
Simple metal fabrications	43.3	25.1	1.14
Motor vehicle and part manufacturing	72.3	40.2	2.00
Other transport equipment manufacturing	72.3	40.2	2.00
Medical and scientific equipment	39.3	21.7	1.10
Electronic equipment	39.3	21.7	1.10
Electrical equipment and appliances	39.3	21.7	1.10
Production machinery and equipment	39.3	21.7	1.10
Other manufacturing	36.8	14.7	1.38

Source: ABS Cat. No. 6325.0 before 1995 and Cat. No. 6310.0 after 1995.

Table H.1 presents data on the share of union members in the manufacturing workforce between 1986 and 2002. Unfortunately, the data available for manufacturing is at a higher level of aggregation than the 19 industries employed in the statistical analysis in NOIE (2004). The ABS supplied union membership summaries at the two-digit Australian Standard Industrial Classification (ASIC) and ANZSIC level. The two-digit ASIC data cover the period from 1986 to 1992. Under this classification, information is available for 12 manufacturing industries. The two-digit ANZSIC data cover the period from 1992 to 2002. Under this classification scheme data are available only for nine broad manufacturing industries.

Table H.2 Proportion of the manufacturing workforce covered under award pay condition—1985 to 2002

	1985	*2002*	*Annual decrease 1985 to 2002*
	%	%	%
Food, beverage and tobacco	79.3	20.0	3.49
Textiles and leather	80.6	44.4	2.13
Clothing and footwear	86.3	48.8	2.20
Wood and paper products	74.3	38.9	2.08
Printing, publishing and recorded media	69.7	36.5	1.95
Simple chemicals	60.2	33.0	1.60
Complex chemicals	60.2	33.0	1.60
Pharmaceuticals	60.2	33.0	1.60
Non-metallic mineral products	76.4	19.9	3.32
Iron and steel manufacturing	82.3	24.8	3.39
Non-ferrous metals	82.3	24.8	3.39
Simple metal fabrications	79.7	24.9	3.22
Motor vehicle and part manufacturing	92.6	26.5	3.89
Other transport equipment manufacturing	92.6	26.5	3.89
Medical and scientific equipment	74.3	22.4	3.05
Electronic equipment	74.3	22.4	3.05
Electrical equipment and appliances	74.3	22.4	3.05
Production machinery and equipment	74.3	22.4	3.05
Other manufacturing	78.5	37.2	2.43

Source: ABS Cat. No. 6306.0 and unpublished data at the two digit ANZSIC level.

The industries that are separately identified under ASIC but not under ANZSIC are:

- textiles and leather separately from clothing and footwear
- basic metals separately from simple metal fabrications
- transport equipment separately from other machinery and equipment

Data at the two-digit ANZSIC level was used between 1992 and 2002 to extrapolate for ASIC industries that are grouped together under ANZSIC. For the other seven industries that have no separate union membership data, the figures adopted are the percentage shares of the broader industry group to which they belong. This is the reason for the repeated numbers in table H.1.

Table H.2 shows the proportion of the manufacturing workforce covered under award pay conditions. The same two-digit ASIC/ANZSIC aggregation problem that was encountered with union membership in manufacturing industries also applies to award coverage. The methodology described above was used to overcome the problem.

H.2 New correlation results

The addition of two new explanatory variables led to new correlation results. Table H.3 presents correlations weighted by industry size (that is, employment in the year 2000). The third and fourth columns in Table H.3 show correlations involving the two new explanatory variables. For comparative purposes, the first and second columns replicate correlations involving productivity growth rates.

Table H.3 Selected weighted correlations in manufacturing over the period 1984–85 to 2000–01

	Labour productivity		*MFP growth*		*Decr. union membership*		*Decr. award coverage*	
LP growth	1.000		0.883	#	0.242		0.324	
MFP growth	0.883	#	1.000		0.053		0.503	*
Change in value-added	0.798	#	0.794	#	-0.063		0.253	
Capital deepening	0.412	*	-0.050		0.417	*	-0.325	
R&D intensity	0.818	#	0.818	#	-0.124		0.226	
OECD LP growth	0.623	#	0.610	#	-0.087		-0.026	
Capital intensity	0.263		0.220		0.041		0.255	
I-O coefficients; ICT inputs	0.692	#	0.710	#	-0.193		0.077	
I-O coefficients; ICT+eng'g inputs	0.716	#	0.694	#	-0.173		0.049	
Tariff reduction	0.150		-0.005		0.529	*	0.006	
Decrease in industrial disputes	0.002		0.164		0.200		0.295	
Share of university trained	0.444	*	0.281		-0.001		-0.401	
Share with post-school qualification	0.209		0.091		-0.282		0.073	
Change in share of uni trained	0.438	*	0.249		-0.005		-0.399	
Change in share of post-school qualf	0.594	*	0.496	*	0.286		0.080	
Decrease in union membership	0.242		0.053		1.000		0.177	
Decrease in award coverage	0.324		0.503	*	0.177		1.000	

# indicates statistical significance at the 1 per cent probability level; * at the 5 per cent level.

Source: Tables H.1 and H.2 in this report; table 5.1 in NOIE (2004).

The two new variables are positively correlated with productivity growth rates, but only one correlation (between decrease in award coverage and MFP growth) is statistically significant at the five per cent probability level with 19 observations. The education variables tend to show stronger correlation with productivity growth than the two new industrial relation variables. Hence, judging by correlations alone, one would expect that the new industrial relation variables will have a smaller effect on productivity growth than education variables. But, surprisingly, a number of regression results do not conform to this expectation. These regressions are discussed in the next section.

H.3 Indications from the regressions

Tables H.5 to H.17 in section H.5 present regression results incorporating the two new industrial relation variables. The regressions reported here are based on those presented in NOIE (2004). Only weighted regressions are examined in this appendix. In single-period weighted regressions from NOIE (2004) the variable called ‘decrease in tariff

protection' is replaced either by 'decrease in union membership' or 'decrease in award coverage' (see tables H.5 to H.13). Tariff protection was not an influential variable in the regressions in NOIE (2004). Its replacement was done in order to conserve the number of degrees of freedom of regressions. In three-period regressions from NOIE (2004) the two new industrial relations variables are added to the set of regressors without replacing any explanatory variable (see tables H.14 to H.17). Given that these multi-period regressions are based on 57 observations, reducing the number of degrees of freedom by two is not a major concern.

The inclusion of the new industrial relation variables led to some unexpected results compared with those reported in NOIE (2004). In some OLS runs the regression constant (zero intercept) turned out to be markedly negative (often over minus 100 per cent of the mean value of the aggregate productivity growth rate). In these instances, the makeup of aggregate productivity growth shows a larger contribution from institutional factors than from technological factors (see the first column in tables H.5, H.6, H.8, H.11, H.13, H.14 and H.16). On the other hand, the variance explained in conventional OLS regressions (the second column in the tables) continues to indicate that technological factors contributed much more to productivity growth than institutional factors. Hence large negative regression constants are associated with marked disparities between contribution estimates based on the makeup of the mean and those based on variance explained.[60]

No similar large divergence between contribution estimates was evident in the regressions used in NOIE (2004). The reason why the introduction of the new industrial relation variables led occasionally to these unexpected results is not entirely clear. In algebraic terms the effect has been to shift the regression constant in the negative direction, with the new industrial relation variable(s) explaining a large portion of the widening gap between the negative constant and the mean productivity growth rate. Given that these variables are usually not statistically significant and account for little of the variance explained, these are puzzling results.

These unexpected findings alerted us to the fact that the OLS-based decomposition approach is not as robust as originally expected, and can lead to markedly inconsistent estimates of relative contributions. In NOIE (2004) no regressions are presented where the constant term is suppressed, because these regressions do not yield minimum variance and are not as mathematically rigorous as OLS regressions (see the discussion in section 6.2.3). Yet the inconsistent results obtained from OLS regressions with large negative constants convinced us to examine also regressions where the intercept term is suppressed. The results from these regressions are presented in the third and fourth columns in the regression tables.

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[60] It is possible that these outcomes were partly caused by repeated numbers in several observations of these variables (see table H.1 and H.2).

All the results from the no-constant term regressions indicate that technological factors made a much larger contribution to productivity growth than institutional factors. The makeup of the mean estimates from these regressions is generally in line with the contribution of individual variables to explaining variance.

Given that the majority of results continue to point to a much greater importance of technological factors in driving both LP and MFP growth, the discordant results from OLS regressions with large negative constants can be considered as mere aberrations.

H.4 New decomposition estimates

It is possible to apply the decomposition method described in section 6.3.1 not only to services but also to manufacturing. Based on data in NOIE (2004), in manufacturing the basic LP growth identity appears as follows:

- annual LP growth 2.16%
- due to capital deepening 1.03%
- due to MFP growth 1.13%

In addition, the ICT price fall effect could be used. This was estimated in section 4.3.3 at 0.36 per cent per annum for the entire market sector. Since the IT intensity of manufacturing (that is, IT investment over value-added) is only 78 per cent of the average of the market sector, the appropriate figure to use for this sector is 0.28 (= 0.36 * 0.78) per cent.

A large number of MFP regressions were run for manufacturing. These are shown in tables 6.2, J.8, J.9, J.10, J.11, J.12, J.13 in NOIE (2004) and in tables H.7, H.8, H.12, H.13, H.16, H.17 in this appendix. The MFP regression results in manufacturing show an even stronger dominance of technological factors over institutional factors in driving productivity growth than in services.[61]

In light of these regression results, as a conservative estimate it appears that overall 60 per cent of manufacturing MFP growth was driven by technological factors and 40 per cent by institutional-economic factors. Taking a confidence interval, like in services, of plus and minus 15 per cent yields an upper estimate of the contribution of technology driven MFP growth at 0.85 (= 0.75*1.13) per cent and a lower estimate of 0.51 (= 0.45*1.13) per cent.

Combining these figures in the manner described in section 6.3.1 yields the following decomposition estimates for manufacturing LP growth.

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61 Notice also that the R^2 ratios in the manufacturing MFP regressions tend to be higher than in services.

Table H.4 The drivers of manufacturing labour productivity growth
1984–85 to 2000–01

LP growth attributed to:	*Lower estimate*		*Upper estimate*	
	Annual contribution	*Share*	*Annual contribution*	*Share*
	%	%	%	%
Increased capital spending per worker	0.75	34	0.75	35
Falling ICT prices	0.28	13	0.28	13
MFP growth due to technical changes	0.51	24	0.85	39
MFP growth due to institutional change	0.62	29	0.28	13
Annual LP growth	2.16	100	2.16	100
Due to technological factors[a]	0.79	56	1.13	80
Due to institutional-economic factors[a]	0.62	44	0.28	20

[a] After discounting the effect of increased capital spending per worker.

The two bottom lines indicate that technological progress accounted for between 56 and 80 per cent of non-capital spending related productivity growth in manufacturing. Institutional-economic factors accounted for between 20 and 44 per cent. These are fairly similar to the estimates for services (table 6.3).

MFP growth in manufacturing is more important than in services (see table 6.3). This has two consequences:

- The 'disembodied' technological component in manufacturing is much larger than 'embodied' technical change resulting from falling ICT prices.[62]
- There is a wider dispersion of the relative contribution estimates in manufacturing than in services.

62 But arguably, the 'embodied' technical change component in manufacturing is underestimated, since much ICT investment through numerical controllers incorporated into machines will not be recorded as ICT investment but rather as investment in machinery.

H.5 Regression results

Table H.5 Regression of LP growth—single period[a]

R^2 = 0.852 adj R^2= 0.795 Constant suppressed R^2 = 0.820	OLS regression		No constant regression	
	Makeup of mean[b]	Variance explained by	Makeup of mean[b]	Variance explained by
Independent variables	%	%	%	%
Capital deepening	11.1	6.7	16.6	10.8
Decrease in union membership	81.3	6.3	25.9	2.2
R&D intensity	55.9	65.3	52.7	66.6
Capital intensity	20.4	5.4	17.2	4.9
Share of university graduates	5.9	1.5	-12.4	-3.4
Unexplained/intercept	-74.7	14.8		18.8
Total	100.0	100.0	100.0	100.0
Due to technological factors	46.7	90.1	83.9	101.7
Due to institutional factors	53.3	9.9	16.1	-1.7

[a] Compare with table 6.1 in NOIE (2004). [b] Mean of dependent variable in OLS is 2.163; in no constant regression it is 2.237.

Table H.6 Regression of LP growth—single period[a]

R^2 = 0.865 adj R^2= 0.813 Constant suppressed R^2 = 0.814	OLS regression		No constant regression	
	Makeup of mean[b]	Variance explained by	Makeup of mean[b]	Variance explained by
Independent variables	%	%	%	%
Capital deepening	24.9	15.0	20.3	12.6
Decrease in award coverage	118.6	10.5	20.4	1.9
R&D intensity	42.2	49.3	50.2	60.5
Capital intensity	10.9	2.9	16.1	4.4
Share of university graduates	35.3	8.8	-7.0	-1.8
Unexplained/intercept	-131.8	13.5		22.4
Total	100.0	100.0	100.0	100.0
Due to technological factors	25.6	73.0	83.2	99.9
Due to institutional factors	74.4	27.0	16.8	0.1

[a] Compare with table 6.1 in NOIE (2004).). [b] Mean of dependent variable in OLS is 2.163; in no constant regression it is 2.230.

Table H.7 Regression of MFP growth—single period[a]

R^2 = 0.422 adj R^2= 0.257 Constant suppressed R^2 = 0.407	OLS regression		No constant regression	
	Makeup of mean[b]	Variance explained by	Makeup of mean[b]	Variance explained by
Independent variables	%	%	%	%
OECD LP growth	78.8	32.6	69.8	30.2
Decrease in union membership	34.7	0.4	-20.9	-0.3
Capital intensity	17.5	2.4	13.0	1.8
Increase in share of post-school qualified	39.6	6.9	38.0	6.9
Unexplained/intercept	-70.5	57.8		61.4
Total	100.0	100.0	100.0	100.0
Due to technological factors	56.4	82.8	82.8	82.9
Due to institutional factors	43.6	17.2	17.2	17.1

[a] Compare with table 6.2 in NOIE (2004). **).** [b] Mean of dependent variable in OLS is 1.134; in no constant regression it is 1.183.

Table H.8 Regression of MFP growth—single period[a]

R^2 = 0.654 adj R^2= 0.554 Constant suppressed R^2 = 0.426	OLS regression		No constant regression	
	Makeup of mean[b]	Variance explained by	Makeup of mean[b]	Variance explained by
Independent variables	%	%	%	%
OECD LP growth	82.7	34.2	67.6	32.4
Decrease in award coverage	274.5	24.5	40.1	4.1
Capital intensity	-3.5	-0.5	1.7	0.3
Increase in share of post-school qualified	41.1	7.1	-9.4	-0.3
Unexplained/intercept	-294.7	34.7		63.5
Total	100.0	100.0	100.0	100.0
Due to technological factors	20.1	51.7	69.3	89.5
Due to institutional factors	79.9	48.3	30.7	10.5

[a] Compare with table 6.2 in NOIE (2004). [b] Mean of dependent variable in OLS is 1.134; in no constant regression it is 1.212.

Table H.9 Regression of LP growth—single period[a]

$R^2 = 0.575$ adj $R^2 = 0.411$	*OLS regression*		*No constant regression*	
Constant suppressed $R^2 = 0.555$	*Makeup of mean*[b]	*Variance explained by*	*Makeup of mean*[b]	*Variance explained by*
Independent variables	%	%	%	%
OECD LP growth	46.0	31.3	40.0	28.1
Capital deepening	15.0	9.1	17.5	10.9
Decrease in union membership	47.7	3.7	3.7	0.3
Capital intensity	14.1	3.7	11.2	3.0
Increase in share of post-school qualified	28.9	9.7	27.7	9.5
UnexplainediIntercept	-51.7	42.5		48.2
Total	100.0	100.0	100.0	100.0
Due to technological factors	43.9	72.5	62.0	76.1
Due to institutional factors	56.1	27.5	38.0	23.9

[a] Compare with table J.1 in NOIE (2004). [b] Mean of dependent variable in OLS is 2.163; in no constant regression it is 2.227.

Table H.10 Regression of LP growth—single period[a]

$R^2 = 0.803$ adj $R^2 = 0.727$	*OLS regression*		*No constant regression*	
Constant suppressed $R^2 = 0.800$	*Makeup of mean*[b]	*Variance explained by*	*Makeup of mean*[b]	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	30.4	18.3	29.2	17.8
Decrease in award coverage	112.3	9.9	98.5	8.8
Capital intensity	31.3	8.3	32.0	8.5
Domestic ICT inputs	33.9	47.4	34.4	48.5
Share of post-school qualified	-77.3	-3.7	-94.1	-4.6
Unexplained/intercept	-30.7	19.7		21.0
Total	100.0	100.0	100.0	100.0
Due to technological factors	65.1	90.0	93.7	93.2
Due to institutional factors	34.9	10.0	6.3	6.8

[a] Compare with table J.2 in NOIE (2004). [b] Mean of dependent variable in OLS is 2.163; in no constant regression it is 2.180.

Table H.11 Regression of LP growth—single period[a]

R^2 = 0.822 adj R^2= 0.754 Constant suppressed R^2 = 0.729	OLS regression		No constant regression	
	Makeup of mean[b]	*Variance explained by*	*Makeup of mean*[b]	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	-1.0	-0.4	11.4	7.2
Decrease in union membership	116.3	8.9	18.8	1.5
Capital intensity	40.8	10.8	31.2	8.7
Domestic ICT plus eng'g services	56.8	57.6	47.4	50.7
Increase in share of university grads	22.5	5.3	-8.8	-2.2
Unexplained/intercept	-135.5	17.8		33.9
Total	100.0	100.0	100.0	100.0
Due to technological factors	41.3	82.8	88.7	101.1
Due to institutional factors	58.7	17.2	11.3	-1.1

[a] Compare with table J.3 in NOIE (2004). [b] Mean of dependent variable in OLS is 2.163; in no constant regression it is 2.281.

Table H.12 Regression of MFP growth—single period[a]

R^2 = 0.802 adj R^2= 0.745 Constant suppressed R^2 = 0.799	OLS regression		No constant regression	
	Makeup of mean[b]	*Variance explained by*	*Makeup of mean*[b]	*Variance explained by*
Independent variables	%	%	%	%
Decrease in award coverage	202.1	18.0	181.3	16.4
Capital intensity	49.3	6.7	49.7	6.8
Domestic ICT inputs	63.8	57.6	64.0	58.5
Share of post-school qualified	-167.0	-2.1	-195.0	-2.5
Unexplained/intercept	-48.1	19.8		20.8
Total	100.0	100.0	100.0	100.0
Due to technological factors	76.3	80.1	113.7	82.4
Due to institutional factors	23.7	19.9	-13.7	17.6

[a] Compare with table J.8 in NOIE (2004). [b] Mean of dependent variable in OLS is 1.134; in no constant regression it is 1.148.

Table H.13 Regression of MFP growth—single period[a]

R^2 = 0.780 adj R^2= 0.717 Constant suppressed R^2 = 0.621	OLS regression		No constant regression	
	Makeup of mean[b]	*Variance explained by*	*Makeup of mean*[b]	*Variance explained by*
Independent variables	%	%	%	%
Decrease in award coverage	269.8	24.1	28.1	2.7
Capital intensity	34.4	4.7	41.4	6.1
Domestic ICT plus eng'g services	71.9	44.3	78.1	52.8
Increase in share of university grads	60.0	4.9	-47.6	-4.2
Unexplained/intercept	-336.2	22.1		42.6
Total	100.0	100.0	100.0	100.0
Due to technological factors	24.4	62.9	119.5	102.6
Due to institutional factors	75.6	37.1	-19.5	-2.6

[a] Compare with table J.9 in NOIE (2004). [b] Mean of dependent variable in OLS is 1.134; in no constant regression it is 1.242.

Table H.14 Three period regression of LP growth[a]

R^2 = 0.624 adj R^2= 0.543 Constant suppressed R^2 = 0.611	OLS regression		No constant regression	
	Makeup of mean[b]	*Variance explained by*	*Makeup of mean*[b]	*Variance explained by*
Independent variables	%	%	%	%
OECD LP growth	-8.2	-2.0	-11.0	-2.8
Capital deepening	23.7	19.9	23.2	20.1
Tariff reduction	-14.3	1.9	-14.9	2.0
Decrease in industrial disputes	0.1	0.7	0.1	0.7
R&D intensity	57.1	36.9	62.5	41.8
Capital intensity	8.3	1.0	10.9	1.4
Share of university graduates	-18.2	-3.1	-39.7	-6.9
Increase in share of post-school qlfd	6.0	1.2	6.7	1.4
Decrease in union membership	104.6	4.4	87.4	3.8
Decrease in award coverage	29.5	1.4	-25.2	-1.2
Unexplained/intercept	-88.7	37.6		39.6
Total	100.0	100.0	100.0	100.0
Due to technological factors	34.7	84.6	81.2	100.4
Due to institutional factors	65.3	15.4	18.8	-0.4

[a] Compare with table J.6 in NOIE (2004). [b] Mean of dependent variable in OLS is 2.162; in no constant regression it is 2.211.

Table H.15 Three period regression of LP growth[a]

R^2 = 0.652 adj R^2= 0.576 Constant suppressed R^2 = 0.651	*OLS regression*		*No constant regression*	
	Makeup of mean[b]	*Variance explained by*	*Makeup of mean*[b]	*Variance explained by*
Independent variables	%	%	%	%
Capital deepening	25.6	21.5	25.7	21.6
Tariff reduction	-14.9	2.0	-15.1	2.0
Decrease in industrial disputes	0.1	0.7	0.1	0.7
R&D intensity	40.2	26.0	41.5	27.0
Capital intensity	12.8	1.6	12.9	1.6
Domestic ICT plus professional services	12.9	9.0	12.2	8.7
Share of post-school qualified	-97.7	-3.3	-114.0	-3.8
Increase in share of post-school qualified	6.1	1.3	5.8	1.2
Decrease in union membership	86.0	3.6	76.4	3.2
Decrease in award coverage	61.6	2.9	54.5	2.6
Unexplained/intercept	-32.6	34.8		35.3
Total	100.0	100.0	100.0	100.0
Due to technological factors	61.5	83.7	89.6	86.5
Due to institutional factors	38.5	16.3	10.4	13.5

[a] Compare with table J.7 in NOIE (2004). [b] Mean of dependent variable in OLS is 2.162; in no constant regression it is 2.174.

Table H.16 Three period regression of MFP growth[a]

R^2 = 0.604 adj R^2= 0.528 Constant suppressed R^2 = 0.548	*OLS regression*		*No constant regression*	
	Makeup of mean[b]	*Variance explained by*	*Makeup of mean*[b]	*Variance explained by*
Independent variables	%	%	%	%
OECD LP growth	-5.0	-1.1	-12.9	-3.1
Tariff reduction	-15.3	1.8	-16.7	2.1
Decrease in industrial disputes	0.0	0.2	0.0	0.2
R&D intensity	80.8	44.0	94.1	54.5
Capital intensity	7.8	0.7	15.0	1.5
Share of university graduates	20.0	2.3	-41.1	-5.0
Increase in share of post-school qualified	2.0	0.3	4.1	0.7
Decrease in union membership	81.3	0.8	35.6	0.4
Decrease in award coverage	180.8	11.5	21.9	1.5
Unexplained/intercept	-252.7	39.6		47.4
Total	100.0	100.0		100.0
Due to technological factors	23.7	72.2	96.1	100.4
Due to institutional factors	76.3	27.8	3.9	-0.4

[a] Compare with table J.12 in NOIE (2004). [b] Mean of dependent variable in OLS is 1.126; in no constant regression it is 1.199.

Table H.17 Three period regression of MFP growth[a]

R^2 = 0.679 adj R^2= 0.618 Constant suppressed R^2 = 0.679	*OLS regression*		*No constant regression*	
	Makeup of mean[b]	*Variance explained by*	*Makeup of mean*[b]	*Variance explained by*
Independent variables			%	%
Tariff reduction	-22.8	2.7	-23.0	2.7
Decrease in industrial disputes	0.0	0.1	0.0	0.1
R&D intensity	73.2	39.8	74.8	41.0
Capital intensity	26.4	2.4	26.4	2.4
Domestic ICT plus engineering services	33.6	14.3	32.2	13.8
Share of post-school qualified	-221.2	-3.3	-238.1	-3.6
Increase in share of post-school qualified	3.5	0.5	3.0	0.5
Decrease in union membership	75.9	0.7	65.9	0.6
Decrease in award coverage	168.0	10.7	158.7	10.1
Unexplained/intercept	-36.7	32.1		32.4
Total	100.0	100.0	100.0	100.0
Due to technological factors	97.5	83.2	133.4	84.5
Due to institutional factors	2.5	16.8	-33.4	15.5

[a] Compare with table J.13 in NOIE (2004). [b] Mean of dependent variable in OLS is 1.126; in no constant regression it is 1.133.

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