# Information Technology and Australia's Productivity Surge

PRODUCTIVITY COMMISSION

Staff Research Paper

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# Abbreviations

| | |
|---|---|
| ABS | Australian Bureau of Statistics |
| AIG | Australian Industry Group |
| BEA | Bureau of Economic Analysis |
| BLS | Bureau of Labor Statistics |
| CEA | Council of Economic Advisers |
| CSLS | Centre for the Study of Living Standards |
| EU | European Union |
| FIRE | Finance, insurance and real estate |
| GDP | Gross domestic product |
| IAC | Industries Assistance Commission |
| IC | Industry Commission |
| ICTs | Information and communications technologies |
| IDC | International Data Corporation |
| IMF | International Monetary Fund |
| IPES | Information processing equipment and software |
| ISI | Information Society Index |
| ISIC | International Standard Industrial Classification |
| IT | Information technology |
| MFP | Multifactor productivity growth |
| OECD | Organisation of Economics Co-operation and Development |
| PC | Productivity Commission |
| ppp | purchasing power parity |
| R&D | Research and Development |
| RBA | Reserve Bank of Australia |

### Key messages

- The adoption of information technology (hardware and software) contributed to Australia’s productivity surge in the 1990s. Australia was very quick on the uptake of information and communications technologies (ICTs) in the 1990s by international standards.
- The contributions of ICTs to labour productivity growth has been at least as strong in Australia as it has been in the US.
  - Contributions from ICT capital deepening are very similar in terms of timing (uplift from 1995) and magnitude (around 0.3 of a percentage point).
  - Australia has had a stronger contribution from multifactor productivity (MFP) growth (1.1 percentage point in Australia, 0.3 of a percentage point in the US), although pinpointing how much of the difference is due to ICTs is problematic.
- Australia’s stronger productivity growth means Australia benefited more from one or both of two factors:
  - greater productivity gains from ICT use, which would suggest that Australian firms were able to use ICTs to catch up more quickly on the efficiency levels of their American counterparts; and
  - greater productivity gains from non-ICT factors, such as policy reforms.
- The *production* of ICT equipment is not necessary to access ‘new economy’ productivity gains. ICT production added up to 0.3 of a percentage point to US productivity growth. Australia enjoyed a productivity improvement of 1.1 percentage points due to *use* of ICTs and other factors.
  - Moreover, relying on imports enabled Australia to benefit from tumbling world prices of ICT equipment. These brought real income gains to Australians.
- Increased use of ICTs has substituted for use of other forms of capital. ICTs have brought no increase in the overall rate of substitution of capital for labour in either country.
- Productivity gains associated with ICT use have been concentrated — at this stage at least — in distribution (wholesale and retail trade) and financial intermediation. The concentration of gains in a few industries suggests that the gains are mainly due to restructuring in these industries.

# Overview

Some of the ‘hype’ about how advances in technology are forging a ‘new economy’ has evaporated. Interest in ‘dot.com’ start-up companies in the US has waned with the decline in stock market valuations. Some of the more extravagant claims — in particular, that the ‘new economy’ would see the end to recessions — have been tempered by the slowdown in the US economy.

But a central, underlying issue — whether information and communications technologies (ICTs) raise a country’s productivity performance over the long term — remains relevant. The US economy is viewed in many respects as a technology and productivity ‘leader’. If a new ICT-based source of productivity growth is established in the US economy (putting aside the short-term cyclical downturn), it raises the potential for other countries, including Australia, to follow suit.

Australia and the US were two of only a few high-income countries to raise their productivity performance over the 1990s (OECD 2000a). The fact that Australia’s productivity surge pre-dated that of the US has been a principal reason to attribute Australia’s surge to other (that is, non-ICT) factors — at least in the initial stages of the productivity uplift. Microeconomic policy reforms are now widely seen to have played an important part in raising Australia’s productivity performance in the 1990s (Bean 2000, OECD 2001a).

But there are differing views on the links between ICTs and Australia’s productivity performance:

- A paper by Wilson (2000), from Goldman Sachs, found that ICTs had played a lesser role in Australia’s productivity performance than in the US; and considered that a second ICT-based productivity wave lay ahead for Australia.
- A discussion paper by the Australian Industry Group (AIG 2000) was more pessimistic. It attributed Australia’s 1990s productivity gains to microeconomic reforms and considered the prospects for continued gains from this source to be limited. It read the US evidence as saying that the link between ICTs and productivity growth came through ICT production, not ICT use. Since Australia produces little ICT equipment, the paper considered that an ICT-based productivity wave is not available to Australia.

- Staff at the Reserve Bank of Australia (RBA) undertook research, reported in Gruen (2001), that suggests that Australia is well-advanced in accessing productivity gains through the use of ICTs.

Clearly, there are some important issues to be examined and sorted out, irrespective of 'new economy hype'.

This paper finds that ICT-related productivity gains can be accessed through use and not just production; and that, through rapid uptake of ICTs, Australia has already caught an ICT-related productivity wave.

## Analysing the productivity gains from ICTs

Computers, telecommunication systems and the Internet have brought revolutionary changes to businesses, consumers, education, health, entertainment and many other aspects of life. A defining characteristic is that the costs of storing, accessing and exchanging information have been greatly reduced. In so doing, ICTs have not only reduced the costs of coordination, communications and information processing but they have also facilitated changes in what businesses do and how they do it.

Some of the gains from ICTs are not measured in conventional performance statistics. For example, the benefits to households from avoiding long queues through Internet search and shopping are real, but are not directly measured in GDP figures.

But many gains are tangible and measurable. For example, US Federal Reserve Board Chairman, Alan Greenspan, pointed to gains that he believes come from greater and cheaper access to information — greater certainty, through the availability of real-time information about customers' demands and the location of inventories and materials flowing through complex production systems, leads to less wastage from extra production, inventories and staff; more efficient and compressed distribution processes; the development of financial instruments to manage risks; and lower search and transactions costs in business-to-business transactions.

Whether these and other claimed gains improve the productivity performance of the whole economy is contested. A number of economists have been sceptical about the significance of efficiency gains from ICT use, especially about claims about 'new' and 'special' qualities of ICTs that generate increasing returns and spillover benefits throughout the economy.

A string of studies set out to analyse the link between ICTs and productivity growth after more rapid advances in technologies, greater investment in ICTs and the wider use of the Internet all coincided with much stronger than expected productivity performance in the US economy in the second half of the 1990s. These studies examined the contribution of the production and use of ICT *equipment* to aggregate labour productivity growth in a growth accounting framework. They have covered business use of ICTs, with only one of the better-known studies including household use.

Figure 1 displays the essentials of the growth accounting framework. It shows two proximate sources of growth in labour productivity. *Capital deepening* (increases in the capital/labour ratio) raises labour productivity because it means that, on average, each unit of labour has more capital to work with to produce output. *Multifactor productivity* (MFP) growth means both labour and capital inputs are combined in ways that produce more output. It raises labour productivity growth because, even though MFP is about the productivity of labour and capital inputs combined, an increase in MFP nevertheless raises the ratio of output produced to labour input used. The implementation of the growth accounting framework is further outlined in box 1.

Figure 1 **Components of labour productivity growth**

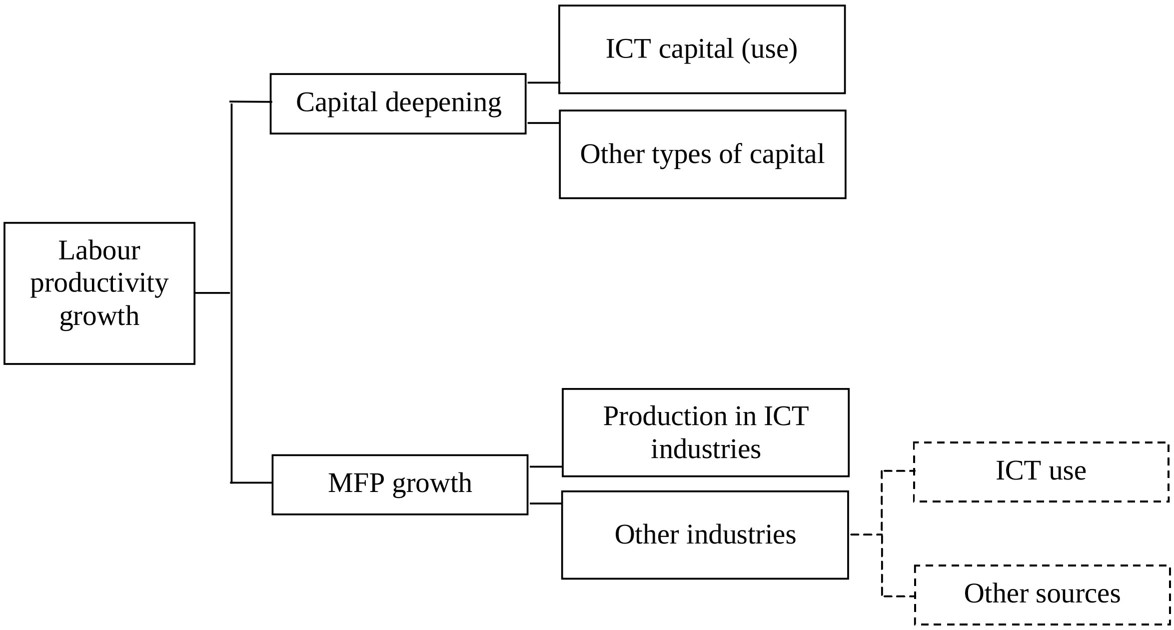



Figure 1 also illustrates three potential sources of gains from ICTs that contribute to aggregate capital deepening and aggregate MFP growth.

- Increased use of ICTs per unit of labour raises ICT capital deepening. This component captures the gains to the direct users of ICTs. The gains are reflected in the income stream attributable to ICTs and, in principle, cover all benefits to ICT owners. They include cost savings from substituting ICTs for other inputs as

ICTs become cheaper. The sceptical view of the benefits from ICTs acknowledges only this form of gain. ICTs are seen as just another production input. Technological advances in ICTs are treated as being embodied in new equipment purchases. Demand for ICTs is driven primarily by price and, conceptually, producers respond to relative price changes by shifting to a different input combination, without a change in technology.

- There are MFP gains in ICT production, which stem from the ability of producers to generate more output — computing power and other characteristics of ICTs — per unit of input. The rapid technological advances in ICT production has led to rapid declines in ICT equipment prices (computer prices in the US declined by 18 per cent a year on average from 1960 to 1995 and by 27.6 per cent a year from 1995 — also see box 1). Cheaper prices have in turn fuelled increased demand and use.
- There may be MFP gains from increasing use of ICTs. In principle, these cover externality benefits in using industries. According to the 'new economy' enthusiasts, ICTs can bring network economies, increasing returns and spillovers, which would be captured in MFP gains in using industries. They are gains generated by producers and some users of ICTs but not captured by them. They are transmitted to others. For example, network economies derive from any increased value of a network (for example, Internet or local purchasing network for e-commerce) to existing members when new members join. However, in practice, analysts cannot separate the ICT-sourced MFP gains in other industries from other sources of MFP gain in other industries, such as industry-specific technology improvements.

Several practical issues undermine the neat allocation of ICT gains to these three sources and frustrate interpretation, particularly of a finding of MFP growth in using industries (box 2). It is likely that a finding of MFP gains in using industries reflects, at least in part, gains captured by ICT investors.

Box 1 **On estimating the contributions of ICTs to productivity growth**

*Growth accounting*

Figure 1 in the text captures the essentials of how the contributions of ICTs have been evaluated in a growth accounting framework. Labour productivity growth is equal to the sum of estimates of capital deepening (growth in the capital-labour ratio weighted by the share of capital in payments to factors of production), MFP growth and (in the US case) changes in labour composition. Capital deepening can be further decomposed by calculating the rates of ICT and other-capital deepening; and aggregate MFP growth can be decomposed by calculating the growth of MFP in the ICT production sector and in the other industries sector and weighting each by the relative size of each sector. However, analysts have not been able to separate the influence of ICT use from other sources of MFP growth in using industries within the growth accounting framework.

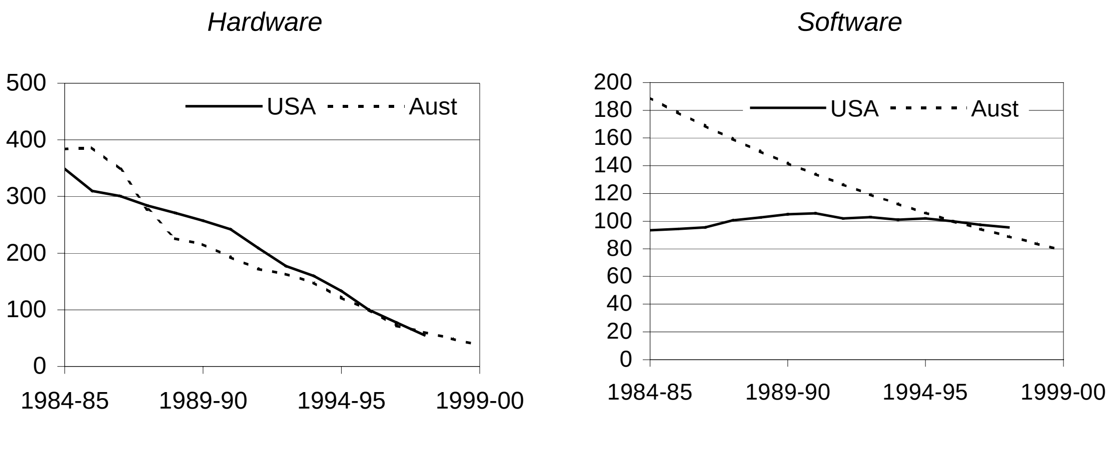
*Measuring ICT production and use*

Volumes of ICTs produced and purchased are calculated by deflating nominal production and investment figures by ‘hedonic’ price indexes. Hedonic price indexes capture the quality-constant movement in prices. Use of hedonic deflators means that volume measures reflect improvements in quality.

For example, hedonic prices take into account changes in a number of characteristics of computers — processing speed, memory capacity and so on. There have been rapid technological advances in computers, especially in the capacity of microprocessors. On the other hand, there has been relatively little movement in the nominal prices of computers. This means that the quality-constant prices of computers have declined.

The figures below show the hedonic prices used in the Australian and US national accounts. The Australian prices of hardware are based on the US hedonic indexes and software prices are based on a Canadian index.

Figure 2 **IT hardware and software price indexes, US and Australia**
Index 1995-96 = 100




(Continued on next page)

Box 1 **(continued)**

Rapidly declining hedonic price deflators mean that, all other things equal, measured volumes of ICTs produced and purchased are increasing rapidly. Compared with the use of deflators that do not adjust for quality, the use of hedonic prices raises the estimates of output (and productivity) growth in ICT production industries and raises the estimates of capital inputs (and lowers estimated productivity growth) in using industries.

This treatment of ICTs implies that technical advances are embodied in equipment and purchasers invest in computer power, communication capability and so on.

*Capital services*

A capital services measure of capital input is used. A capital services measure takes account of efficiency losses in different types of assets over time. It captures the flow of services used in production (which for some assets may be steady over time). A capital stock measure, on the other hand, is a wealth measure of capital and captures the loss of income-earning capacity of an asset over its economic life.

*Labour input*

Labour input is measured by hours worked. US studies also include a labour composition or quality component, which captures changes in the hours worked of groups with different marginal products. Allowance for composition effects (as in the US) reduces measured MFP growth by the same amount, compared with estimates that do not make such an allowance (as in Australia).

One pertinent issue is whether there have been any distinctly new productivity-enhancing qualities about ICTs in the late 1990s and, if so, how they are captured in growth accounting. Technological advances in ICTs are treated as being embodied in increases in the volume of ICT capital inputs. Gains are captured in the income flows to the increasing volume of ICT input. But has there been a 'non-linear' increase in gains from the advances in ICTs?

Many think there has. For example, ICTs are increasing seen as 'general purpose' technologies, which take time to bring to their full potential and which enable complementary innovations that bring further, substantial gains. It may be that some threshold of diffusion, knowledge or complementary actions are required before the more substantial gains are unlocked. Or it may be that there is some new capability associated with ICTs themselves that is not reflected in the standard input volume measure. The wider availability of the Internet could be an example. In such cases, benefits would go beyond the direct and immediate income flows that are attributed to ICT assets. Some of the returns to those investing in ICTs would be reflected in MFP gains and not just in capital deepening.

**Box 2 Measuring and allocating the gains from ICTs in practice**

The measurement of MFP gains in ICT production depends crucially on the accuracy of measurement of ICT prices. Hedonic prices are used to deflate nominal output of and expenditure on ICTs (box 1). Mismeasurement of deflators would affect the measurement of both the volume of output produced and the size of MFP gains in ICT production and the volume of capital in use and therefore the size of MFP gains in using industries. Incorrect measurement of prices could see advances in the technical characteristics of ICTs show up in MFP gains in using industries, or some MFP gains from use incorrectly allocated to ICT production.

The allocation of gains between capital deepening and MFP can be influenced by a number of factors. As discussed in the text, there is an issue of whether technological advances in ICTs bring any 'new' qualities to production — whether there are technological spillovers from producers to users. The growth accounting framework cannot pick up any 'new' qualities as part of the internalised returns to IT investors. If there are new qualities, output growth and MFP gains in using industries will be greater. It may also be that ICTs are providing relatively high returns — some of which show up in MFP gains — while holdings of ICTs are below their long-run equilibrium levels, as is likely in the presence of rapidly declining prices (Brunker 2001).

Brynjolfsson and Hitt (2000) note that the gains reflected in capital deepening are constrained by the assumption that asset holdings are in equilibrium and therefore earn a common 'normal' rate of return (after asset-specific taxes, depreciation and allowance for capital gains or losses). If in reality ICTs earn higher returns due to complementary investments in business restructuring, the additional gains would show up in MFP growth — even though they are gains internalised by ICT investors.

Thus, whilst the allocation of ICT benefits in the growth accounting framework is reasonably straightforward in principle, the practice is much less straightforward. Moreover, the interpretation of a finding of MFP gains in using industries is clouded. It cannot be taken as necessarily establishing the presence of ICT spillovers, especially in the form of network externalities. In practice, the growth accounting framework is not well tuned to make fine distinctions between the different types of gains from ICTs and to quantify any 'special' properties of ICTs. (See chapter 3 for further discussion.)

## The message from US studies — gains come from use and not just production

Oliner and Sichel (2000) conducted what has become a central study. They found that ICTs contributed about 0.7 of a percentage point (or about two-thirds) of the 1 percentage point acceleration in US labour productivity growth between the first and second halves of the 1990s (specifically, between 1991-95 and 1996-99). This comprised 0.45 of a percentage point from ICT capital deepening and 0.26 of a percentage point from MFP growth in ICT production. Capital deepening from other forms of capital contributed almost nothing to the acceleration, leaving MFP growth in industries outside of ICT production to account for the rest (table 1). Jorgenson and Stiroh (2000a) came to similar conclusions.

Robert Gordon (2000b) has been the most prominent sceptic. He removed what he considered to be a transient cyclical component from the aggregate labour productivity acceleration and made a further correction for mismeasurement. The remaining structural acceleration in labour productivity growth of 0.8 of a percentage point, less the contribution from capital deepening, virtually equalled his estimate of the MFP gains from computer production. This left virtually no room for any MFP gains from any other industries (table 1).

The widespread reporting of Gordon's conclusion has undoubtedly contributed to a fairly common view that production of ICTs is the only way to access 'new-economy' productivity gains (even though Gordon accepted that ICT use did contribute to labour productivity growth through capital deepening).

However, the evidence of MFP gains in industries outside of ICT production found in other studies is hard to 'explain away'. More recent studies reveal stronger MFP acceleration in the US economy (up to the year 2000). An update from Oliner and Sichel (2001) and the Council of Economic Advisers (CEA 2001) found a stronger labour productivity acceleration to the year 2000, most of which is attributed to stronger MFP acceleration. Around three-quarters of the MFP acceleration was attributed to non-ICT-producing industries (table 1). (These later estimates of the labour productivity acceleration may turn out to be on the high side, given a recent announcement that labour productivity growth estimates — especially for the year 2000 — have been revised downward.)

Table 1 **Estimates of contributions to the US MFP acceleration in the 1990s**

| | *Gordon* | *Oliner and Sichel* | | *CEA* |
|---|---|---|---|---|
| | *(2000b)* | *(2000)* | *(2001)* | *(2001)* |
| 1. MFP acceleration | 0.29 | 0.67 | 0.91 | 1.19 |
| 2. ICT production | 0.29 | 0.26 | 0.26 | 0.18 |
| 3. Other industries | 0.00 | 0.41 | 0.64 | 1.00 |

More detailed industry studies are now showing evidence of productivity acceleration in ICT-using industries. Nordhaus (2001) found that industries outside of broadly-defined 'new economy' production contributed about a half of the aggregate labour productivity acceleration. Stiroh (2001) found that (a narrower group of) ICT production industries contributed about one-fifth of the aggregate acceleration and ICT-using industries contributed nearly all of the remainder, with little acceleration in industries outside of ICT production or use. Studies of firms have shown very substantial gains from ICT use (Brynjolfsson and Hitt 2000).

Whilst this evidence of productivity acceleration in using industries does not establish conclusive proof of ICT-related effects, since non-ICT factors could still be at work in ICT-intensive industries, it strongly suggests that ICT use has contributed to productivity acceleration in ICT-intensive industries. This conclusion is also supported by the findings from a major OECD study of factors contributing to differences in growth rates across economies in the 1990s (OECD 2001c). It found that productivity gains came from ICT use, as well as production.

## Australia is an advanced ICT user, not producer

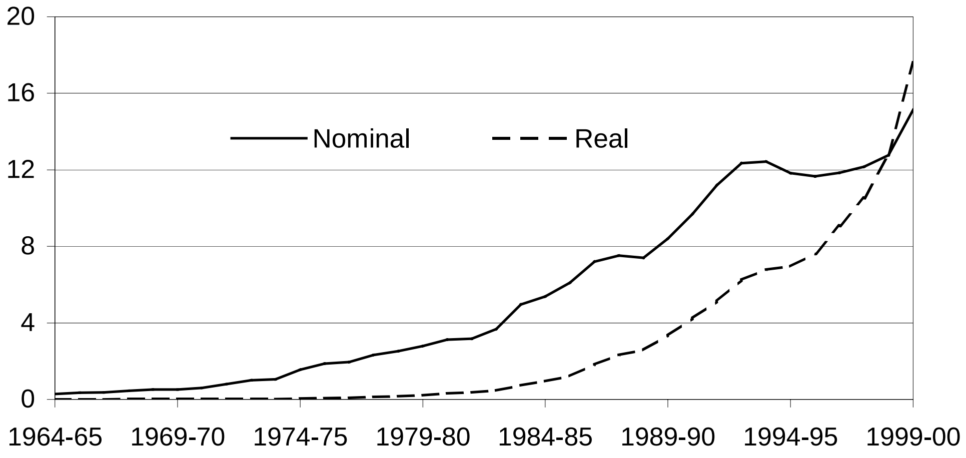
A wide range of indicators of production and use of ICTs is reviewed in chapter 2. Indicators cover production of ICT equipment and services as well as business and private use of ICTs. The main points relating to the focus in this paper on ICT equipment production and business use are that:

- Australia ranks low in terms of size of its ICT equipment production industries — at the very low end of OECD countries. Australia imports most of its ICT equipment requirements.
- Australia ranks in the medium to high range of business use indicators. On a number of major indicators covering infrastructure and business use, Australia rates in the top handful of countries in the world.

Investment in IT became a sizeable proportion of total investment in Australia from the mid-1980s (figure 3). Since then, the growth of investment has been very strong, especially in the 1990s, when investment in hardware grew by 35 per cent a year and software investment grew by 20 per cent a year in real terms. Investment in IT in 1999-00 represented nearly 18 per cent of annual market sector investment in real terms or 15 per cent in nominal terms. (IT is a higher proportion in real terms because of its declining relative and absolute price.)

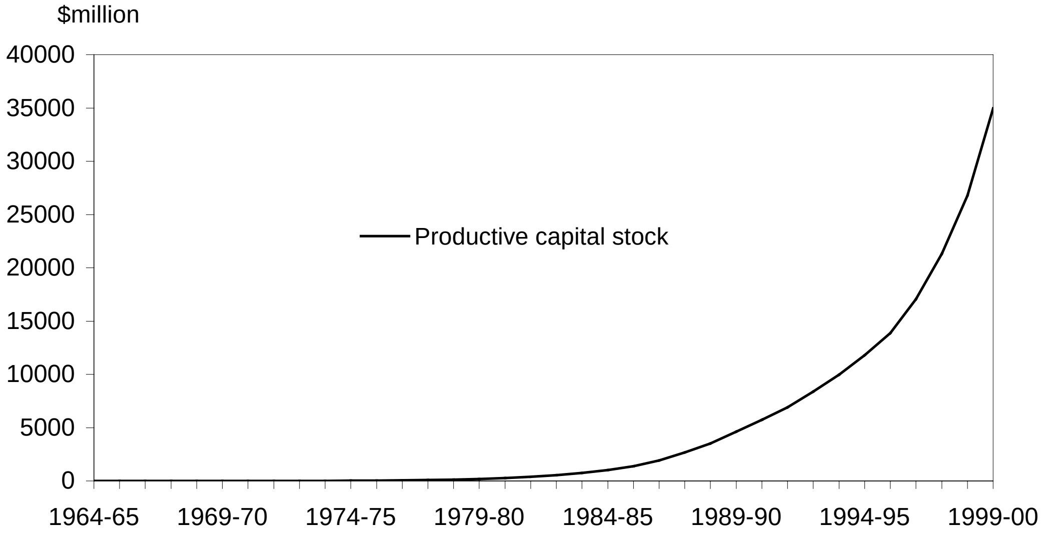
Figure 3 **IT share of real and nominal investment in Australia's market sector, 1964-65 to 1999-00**

Per cent




The strong growth in investment, of course, led to strong growth in IT capital input to production — particularly in the 1990s. This is best illustrated by the exponential growth in the productive IT capital stock (figure 4).

Figure 4 **Productive capital stock of IT assets in Australia's market sector, 1964-65 to 1999-00**



## ICT contributions to productivity growth — the US and Australia compared

A range of US and Australian studies of ICT contributions to productivity growth are reviewed in the body of this paper. For brevity, however, this overview focuses on comparisons between the US, based on Bureau of Labor Statistics (BLS) data, and Australia, based on Australian Bureau of Statistics (ABS) data. Other studies have compared Australia with the US results from Oliner and Sichel (2000). But using BLS data brings two advantages:

- ABS models its methods closely on BLS methods, and this enhances comparability; and
- access to the BLS dataset assists flexibility in choosing periods for comparison.

The BLS and the ABS are at the forefront of moves toward international standards in national accounts and productivity measurement. The degree of commonality in methods means that comparisons between the US and Australia can be made much more readily than with most other countries. Nevertheless, there are some data differences relevant to this exercise (box 3). Australian data cover IT, without communications equipment. And, because a labour composition or 'quality' component cannot be measured for Australia, this component is added back (in this Overview) into US MFP growth estimates to improve the comparability of the two countries' estimates.

Period selection is an important issue. As will be demonstrated, the results are sensitive to the selection of periods over which to calculate and analyse growth rates.

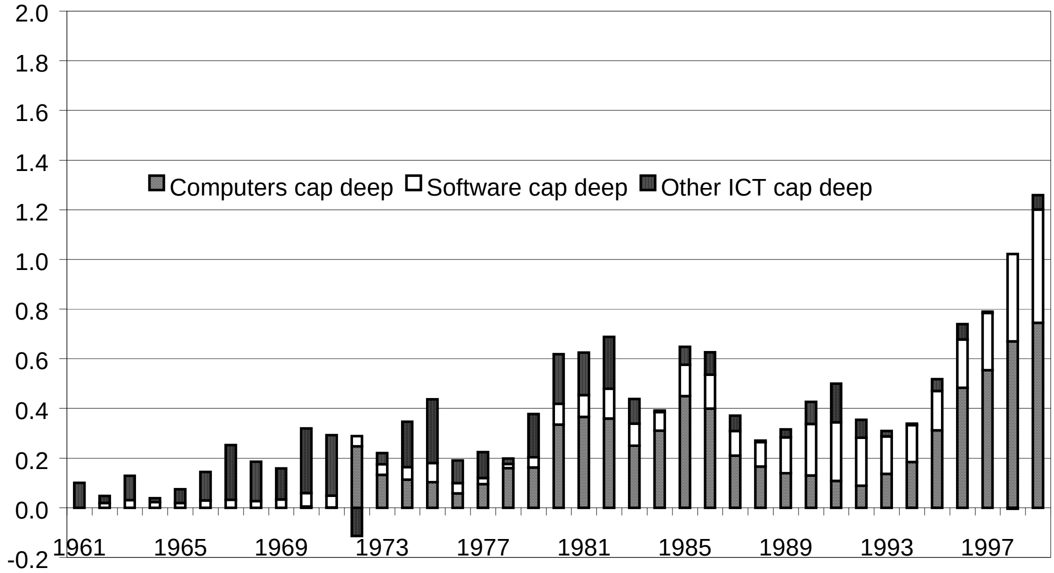
### Year-to year contributions — IT capital deepening

Figures 5 and 6 show the year-to-year contributions of ICT capital deepening to labour productivity growth in the US and Australia respectively.

The timing and strength of the contributions in both countries are remarkably close, with a big step up in contributions from 1995 (US) and 1995-96 (Australia).

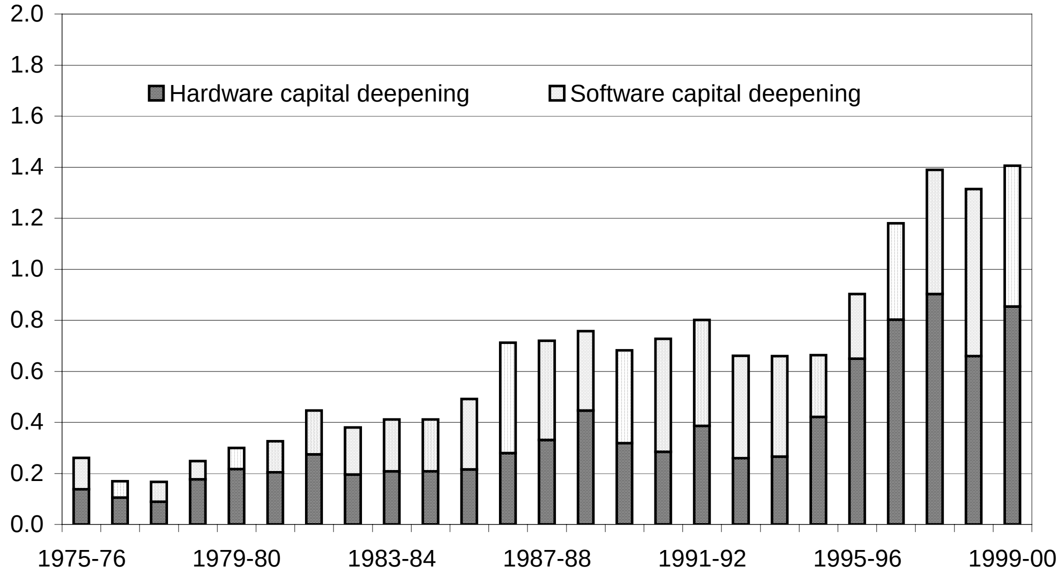
### Figure 5 **Contributions of ICT capital deepening to US labour productivity growth, 1961 to 1999**

Percentage points




### Figure 6 **Contributions of IT capital deepening to Australian labour productivity growth, 1975-76 to 1999-00**

Percentage points



## Contributions to the productivity acceleration in the second half of the 1990s

US studies have analysed the labour productivity acceleration in the second half of the 1990s — that is, before and after 1995, the point of take-off in advances in technology, declines in ICT prices, growth in investment in ICTs and growth in labour productivity. Gordon (2000b), Jorgenson and Stiroh (2000a), the BLS in its own published work and the CEA (2001) all compared periods up to and including 1995 with the period from 1995 on.

The decomposition of the acceleration in labour productivity growth between the first and second halves of the 1990s is presented for both the US and Australia in the first column of table 2. It can be seen that the ICT capital deepening contribution is similar in both countries, but Australia's labour productivity and MFP accelerations are much higher.

### Box 3 **Measurement differences between the US and Australia**

The BLS is able to separately identify communications equipment in its list of asset types in the US data. The ABS cannot do this for Australia. Consequently, the growth accounting covers ICTs for the US, but IT for Australia.

The inclusion of communications equipment in the US estimates, and its exclusion from the Australian estimates, may not have had much influence on the comparisons. The contribution from 'Other ICT', which includes communications equipment in the US data, hardly registers in the accounting for the 1990s labour productivity acceleration.

The strong point in the comparability of BLS and ABS methods lies in the treatment of the capital input measure. This is obviously crucial to an exercise designed to determine the contribution of capital assets. Both agencies construct capital services in the same way and with the same key parameter selections. This greatly reduces the scope for biases in comparative growth rates and contributions that would otherwise appear.

The similarity in use of hedonic price deflators is also a feature crucial to a comparative exercise involving ICTs. However, while the hardware deflators are very similar, the software deflators used for Australia show more rapid price declines than those used for the US (box 1). This could raise the contribution of IT in Australia compared with the US. However, software makes only a negligible contribution to Australia's acceleration in the 1990s and is less than the software contribution in the US.

The BLS is able to separately identify the contribution of labour composition effects (box 1). Since the ABS cannot, the US labour composition component is added back in to US MFP estimates in this Overview to assist comparability between the two countries' estimates.

Table 2 **Sensitivity of productivity acceleration and contributions to period selection**

| | *1990-95 to 1995-99* | *1991-96 to 1996-99* | *1991-95 to 1996-99* |
|---|---|---|---|
| *United States* | | | |
| Labour productivity growth | 1.1 | 0.7 | 1.0 |
| Capital deepening | 0.5 | 0.7 | 0.8 |
| • ICT | 0.5 | 0.6 | 0.6 |
| • Other | 0.0 | 0.2 | 0.2 |
| MFP | 0.5 | 0.0 | 0.1 |
| *Australia*[a] | | | |
| Labour productivity growth | 2.0 | 1.4 | 1.8 |
| Capital deepening | 0.6 | 0.9 | 1.0 |
| • ICT | 0.4 | 0.5 | 0.6 |
| • Other | 0.1 | 0.4 | 0.4 |
| MFP | 1.4 | 0.5 | 0.9 |

[a] For Australia, the periods refer to years ending 30 June.

However, the discussion does not dwell on these results, because it turns out that the estimates of productivity accelerations between the first and second halves of the 1990s are quite sensitive to the selection of periods for comparison. The year 1995 may mark a take off in ICT use, but it is essentially arbitrary and misleading with respect to underlying productivity trends.

Table 2 shows alternative period selections. The period selection in the second column uses 1996 rather than 1995 as the boundary between periods. The selection in the third column uses the same periods as Oliner and Sichel (2000) — the US comparator used in previous Australian studies.

The three period selections show marked variation in the estimates of labour productivity acceleration and the contribution from MFP acceleration. Estimates of the US labour productivity and MFP accelerations vary in a range of half a percentage point, while Australian estimates vary in a range of nearly one percentage point.

Estimates of the ICT capital deepening component, on the other hand, are relatively robust — varying within a range of 0.2 percentage points in both countries. The variation in overall capital deepening is slightly higher in the Australian estimates due to slightly higher variation in estimates of the contribution of capital deepening with other forms of capital.

This sensitivity undermines the confidence that can be placed in any estimates as representing the contribution of ICTs to underlying, long-term productivity trends.

There has been debate about whether the acceleration in US labour productivity growth between the first and second halves of the 1990s reflects a shift in trend. Robert Gordon (2000a) considered that there was a sizeable cyclical component and made an adjustment for it. As shown in chapter 4, US labour productivity growth picked up from 1995, but from a position below trend. Using 1995 to define the start of the second half period means productivity growth is measured from a trough to a peak over that period.

## Productivity cycles

The sensitivity to period selection can be set aside by analysing contributions to trend rates of productivity growth. The ABS method of estimating productivity growth over productivity cycles — from productivity peak to productivity peak — is one way of measuring underlying trend rates of growth.

### *The US*

Figure 7 shows contributions to US labour productivity growth over productivity cycles since the 1960s. The 1990s cycle turns out to be from 1992 to 1999.

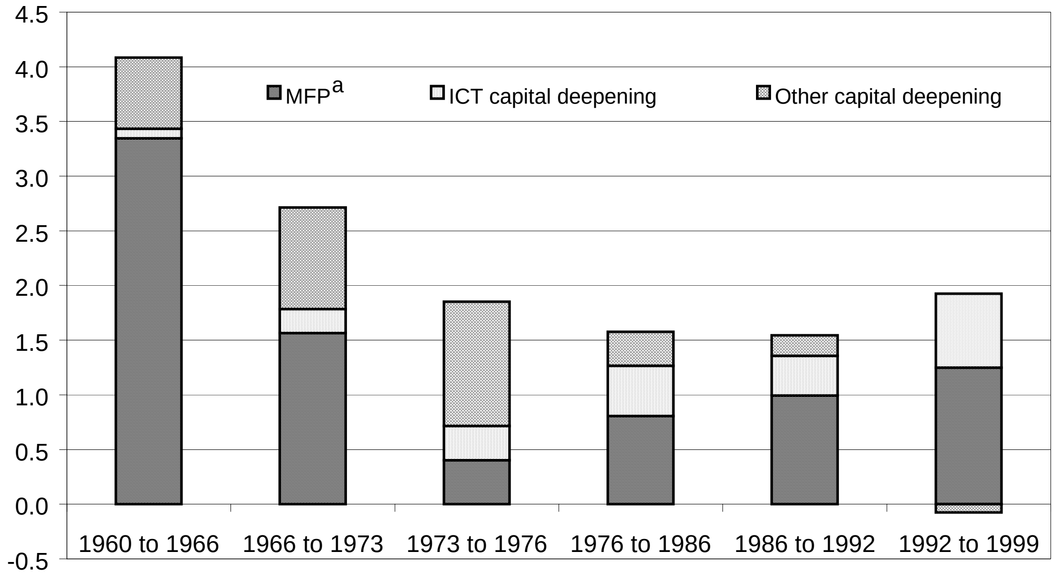
The figure shows that the magnitude of labour productivity and MFP growth in the 1990s was certainly not unprecedented. However, it is worth remembering that, in the 1980s and early 1990s, expectations of returning to the productivity growth rates of the 1960s, or even improving markedly on post-1973 growth rates, had been severely dented (Krugman 1992).

The productivity growth accounting has a number of other features:

- ICTs made a high contribution in periods prior to the 1990s, especially 1976 to 1986;
- The 1990s growth in ICTs has come at the expense of growth in other capital. The contribution of capital deepening from non-ICT capital dwindled from the mid-1970s and actually turned negative in the 1990s.
- Growth in MFP was strong in the 1990s compared with other periods after 1973.

Figure 7 **Contributions to growth in labour productivity for the United States over labour productivity cycles, 1960 to 1999**

Per cent




[a] Includes the labour composition (quality) contribution.

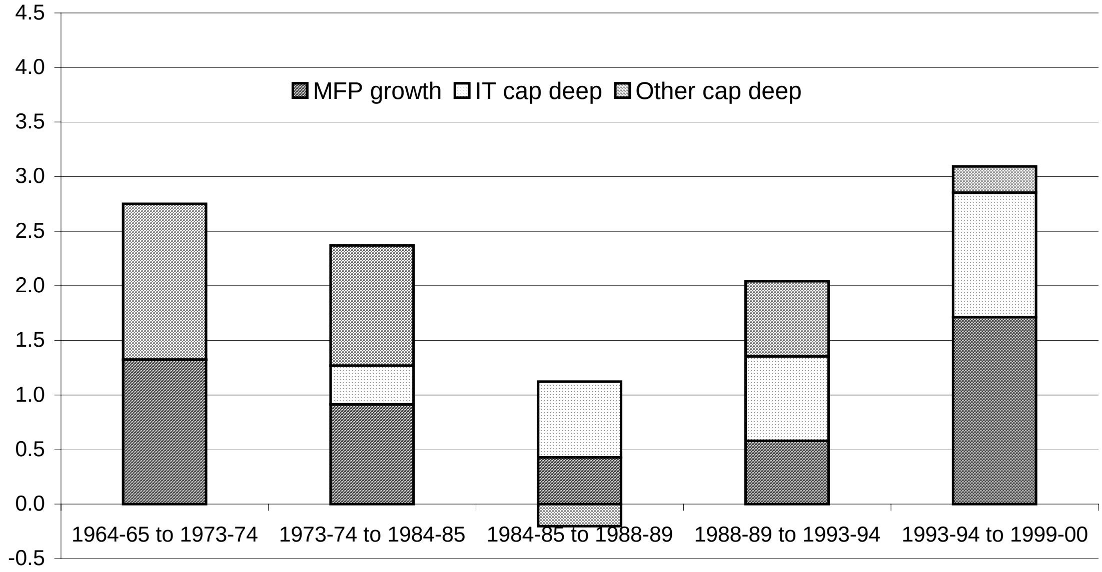
*Australia*

The ABS has determined the 1990s productivity cycle to be from 1993-94 to 1999-00. The contributions to labour productivity growth over the ABS productivity cycles are shown in figure 8:

- As before, the importance of IT in capital deepening has increased since the mid-1970s.
- In the 1990s cycle, IT capital deepening accounted for around 1.1 percentage points or just over one third of the record-high labour productivity growth, and just over 80 per cent of all capital deepening.
- Apart from the late 1980s cycle, the contribution of overall capital deepening has been relatively constant — at around 1.4 per cent a year. Increases in IT capital deepening over time have substituted for increases in other forms of capital deepening.
- MFP growth accounted for over half of the growth in labour productivity in the 1990s. The variation in labour productivity growth across cycles is mainly explained by variation in MFP growth.

Figure 8 **Contributions to market sector labour productivity growth for Australia, 1964-65 to 1999-00**

Per cent per year




### *The US and Australian accelerations compared*

According to the productivity cycle method, the US labour productivity acceleration is a much less spectacular 0.3 of a percentage point (table 3), compared with the 1.1 percentage point found in the comparisons between first and second halves of the 1990s. Arguably, this may understate the size of the 1990s productivity acceleration. Robert Gordon, the most vigorous proponent of a cyclical component, found a structural acceleration of 0.8 of a percentage point.

Nevertheless, taking the productivity cycle estimates at face value, ICT capital deepening accounts for a similar magnitude (0.3 of a percentage point). However, the increased use of ICTs substitutes for use of other forms of capital, leading to offsetting negative growth in other capital deepening. In contrast to other studies, there is little overall contribution from capital deepening. This leaves MFP growth to fully account for the labour productivity acceleration.

For Australia, the trend acceleration in labour productivity growth is 1.1 percentage points. Hardware capital deepening accounts for about 40 per cent of the labour productivity acceleration, whereas there was barely any increase in contribution from software capital deepening over the 1990s period. However, as in the US case, IT capital deepening was offset by lower use of other forms of capital per unit of labour. There was little or no increase in contribution from overall capital deepening.

Table 3 **Contributions to 1990s acceleration in US and Australia labour productivity growth**

Per cent per year

| | *US*[a] | *Australia*[b] |
|---|---|---|
| Labour productivity growth | 0.3 | 1.1 |
| Capital deepening | 0.1 | -0.1 |
| - ICT Capital | 0.3 | 0.4 |
| * Hardware | 0.3 | 0.4 |
| * Software | 0.1 | 0.0 |
| * Other | 0.0 | |
| - Other capital | -0.3 | -0.4 |
| MFP growth[c] | 0.3 | 1.1 |

[a] Growth in 1992 to 1999 less growth in 1986 to 1992. [b] Growth in 1993-94 to 1999-00 less growth in 1988-89 to 1993-94. [c] MFP growth for the US includes the contribution to labour productivity growth from labour quality.

MFP growth was therefore the major contributor to Australia's labour productivity acceleration. In the Australian case, little if any of the MFP growth would have come from ICT production industries, simply because Australia produces only small volumes of ICT equipment.

A comparison between the Australian and US results over productivity cycles reveals:

- The US labour productivity acceleration appears less impressive — 0.3 of a percentage point compared with 1.1 percentage points in Australia.
- The contribution of IT capital deepening is of the same order of magnitude in both countries — 0.3 of a percentage point in the US, compared with 0.4 of a percentage point in Australia.
- In both countries, the contribution of ICT capital deepening to the labour productivity acceleration is wholly or mostly offset by lower capital deepening with respect to other forms of capital. The acceleration in ICT use is offset by deceleration in use of other capital. The increased use of ICTs is not associated with any increase in the overall rate of substitution of capital for labour.
- The contribution of MFP growth is smaller in the US than in Australia — 0.3 of a percentage point in the US, compared with 1.1 percentage points in Australia.

## An industry perspective

The coincidence of industries in the US and Australia that are high both on ICT use and on productivity growth provides some further circumstantial evidence of a link between productivity growth and ICT use.

Several studies have found evidence of productivity acceleration in the 1990s in the following US industries: Wholesale trade, Retail trade and Finance, insurance & real estate (especially in financial intermediation). These have also been characterised as intensive users of ICTs.

Australian industry productivity growth rates estimated by the Productivity Commission show that, from a longer term perspective, the 'traditional' contributors to aggregate MFP growth in the 1970s and 1980s — Agriculture, Mining and Manufacturing, as well as Electricity, gas & water and Communication services — have been overshadowed in the 1990s by the 'new' contributors, especially Wholesale trade and Finance & insurance. The new contributors are relatively intensive users of IT.

High labour productivity growth would be associated with high IT use if the IT use brought high capital deepening and/or high MFP growth. These links among Australian industries are explored in chapter 5.

The existence of a link between IT use and MFP growth is of particular interest. However, there is increased scope for measurement error — of both IT use and productivity growth — at the industry level. With that qualification in mind, the investigation found:

- There is no strong, positive relationship between IT use and MFP across all industries.
- There is strong (above-average) positive relationship between IT use and MFP in Finance & insurance.
- There is also a positive relationship in Wholesale trade, depending on which measure of IT intensity is employed.
- Other industries show a positive relationship in only some measures — Communications, Construction, Retail trade, and Accommodation, cafes & restaurants.
- Community & recreational services is one industry that tends to be above average in IT use but is well below average on MFP measures. Electricity, gas & water had a large increase in IT as a share in total inputs, but showed a deceleration in MFP growth.

The lack of systematic relationship undoubtedly reflects the fact that IT use is not the only factor affecting industry MFP growth. To take just one example, it is highly unlikely that an increase in IT use led to a deceleration in MFP growth in Electricity, gas & water in the second half of the 1990s. It is much more likely that the deceleration reflects the fact that other factors (including government business enterprise reforms) promoted particularly strong MFP growth in the 1980s and early 1990s.

But the lack of a systematic relationship tends to signal that the productivity gains from ICT use are — for the moment at least — concentrated in distribution and financial intermediation.

On the other hand, there is some possibility that the relationship between IT use and productivity growth is more complex than the analysis allows. It may be that, in keeping with the general-purpose technology view, IT is at work, but other changes, complementary to the introduction of new IT, may be required to unlock substantial productivity gains. An earlier study by Productivity Commission staff suggests that this is true of the Wholesale trade industry (Johnston et al. 2000). One important finding in that study was that IT had facilitated a transformation of wholesaling in certain areas. It was not that wholesaling businesses had necessarily had to install large quantities of IT equipment. But IT, and particularly bar-coding and scanning technology, enabled businesses to streamline their processes, moving away from storage-based to fast flow-through systems and thereby reduce the need for additional storage (capital use) and handling (labour input). That is, IT could facilitate MFP gains through business restructuring and not necessarily by greatly increasing the IT intensity of operations. This example relates to a distribution industry, but the principle could also apply more generally.

The Wholesale industry example accords with a key insight from a review of US studies of IT use in firms. Brynjolfsson and Hitt (2000) found solid evidence of large cost savings from use of IT at the firm level. However, the gains varied between firms. They saw IT as a general-purpose technology that needs other complementary changes to maximise the gains from IT use. Short-term returns represent the direct effects of IT investment. But there are large and long-term gains that require: time to identify and implement changes; and complementary actions to reorganise firms, product lines, management practices, work arrangements and supplier relationships. Flexibility and adaptation are key ingredients. They state:

> As computers become cheaper and more powerful, the business value of computers is limited less by computational capability and more by the ability of managers to invent new processes, procedures and organisational structures that leverage this capability. (p. 24)

Thus, the gains may be linked directly to increased IT intensity in some cases (computer-based operations in Finance & insurance), but indirectly in others — subject to lags and complementary intangible investments in restructuring. In some part and in some further instances, MFP gains are likely to be unrelated to IT.

Whilst the productivity gains appear to be narrowly-based, the benefits are enjoyed by a wider range of industries. Many services, including distribution and financial intermediation, are used extensively by manufacturing and other industries (Simon and Wardrop 2001). And these linkages can be driving the changes in the service industries. The study of the Wholesale industry provided the example of the passenger motor vehicle industry, which looked for productivity improvements in all areas of the 'value network' in production, distribution and marketing, in response to sharper competition from cheaper imported vehicles (Johnston et al 2000). The productivity gains in Wholesaling, even though very large, were passed on, with profit margins declining in the 1990s (Parham et al 2000).

## Conclusions

Australia has already caught an ICT-based productivity wave. Australia was very quick on the uptake of ICTs in the 1990s by international standards. Part of Australia's strong productivity surge can be linked to ICTs.

Australia compares very favourably with the US in terms of the contributions of ICTs to labour productivity acceleration. The contributions of ICT capital deepening are very similar in the two countries, in both timing and magnitude of increase. Australia has had a stronger contribution from MFP growth, although pinpointing the amount due to ICTs is problematic.

Previous studies have overstated the underlying or long-term increase in labour productivity growth. The acceleration in US productivity growth found in this study over peak-to-peak productivity cycles is a more modest 0.3 of a percentage point, compared with the 1 percentage point or so found in other studies. However, whilst the 1 percentage point figure is too high, it could be argued that the 0.3 figure is on the low side. Another US productivity cycle is needed to be sure of the strength of the change in productivity trends. Previous Australian studies have also overstated the productivity acceleration.

Previous studies have also overstated the contribution of ICTs to productivity growth. Despite the rapid growth in use of ICTs, there has been little overall contribution from capital deepening in both countries over productivity cycles. The increased use of ICTs has substituted for increased use of other forms of capital. There has been no increase in the overall rate of substitution of capital for labour.

This leaves MFP growth to account for essentially all of the acceleration in labour productivity growth in both countries.

The big difference between Australia and the US lies in the strength of their respective productivity accelerations. Australia's underlying labour productivity growth accelerated by 1.1 percentage points in the 1990s (from 2.1 to 3.1 per cent a year). An acceleration in MFP growth of also 1.1 percentage points (from 0.6 to 1.7 percentage points) accounted for all of the labour productivity acceleration. The US labour productivity acceleration of 0.3 of a percentage point (from 1.5 to 1.9 per cent a year) was fully accounted for by MFP acceleration (from 1.0 to 1.3 per cent a year).

Australia's stronger productivity growth means that Australia benefited more from one or both of two factors:

- Australian firms benefited more from the uplift in use of ICTs. This does not necessarily mean that Australian firms have sprinted ahead of their American counterparts. And it is also unlikely that ICTs would have had stronger direct effects in Australia than in the US. It is more likely that Australian industries have had more scope to undertake substantial business restructuring — an indirect effect of ICTs — to catch up on ground previously lost.
- Australia could have benefited more from non-ICT factors. The effect of policy reform is an obvious possibility in areas such as government business enterprises (PC 1999). Whilst relatively intensive IT-using industries contributed most to Australia's productivity surge in the 1990s, even in those industries, some of the gains are likely to be due to factors such as industry-specific deregulation and broadly-based industrial relations reforms (as the Wholesaling case illustrates).

Some detailed comparisons would be needed to distinguish conclusively between these two possibilities. But catch-up and greater incentives and flexibility to restructure are likely to be prominent.

What is clear is that production of ICTs is not necessary to generate productivity gains. Both the US and Australian experience demonstrate that productivity gains also come from the *use* of ICTs. The US received an MFP contribution of up to 0.3 of a percentage point from ICT production (although the contribution to trend productivity growth may be lower). Australia generated a productivity acceleration of 1.1 percentage points from use of ICTs and other factors. From a community welfare point of view, it is the productivity gains that count and not necessarily in which industries they are generated.

The coincidence of industries in both the US and Australia that are both relatively intensive IT users and strong productivity performers provides some further evidence to link IT with productivity growth.

But this evidence also suggests that the links are concentrated — at least at this stage — in industries in distribution and financial intermediation.

This in turn suggests that, to the extent that ICTs are linked to MFP gains, the productivity gains are unlikely to be spillovers from network economies. One would expect evidence of network economies to be stronger in the US than in Australia (although the time periods used are too early to catch the take-off in e-commerce at the end of the 1990s). Yet, the productivity gains are stronger in Australia. Further, one might expect network effects to be broadly-based rather than concentrated in a few industries.

Finally, there must be some caution about drawing very strong conclusions from growth accounting analyses in this area, given a range of measurement issues and, arguably, some limiting assumptions. This study has pointed to the need for accurate prices of ICTs and cost shares and related income flows attributed to ICTs. These are complex areas to discover the magnitudes of error, let alone find ways to make improvements.

## Implications

A major implication from this study is that it is not necessary to pursue a strategy of producing ICT equipment in order to generate 'new economy' productivity gains.

Australia does not have a large ICT production sector and has instead relied on importing most of its ICT requirements. Relying on imports in the context of rapidly declining world prices of ICT equipment has produced a terms of trade gain in Australia's favour, all other things equal, boosting the real incomes of Australians.

Even if there is uncertainty about the true measure of price changes, Australia is still in a position to benefit. More rapid price declines would accentuate the terms of trade gains, while less rapid price declines would accentuate the MFP gains from use. Either way, Australia would enjoy welfare gains.

Whether Australia could generate productivity gains from substantial ICT production (aside from niche areas, particularly in software) would depend on whether Australian-based firms could generate substantial technological advances in ICT production, especially in microprocessors, and could generate adequate returns in a competitive world market with rapidly declining prices.

Facilitating greater use of ICTs would appear to be a surer way for an economy like Australia's to bring productivity and other welfare gains. Providing greater flexibility to enable firms to restructure in appropriate ways also helps to tap the full potential that ICTs offer. Facilitating use also makes sense in the context of a general-purpose technology. It can enhance the ability of firms and researchers to generate further innovations.

With the rapid uptake of ICTs in the 1990s and complementary restructuring of firms, Australia also appears well placed to take advantage of further ICT-based gains. These could occur incrementally as firms adapt and innovate further. Or it could be that network effects or related e-commerce developments start to deliver substantial productivity dividends.

Policy reforms have likely played a major role in facilitating the uptake of ICTs and business restructuring. The uptake of ICTs or other new technologies does not happen automatically. Australia has been very quick on the uptake of ICTs in the 1990s, compared with its own history (see PC 1999) and compared with many other high-income countries. Uptake of ICTs can be seen as a proximate factor in aggregate productivity growth, but other underlying factors are necessary to drive the uptake of ICTs and ensure that they are used in ways that generate the most advantage.

Other work at the Productivity Commission (for example, PC 1999 and Johnston et al 2000) supports the view that microeconomic reforms have played a key role in providing incentives, principally through competition, to be more productive. Responses have included the quick uptake of ICTs. Moreover, reforms have also provided greater flexibility for businesses to restructure in ways that enhance the productivity gains from using ICTs.

# 1 Introduction

As could be expected, growth rates differed across high-income countries in the 1990s. But growth rates did not conform to an established pattern of catch-up and convergence, whereby 'follower' countries show relatively rapid growth in catching up to the 'leader' country or countries.

The OECD (2000a) identified a small group of countries that grew more rapidly in the 1990s compared with both other countries and their own performance in the 1980s. The group included Australia, Denmark, Ireland, the Netherlands, Norway and, importantly, the US — the country usually considered as the 'leader' in levels of productivity and GDP per head. Ireland's very strong performance can be attributed, in part, to catch up. But the strong performance of other countries in the group cannot be attributed simply to catch up. They had little or no more scope to catch up than other countries — such as Japan, Germany and France — that showed weak growth in the 1990s. Overall, the pattern of countries' growth rates in the 1990s implied greater divergence, rather than convergence.

While the underlying determinants may have differed across countries, the OECD identified two proximate sources of growth common to the high-growth group of countries. There were increases in rates of labour utilisation (the rate at which the population is actively engaged in work) and increases in productivity growth (OECD 2000a). The acceleration in productivity growth is the prime focus of this paper.

## 1.1 The dawn and demise of the 'new economy'?

The acceleration in US productivity growth in the second half of the 1990s has attracted much attention. The productivity uplift came at a stage in the business cycle when a slowdown in output and productivity growth would normally be expected.

There has also been particular interest in the role that computers — and information and communication technologies (ICTs) in general — played in sustaining the strong US performance. The US productivity acceleration coincided with an acceleration in advances in ICTs, investment in ICT equipment and the takeoff in the wider use of the Internet.

The role of ICTs in promoting productivity and output growth is of considerable interest to other countries as well. As a productivity leader, the US economy does not catch up — it is at the forefront. The US economy essentially relies on technology breakthroughs to step up its rate of productivity growth. If a new way to increase productivity growth is found in the US, it raises the prospects for other countries to follow and ride on a new productivity wave.

The unexpectedly strong performance of the US economy in the latter part of the 1990s ignited talk of a 'new economy' paradigm. Unfortunately, the new economy concept does not have a clear or unambiguous meaning. Stiroh (1999) divined three different, but related, expressions of the new economy concept, all within an underlying theme of increased globalisation and expanding (information) technologies as key drivers of structural change in the economy:

- A long-run growth version emphasises stronger productivity growth that allows the economy to grow faster without inflationary pressures.
- A business-cycle version suggests that the short-run tradeoff between inflation and unemployment has changed, allowing low unemployment to co-exist with low inflation.
- A sources-of-growth version emphasises the nature of the information age and the role of ICTs in generating network economies, increasing returns and spillover benefits that change the way an economy grows.[1]

To the extent that computers have been identified with new economy phenomena, early expressions put emphasis on the *use* of computers. For example, Federal Reserve Board Chairman, Alan Greenspan, identified a number of ways in which he considered the more widespread use of computers and computer networks enable greater efficiency. According to Greenspan, ICTs and associated networks allow: greater certainty — through the availability of more real-time information about customers' demands and the location of inventories and materials flowing through complex production systems — which leads to less wastage from extra production, extra inventories and extra staff; more efficient and compressed distribution processes; the development of financial instruments to manage risks; and lower search and transactions costs in business-to-business transactions (Greenspan 2000a,b).

[1] The Council of Economic Advisors (CEA 2001) has linked the new economy phenomenon to a number of these elements. It points to four exceptional features of the US economy — strong productivity growth, co-existence of lower unemployment and low inflation, the disappearance of government budget deficits, and the strength of US growth compared with other countries (despite its already leading position). They attribute these features to technological innovation, organisational changes in businesses and public policy.

However, a series of academic studies (outlined in chapter 4) pointed to the importance of productivity gains in the *production* of ICTs. While investment in ICTs was shown to raise labour productivity by raising the amount of capital per hour of labour input, the studies did not provide strong evidence of efficiency gains from the *use* of computers. Gordon (2000b), in particular, attributed *all* of the acceleration in US (multifactor) productivity growth he identified to productivity gains in computer production.

Perhaps influenced by this view, the emphasis in some new economy discussions narrowed onto the *supply* of technology, knowledge and information. But the underlying interest tended to be more on information technology start-up companies and their prospects as a destination for investment. The link to productivity growth and economywide gains, from this narrow new economy perspective, became tenuous or lost.[2]

Some of the interest in the new economy, from this narrow perspective, has now waned as technology stock prices have tumbled. Similarly, some have said that the recent slowdown in the US economy signals that new economy claims about the economy now behaving differently have been proven wrong. However, while some perspectives have been narrow and short term in focus, and some new economy claims have been extreme, a central issue of whether the production and use of ICTs contributes to an increase in the longer-term rate of productivity and output growth, remains quite relevant.

## 1.2 Australia and the new economy paradigm

Australia had a particularly strong increase in productivity growth over a long period in the 1990s. Multifactor productivity (MFP) growth was at an annual average rate of 1.7 per cent over the six years from 1993-94 to 1999-00 — well above its prior annual average of 0.9 per cent. Whilst this increase comforms with a central criterion in the broad expressions of the new economy paradigm — a trend uplift in productivity growth — the link to the ICTs and globalisation theme has not been firmly established. (Edwards (1999) and Parham (1999) used the ‘new economy’ term to capture the shift toward a more productive Australian economy.)

In the midst of a fluid discussion and debate, Australia has been labelled in some quarters as an ‘old economy’. This is according to the ‘narrow’ new economy criterion, focusing on the importance of ICT companies in economic supply (or perhaps, more specifically, in stockmarket capitalisation).

[2] The International Monetary Fund (IMF 2000) provides an insight into stockmarket behaviour in regard to technology stocks.

Australia's surge in productivity growth came before the US acceleration, suggesting that different factors were at work — at least in the initial years. A package of microeconomic policy reforms is generally considered to have played an important role (PC 1999). Nevertheless, in contrast to earlier decades, the uptake of the latest technologies in Australia has been quite strong in the 1990s. In this context, the use of new technologies could be seen as an immediate or proximate source of stronger productivity growth; and policy reforms could be seen as underlying determinants that shape an environment more conducive to the adoption of new technologies and other productivity enhancements. In short, a more open and competitive and less-regulated business environment provides greater incentives and flexibilities for firms to move toward 'best practice'.

The role of ICTs in Australia's strong economic performance of the 1990s has not been as thoroughly examined as the US case. Wilson (2000) has studied the uptake of information technology in Australia, for comparison with academic studies of the US (reviewed in chapter 4 of this paper). The Wilson study is not widely available, although the Australian Treasurer has released its key findings (Costello 2000). The thrust of Wilson's findings is that, so far, investment in information technology in Australia has played an important, but lesser, role than in the US.

This reinforces a view that Australia's adoption of technologies in the 1990s is more about catching up on ground that was lost in previous decades by failing to adopt new technologies and management and work practices (PC 1999). According to this view, if a new frontier of technology-related productivity growth has opened up in the US economy, this new source of productivity growth may still lie ahead for the Australian economy.

But there are other views. On the one hand, Reserve Bank of Australia research presented by Gruen (2001) finds a stronger role for the adoption of ICTs in Australia's productivity acceleration — stronger than the contribution found by Wilson and stronger in some respects than the contribution found in the most commonly cited study of the US. (The Wilson and Reserve Bank studies are examined in chapter 5.) According to this view, Australia has already caught the new (ICT) productivity wave — through the *use* of ICTs.

Against this, the Australian Industry Group (AIG 2000) downplayed expectations about a continuation of very strong productivity growth in Australia. It saw Australia's productivity surge as a static or 'step-up in levels' response to past microeconomic reforms, that are now on the wane. It did not see any prospect for Australia to catch a new ICT wave, because it read the US evidence as saying that *production* of ICT equipment (of which there is little in Australia) — and not *use* — holds the key to an ICT-led productivity acceleration.

Clearly, there are some arguments and evidence to be sorted out to determine the past and potential future role of ICTs in Australia's productivity performance. Better understanding of these roles can help guide policy formation on information and related technologies.

## 1.3 Objectives and scope of the paper

The objective of this paper is to examine the role of ICTs in Australia's productivity growth and to compare the strength of that role with observations of the US. A related objective is to form a view on whether the US experience suggests that a second ICT-related wave of productivity acceleration lies ahead for Australia (or is already in evidence) and whether the production or use of ICTs is essential to catch that wave.

The next chapter outlines the international picture on ICT production and use. The aim is to show how Australia compares with other countries in the production and use of ICTs.

Chapter 3 outlines the growth-accounting framework and other aspects of the methodology used to assess the contribution of ICTs to output and productivity growth.

Chapter 4 reviews the US evidence on the role of ICTs in output and productivity growth. Major academic studies are well known. But more recent evidence from official sources paints a picture that differs in important ways.

The role of ICTs in Australia's acceleration in output and productivity growth is examined in chapter 5.

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# 2 Australia's production and use of ICTs

This chapter compares Australia's production and use of information and communication technologies (ICTs) with those of other high-income economies. Some crucial measurement issues are examined in the next section, before examining international data, mainly from the OECD. These show Australia to be comparatively high on various measures of ICT use, but low on ICT production.

The details of some of the material presented in this chapter are presented in appendix A.

## 2.1 Measurement of ICTs

There are two crucial questions concerning the measurement of ICTs:

- What is the industry coverage? Different studies use different industry and product definitions. This can affect measures of the size of production sectors and the extent of use. Unavoidably, different definitions are used in different parts of this study:
  - The OECD, which attempts to harmonise definitions across countries to assist international comparisons, defines ICTs to include both *equipment* and *service* components of ICT production.
  - The definition used in US studies of ICTs (reviewed in chapter 4) covers ICT equipment, but not the provision of ICT services (for example, telecommunication services are excluded).
  - The study of the Australian case in chapter 5 is confined by data availability to information technology (IT) equipment and excludes communications equipment and services.[1]

[1] Other studies also differ on the inclusion of computer software, as well as hardware, and whether household use is included along with business use. In the 'contribution' studies in chapters 4 and 5, both hardware and software are included, but (with one exception) only business use is examined.

- Which type of price deflator is used to calculate volumes of ICTs produced and purchased? Some studies use 'hedonic prices', which take account of quality improvements in ICTs. Given rapid advances in computer and communication technologies, use of hedonic prices makes a substantial difference to the estimation of volume trends.

Because the hedonic price method is so important to the measurement and interpretation of ICT trends, it is now discussed in some detail.

### Hedonic prices

ICT equipment embodies often substantial improvements in technical characteristics. For example, there are improvements in processing speed and memory capacity in different generations of microprocessors — a Pentium III versus a Pentium IV.

Technical improvements in ICTs are made quite rapidly. 'Moore's Law' says that the capacity of semiconductors doubles every 18 months to 2 years. This implies exponential growth of chip capacity at 35-45 per cent per year (Jorgenson 2001). The pace of technical advances may have accelerated even further in the 1990s.

A true measure of the quantity of capital assets produced and purchased makes allowance for the additional characteristics embodied in new equipment. For example, suppose that a computer purchased today is twice as powerful as a computer purchased two years ago. Then today's computer would be *two* computer-equivalents measured in terms of the old computer's power. Failure to allow for such improvements would understate (severely in the case of computers) the volume of capital capacity used in production.

Technical improvements are incorporated into capital measures through the use of hedonic price deflators. Hedonic prices capture constant-quality movements in asset prices. Thus, deflating current price expenditure on ICTs by a hedonic price index produces a volume measure of ICTs that excludes the effects of pure price inflation but includes improvements in quality.

To continue the above simple example, assume that the nominal expenditure on the old and new computer is the same. If a standard equipment price deflator showed a 10 per cent increase in price and was used as the ICT price deflator, the real volume of investment in computers would be measured as decreasing by around 10 per cent with the purchase of the new computer. In contrast, an hedonic price index, allowing for technical improvements, would have decreased by around 50 per cent (since twice the computer power is available for the same nominal price). Using an hedonic price deflator would show an approximate doubling in the volume of computer investment. The volume measure has the interpretation of investment in computer power, rather than investment related to expenditure or number of computers purchased.

In practice, quality-adjusted prices of ICTs have declined rapidly, both absolutely and compared with other prices. Nominal equipment prices have been static or only moved reasonably slowly, while technical improvements have been incorporated very rapidly. The constant-quality prices of computers have been falling in the US by around 18 per cent a year from 1960 to 1995. This decline has accelerated to 27.6 per cent per year since 1995 (Jorgenson and Stiroh 2000a).[2]

The implication is, of course, that the measured volume of ICTs produced and purchased for use in production has grown to a much greater extent than nominal expenditure and production figures would suggest.

Hedonic prices are difficult and expensive to construct, requiring detailed knowledge of technological characteristics and advanced statistical and econometric techniques. The Bureau of Economic Analysis (BEA) constructs hedonic prices for computers (separate hardware and software indexes) in the US and the Bureau of Labor Statistics (BLS) uses these indexes in estimating the input of ICTs in its productivity calculations.[3]

The Australian Bureau of Statistics (ABS) also uses hedonic prices for computers in its Australian calculations. The ABS uses the same BEA hedonic price indexes for computer hardware, adjusted for movements in the US/Australian exchange rate, and with a lag. The implicit assumptions are that computer hardware is available at world prices in Australia and that US computer prices represent world prices.[4] The ABS uses the adjusted BEA deflator back to the 1960s (ABS 2000a). The Australian and US price indexes are displayed in figure 2.1.

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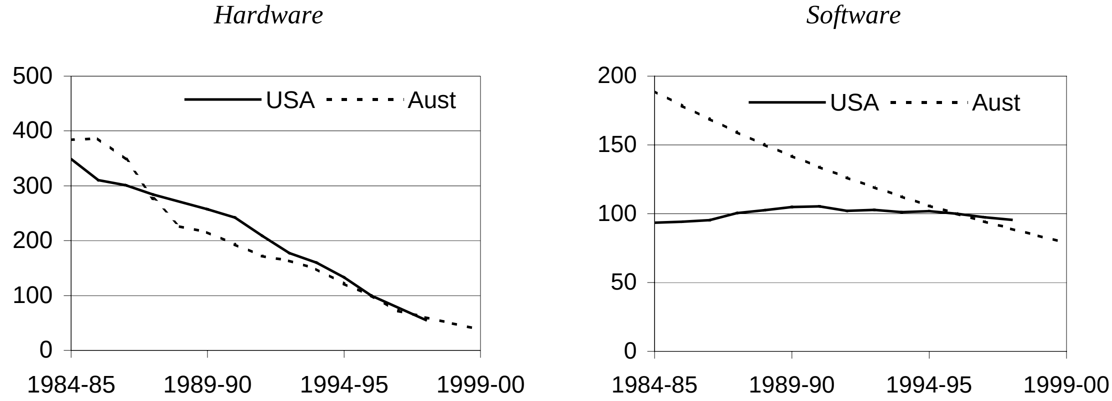
[2] Jorgenson (2001) gives an overview of technological developments and statistical treatment in the US. See also Jorgenson and Stiroh (2000a), who argue that the US price index for software, which only started to decline by around 2 per cent a year from the late 1980s, understates the true constant-quality rate of price decline.

[3] Jorgenson (2001) notes that the BLS has only incorporated constant-quality prices for computer hardware and semiconductors in the 1990s, without backcasting through historical data. However, information from the BLS website suggests that BEA price indexes for computers have been backcast to at least 1970.

[4] This approach would introduce a bias if Australia imported computers from other countries that did not maintain exchange rate parity with the US; or if there were a variation in any trade restrictions on the importation of hardware or software into Australia.

## Figure 2.1 **IT price index**

Index 1995-96 = 100




*Data source:* Unpublished ABS data, and BLS.

The ABS departs from the comparable US practice in its use of software price indexes. The ABS uses a Canadian deflator, which shows a 6 per cent a year decline in software prices. This estimate is constructed by observing the trend in software prices over time for popular PC software (ABS 2000a). Some consider the US deflator to understate the true extent of software price declines (see footnote 2).

The use of hedonic prices in other countries varies, often confounding international comparisons. For example, hedonic prices are used in the US, Canada, Japan and partly in France, but not in Germany (Schreyer 2000). To combat this and to control for some of the international differences in deflation methods which might affect the comparability of results, a 'harmonised' price index was introduced and used by Schreyer (2000). It has also been used in other OECD work and notably in the major comparative study (OECD 2001b) that is drawn upon in the next section.[5]

[5] The harmonised price index is based on the assumption that the differences between price changes for ICT capital goods and non-ICT capital goods are the same across countries. It is an 'average' price deflator for each country to facilitate international comparisons. Such a methodology for deflation might introduce other biases as it ignores all cross-country differences in real ICT prices that reflect differences in composition of ICT investment and pace of changes in real ICT prices due to market barriers, impact of government regulations and tax systems. To date, however, the extent of these barriers cannot be established. It was felt that they were smaller than the biases incurred by choosing national deflators that were manifestly based on very different methodologies (Schreyer 2000).

## 2.2 Indicators of production and use of ICTs

### An OECD view

In the last two years, the OECD has published several reports which contain comparisons of ICT investments, ICT production and usage across OECD countries.

*The production of ICTs*

In a report entitled *Measuring the ICT Sector*, the OECD (2000c) used four indicators — value added in ICT production, employment in ICT production, research and development (R&D) intensity in the ICT sector and trade of ICT goods and services, to compare production of ICTs across countries. The ICT production sector is defined to include production of ICT equipment and services (see box 2.1).

Box 2.1 **The OECD definition of the ICT sector**

The OECD's definition of the ICT production sector covers the following ISIC industry classifications.

*Manufacturing*

3000 - Office, accounting and computing machinery

3130 - Insulated wire and cable

3210 - Electronic valves and tubes and other electronic components

3220 - Television and radio transmitters and apparatus for line telephony and line telegraphy

3230 - Television and radio receivers, sound or video recording or reproducing apparatus, and associated goods

3312 - Instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process equipment

3313 - Industrial process control equipment

*Services – goods related*

5150 - Wholesaling of machinery, equipment and supplies

7123 - Renting of office machinery and equipment (including computers)

*Services – intangible*

6420 - Telecommunications

7200 - Computer and related activities.

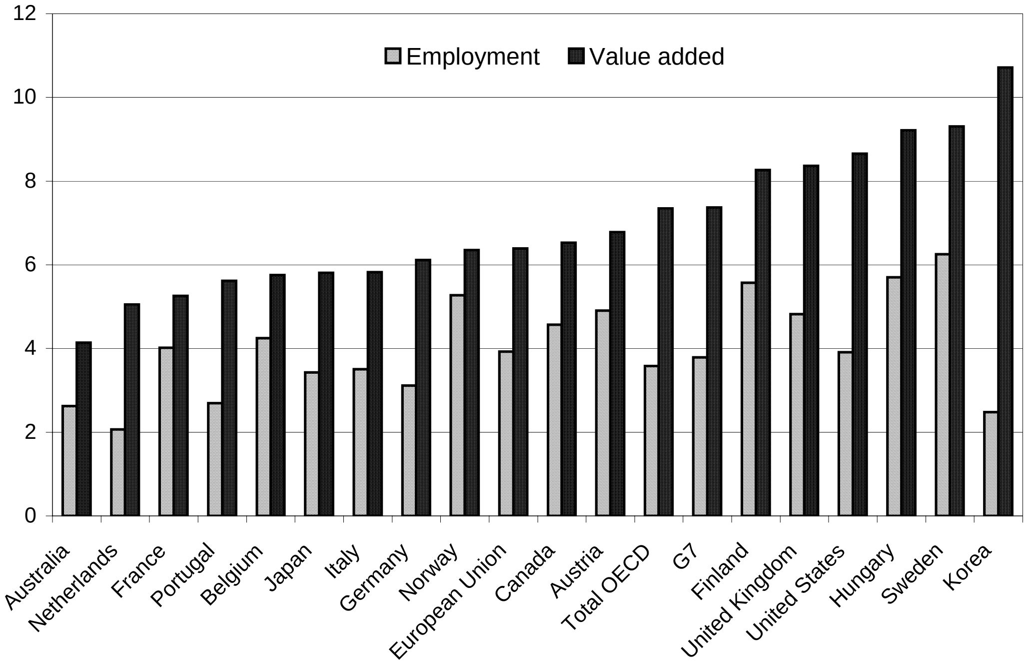
Source: OECD (2000c).

The main points in relation to Australia's ICT sector, in comparison to other OECD member countries, are as follows:

- Australia's ICT production sector is relatively small, as measured by the contribution of the ICT sector to GDP.
  - In 1998-99, Australia's ICT sector (production of both equipment and services) accounted for 4.1 per cent of the total value added in the business sector (measured in $US purchasing power parity). This was significantly below the OECD average (7.4 per cent for 1997) and the US figure (8.7 per cent). (See figure 2.2.)
  - Australia's ICT sector is primarily oriented towards services, with telecommunications (55.3 per cent of ICT value added) and other ICT services (41.3 per cent of value added) predominating.
- Australia ranks low in terms of employment in the ICT sector as a proportion of total employment in the business sector.
  - The ICT share of the total business sector's employment in Australia was 2.6 per cent in 1998-99 — well below the OECD average (3.6 per cent for 1997) and the US share (3.9 per cent). (See figure 2.2.)
- Australia's R&D in the ICT sector ranks at a medium level.
  - Australia's R&D expenditure by the ICT sector as a share of total business sector R&D was nearly 27 per cent in 1998-99. This is lower than the OECD average (35 per cent), but is slightly higher than the average for the European Union (24 per cent).
- Australia relies on imports of ICT equipment from overseas. The ICT trade balance (goods and services) has been in deficit since 1990. However, ICT exports have grown faster than ICT imports, with ICT services trade showing a surplus. The ICT services trade accounted for 40 per cent of the value of total ICT exports, and for 10 per cent of ICT imports in 1998.

Figure 2.2 **Shares of ICT in total business sector value added and employment, selected OECD countries, 1997**

Per cent




*Data source*: OECD (2000c).

### *Use of ICTs*

The OECD does not provide a general international rating for member countries in use of ICTs. However, the OECD provides comparative information on ICT usage in the following publications: S*cience, Technology and Industry Outlook 2000* (OECD 2000e), *A New Economy? — The changing role of innovation and information technology in growth* (OECD 2000a) and *OECD Information Technology Outlook 2000* (OECD 2000b). Indicators in these sources suggest that Australia is in the medium to high range of ICT users.

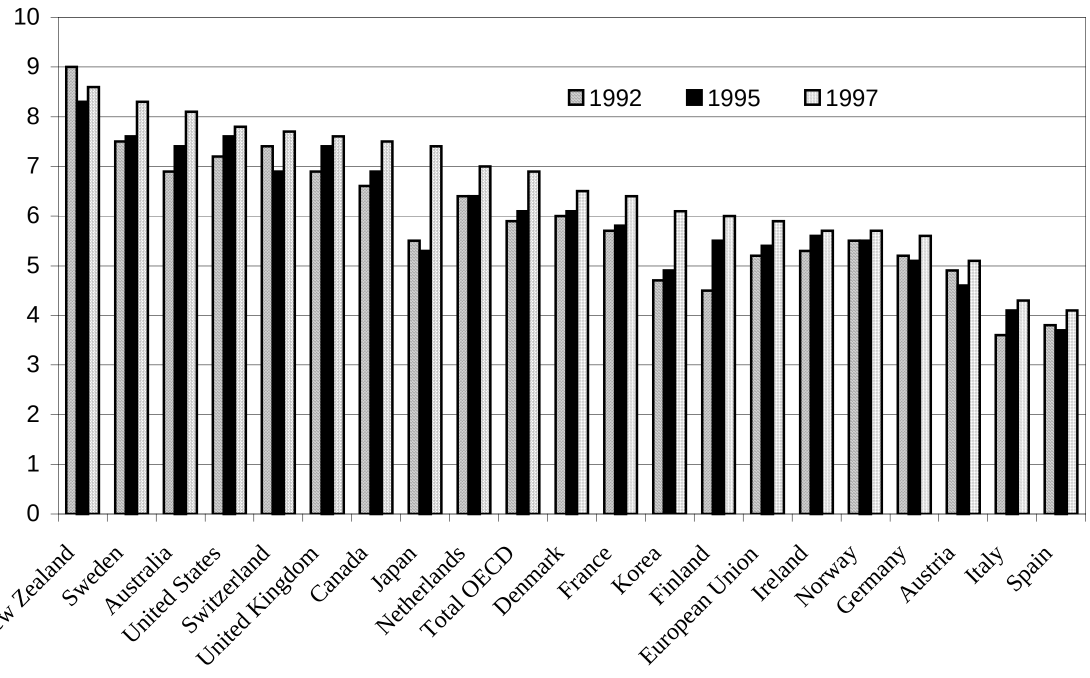
### *Australia ranks high on ICT expenditure as a percentage of GDP*

The overall expenditure on ICT goods and services by both business and households increased markedly in Australia and other OECD economies in the 1990s.

- Total expenditure on ICTs, including IT hardware, software and services and telecommunications equipment and services, surged in the 1990s. ICT expenditure as a percentage of GDP in Australia increased from 6.9 per cent in 1992 to 8.1 per cent in 1997. This was next only to New Zealand (8.6 per cent) and Sweden (8.3 per cent), and was higher than the US proportion (7.8 per cent) and the OECD average (6.9 per cent). (See figure 2.3.)

- For the period 1990 to 1999, ICT investment in Australia grew at an annual rate of 14.8 per cent (at constant prices based on the harmonised ICT price index), which was in the middle of the OECD range. This is slower than the rate for the US (17.7 per cent) and France (15.5 per cent), but is higher than many other OECD countries (OECD 2001b and OECD 2000d).
- Based on nominal price data, the share of ICT equipment and software investment in non-residential gross fixed capital formation in Australia was 20.8 per cent in 1999, which was behind Finland (36 per cent) and the US (31.7 per cent), but higher than many other OECD countries (OECD 2001b).

Figure 2.3 **ICT expenditure as a percentage of GDP, selected OECD countries**
Per cent




*Data source:* OECD (2000e).

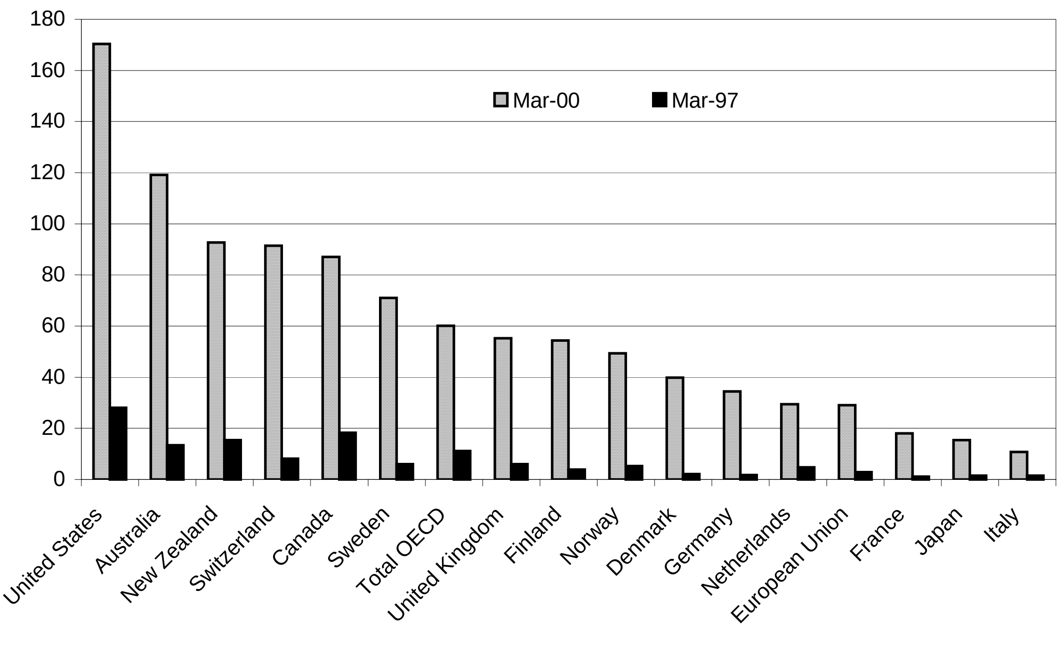
*Business use of ICTs in Australia is at a medium to high level in the OECD range*

- In Australia, over 76 per cent of businesses used computers in the workplace, 56 per cent had Internet access, and 16 per cent had a website or home page in 1999-00.

- Australia is in the middle of the OECD range of proportion of employees who use electronic commerce enabling technologies (50 to 65 per cent of employees), with 57 per cent of employees in businesses using websites and the Internet for e-commerce. This compares with 65 per cent for the US (OECD 2000b) (see figure 2.7).
- In terms of usage of secure web servers for e-commerce, Australia is in the top three of the OECD range. In March 2000, the density of use of secure websites per million inhabitants was 119 in Australia, next only to Iceland (194) and the US (170). This was much higher than the OECD average (60) (OECD 2000e). (See figure 2.4).

Figure 2.4 **Secure web servers for electronic commerce in selected OECD countries**

Density per million inhabitants



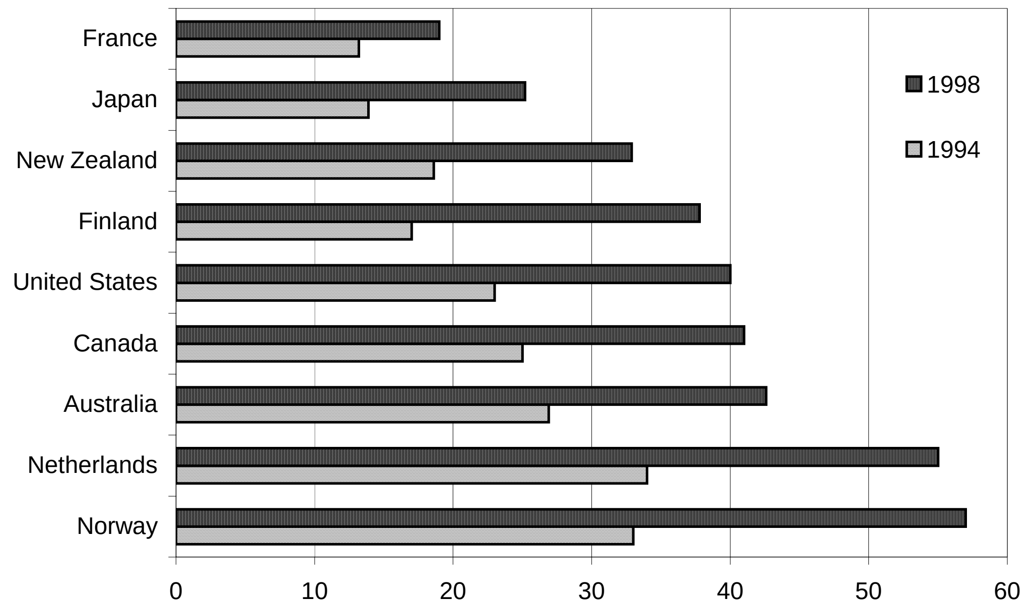

*Data source:* OECD (2000e).

*Household use of ICTs in Australia is ranked at the medium to top level of the OECD range.*

- In 1998, 42 per cent of Australian households owned computers, compared with 40 per cent in the US (figure 2.5).
- Australia is also ranked in the middle of the OECD range in terms of Internet penetration. Internet users per 1000 inhabitants in Australia were 55 in 1999. This compares with 160 in the US and 23 in the European Union (see figure 2.6).

Figure 2.5 **Percentage of households owning a personal computer in selected OECD countries**

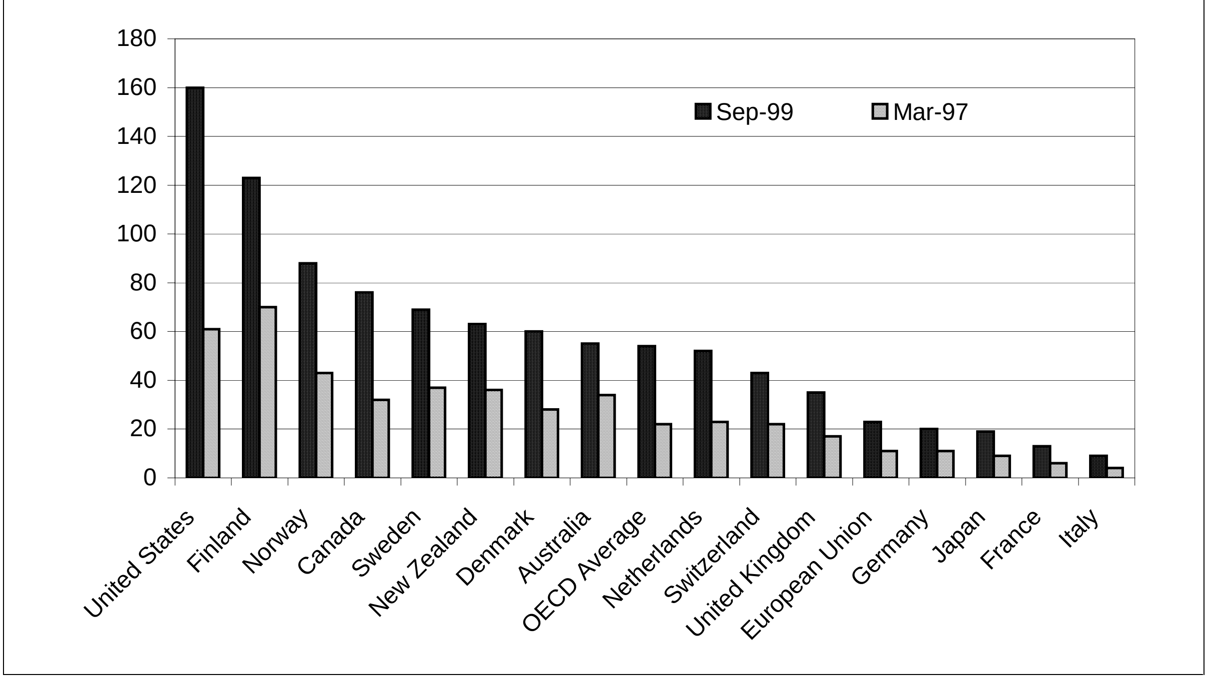
Per cent




*Data source:* OECD (2000e).

Figure 2.6 **Internet penetration in selected OECD countries**

Per 1000 inhabitants




*Data source:* OECD (2000e).

## Other international indicators

The International Data Corporation (IDC) is another source of information on international comparisons. It presents a comprehensive international comparison and ranking of 55 countries in uses of ICTs, using a composite Information Society Index (ISI) and ICT infrastructure indices.

### *IDC indices*

Using OECD databases and national statistics published by each country, the IDC (in co-operation with the *World Times*) has established comprehensive indexes since 1997 to measure the penetration of ICTs in various countries. Its *IDC/World Times Information Society Index* covers 55 countries including all OECD countries and some other countries such as China, India and Singapore. The Information Society Index (ISI) index has four sub-indexes covering a computer infrastructure index (6 variables), an Internet infrastructure index (4 variables), an information infrastructure index (8 variables), and a social infrastructure index. The first three indexes are combined as an ICT infrastructure index (see box 2.2 for details of the definition and coverage of each index).

The major findings about ICTs in Australia compared to other countries are:

- Australia was ranked eighth in the world for overall ICT infrastructure in 2000, while Sweden, Norway and Finland were ranked first, second and third respectively. The US has slipped from the second to the fourth place since 1999 (IDC 2001).
- Australia makes it into the top three in computer and Internet infrastructure next to Sweden and Singapore, whereas the US was ranked tenth in this category.
- Australia was ranked second behind the US in the density of secure web servers for electronic commerce in 2000 (IDC 2001).

**Box 2.2 Definition of ICT infrastructure index**

The IDC has developed an Information Society index, which includes ICT infrastructure measures. There are three ICT related sub-indexes – computer infrastructure index, Internet infrastructure index and information infrastructure index, plus one social infrastructure index. The variables used to compose these indexes are:

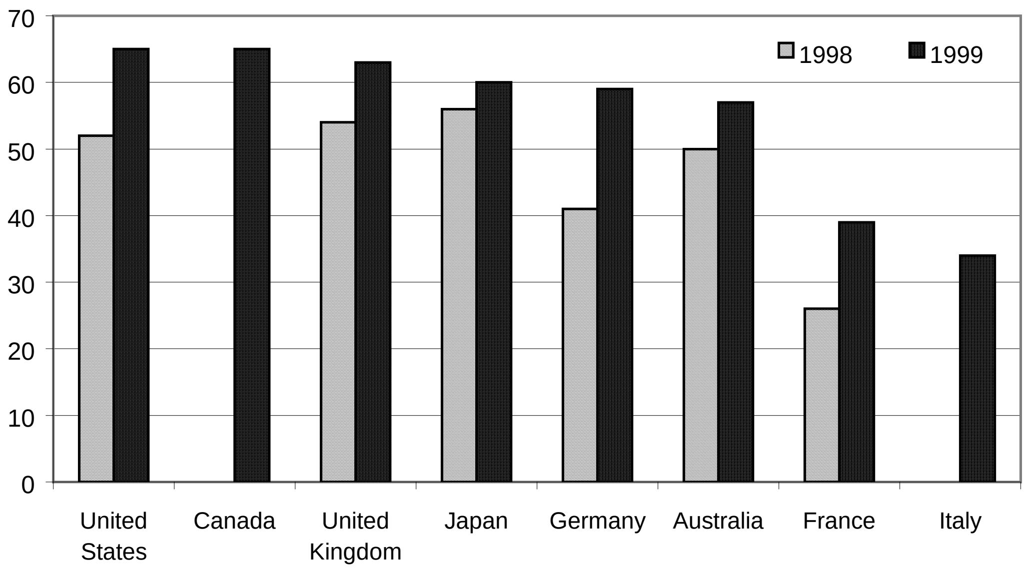
- Computer infrastructure index
  - PCs installed per capita
  - Home PCs shipped per household
  - Government and commercial PCs shipped per non-agricultural worker
  - Educational PCs shipped per student and faculty
  - Percent of non-home networked PCs
  - Software vs, hardware spending
- Internet Infrastructure index
  - Business Internet users per non-agricultural workforce
  - Home Internet users per household
  - Education Internet users per student and faculty
  - E-commerce spending per total Internet users
- Information infrastructure index
  - Cable subscribers per capita
  - Cellular phone ownership per capita
  - Cost per phone call
  - Fax ownership per capita
  - Radio ownership per capita
  - Telephone line error rates
  - Telephone lines per household
  - TV ownership per capita
- Social infrastructure index
  - Civil liberties
  - Newspaper readership per capita
  - Press freedom

*Source:* IDC (2001).

### *Other sources of international indicators*

E-commerce has grown rapidly in Australia, although it is still at an early development stage. The estimated total value of sales/orders via the Internet was $5.1 billion in Australia in the 1999-00 financial year, accounting for 0.4 per cent of total sales of goods and services (ABS 2000b). In the US, 1.01 per cent of retail sales are e-commerce sales (BEA 2001). According to a Sanders and Temkin (2000) forecast, the value of sales in Australia via the Internet will grow to reach $207.6 billion or 16.4 per cent of total sales by 2004. This compares with 13.3 per cent forecast for the US.

Figure 2.7 **Percentage of employees using e-commerce enabling technologies[a]**




[a] E-commerce enabling technologies are websites, frequently used EDI or external e-mail..

*Data source:* UK Cabinet Office (1999) for G-7 data, and ABS (2000c) for Australian data.

## Domestic indicators

The ABS published three reports on ICTs in Australia in 2000: *Information Technology Australia 1998-99* (ABS 2000d), *Business Use of Information Technology Australia 1999-2000* (ABS 2000b) and *Household Use of Information Technology Australia 1999* (ABS 2000c). These statistical reports provide additional information on use and production of ICTs in Australia.

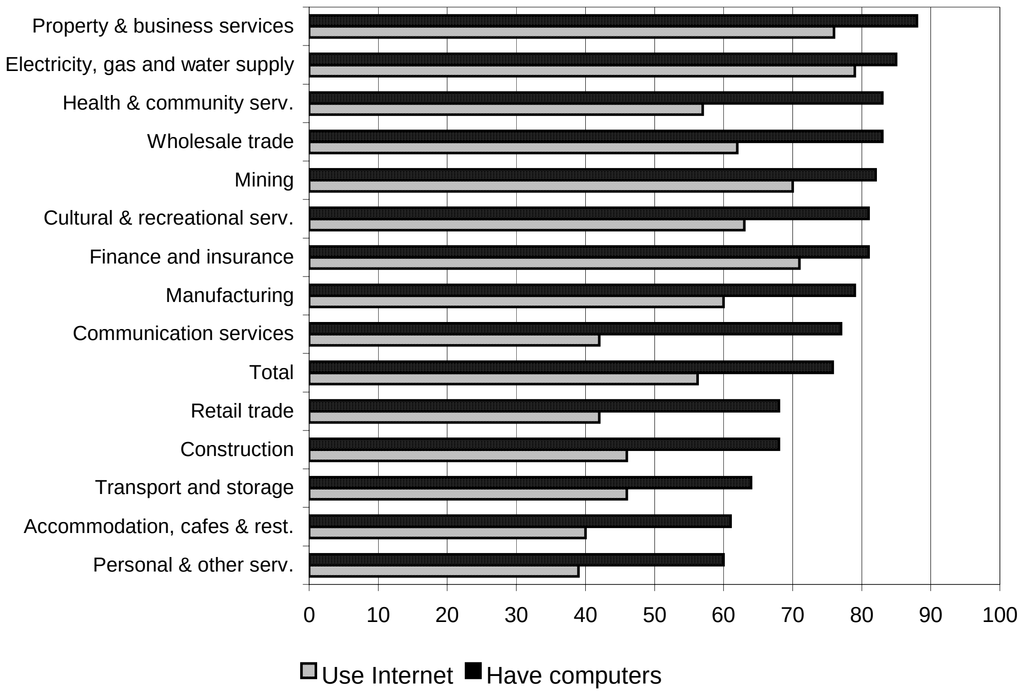
The additional points derived from these reports, apart from those presented in OECD publications, include:

- Over 76 per cent of Australian businesses used computers in 1999-00, and 56 per cent of businesses had Internet access, with 16 per cent of businesses having websites or homepages. This compares with 82 per cent of businesses using computers and 53 per cent of businesses having Internet access and 22 per cent of businesses with a website or homepage in Canada in 1999 (ABS 2000b).

- Business use of ICTs in Australia varies across industries. Mining, Property & business services, Wholesale trade, Communication services, Finance & insurance, Cultural & recreational services and Manufacturing industries use computers and the Internet more intensively than other industries (figure 2.8).
- Business use of ICTs also varies with firm sizes. In 1999, all firms with 100 or more employees used computers and over 90 per cent of them used the Internet. Over 90 per cent of firms with 20-99 employees were equipped with computers and the Internet, and over 80 per cent of small firms with 5-19 employees used computers and the Internet (see figure 2.9).
- Usage of computers and the Internet in Australian households varies in line with family income levels. In general, families with higher income have greater access to computers and the Internet at home, as shown in figure 2.10.

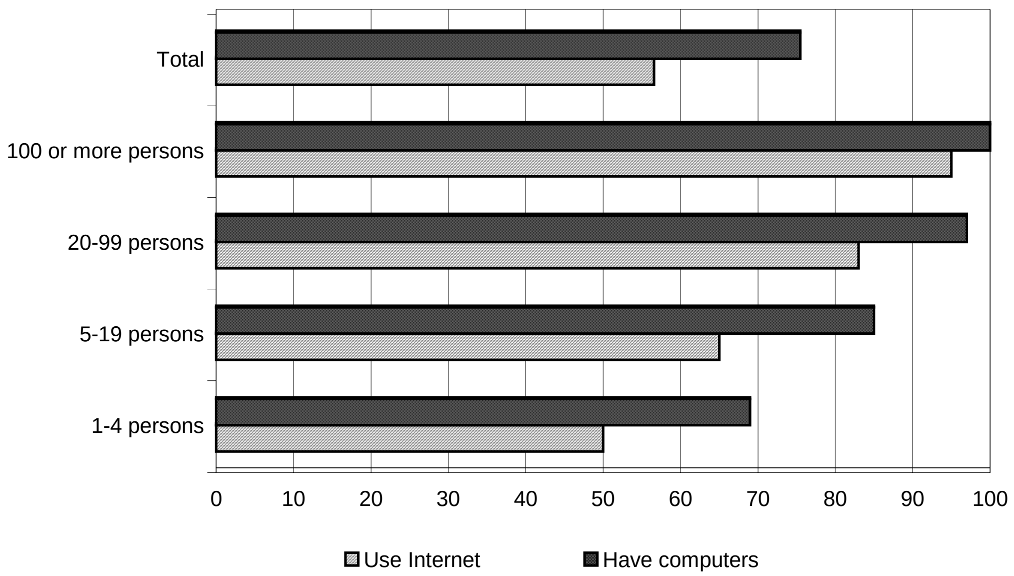
Figure 2.8 **Business use of computers and the Internet by sector in Australia, 1999**

Percentage of businesses




*Data source:* ABS (2000b).

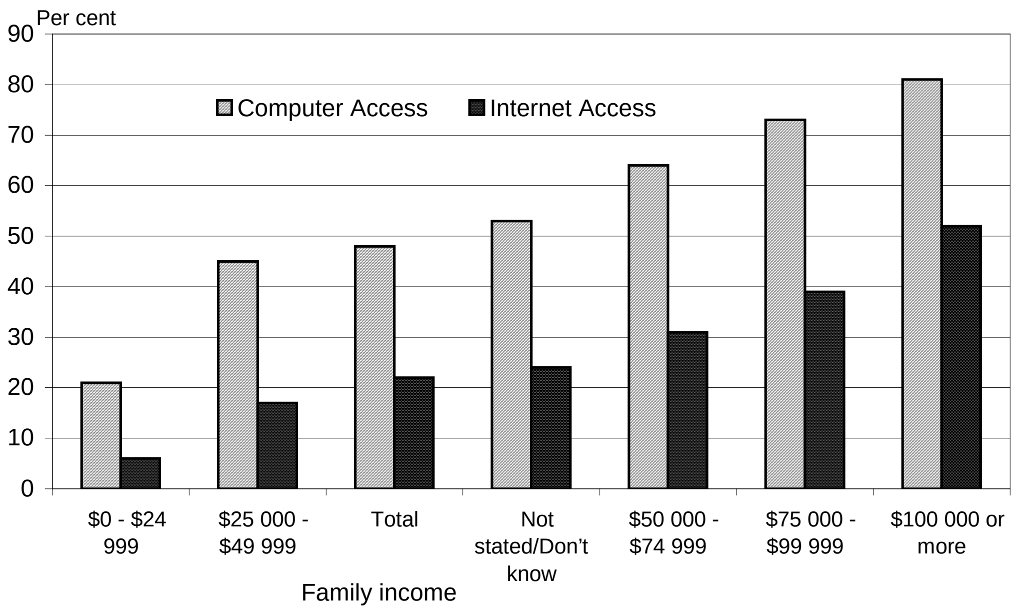
## Figure 2.9 **Business use of computers and the Internet in Australia by firm size, 1999**




*Data source:* ABS (2000b).

## Figure 2.10 **Households with home computer and Internet access in Australia, 1999**

Per cent




*Data source:* ABS (2000c).

## 2.3 Summary and assessment

As noted in previous sections, prices of computer hardware and software have been declining rapidly in both relative and absolute terms. Capturing these declines through hedonic price deflators makes a major difference to the measurement of ICT production and use trends. Australia uses hedonic price deflators that are closely aligned with the US deflator in ICT hardware prices and with a Canadian deflator in software prices.

Available statistical indicators and indexes published by the OECD, ABS and IDC suggest the following:

- Australia is ranked low in ICT production, especially ICT manufacturing.
- Australia is ranked in the middle to top range of OECD countries in overall ICT infrastructure and usage of ICTs.
  - For household use of ICTs, including computer ownership and Internet access, Australia is ranked within the top eight countries.
  - For business use of ICTs, including computer usage, Internet access, use of websites and servers for e-commerce, Australia is ranked within the top ten countries.

Further implications can be drawn for Australia from the above facts.

- With a small ICT production sector and a high level of ICT use, Australia mainly depends on imports of ICT equipment.
- Declining prices of ICT equipment that is mostly imported provide a source of real income gain to Australians.

# 3 The growth accounting framework

Recent studies have analysed the contribution of information and communications technologies (ICTs) to output and productivity growth in a growth accounting framework. This chapter outlines the essential features of this approach. The framework is applied in the chapters that follow.

The growth accounting framework provides a statistical accounting or decomposition of contributions to output or productivity growth. It does not necessarily provide an indication of the total causal effect of, for example, the growth of ICT inputs on the growth of output or productivity — as might be obtained from a properly constructed econometric analysis. For example, any complementarities between ICT investment and the demand for certain skill groups (and the further payoff for output and productivity growth) are not taken into account.

ICTs can have three different effects on productivity growth:

- increases in labour productivity through capital deepening — raising the ratio of capital to labour used in production;
- increases in multifactor productivity (MFP) growth in the production of ICTs; and
- increases in MFP in ICT-using industries associated with the use of ICTs.

The chapter shows how the growth accounting framework is used to identify the first two effects explicitly. Whilst the third can be identified in principle, the available studies have not been able to separate ICT-associated MFP gains from other sources of MFP gains in ICT-using industries. Indeed, there is some contention about the existence of MFP gains from ICT use.

The chapter also covers methods for capturing quality changes in labour and capital input measures. Finally, there is discussion of a number of issues that affect the measurement and interpretation of estimates of the productivity benefits of ICTs.

## 3.1 Accounting for output growth

Growth in output $(\dot{Y})$ is equal to growth in inputs $(\dot{I})$ plus growth in the efficiency with which inputs are combined to produce output. Efficiency growth is broadly defined and represented by multifactor productivity growth $(M\dot{F}P)$. MFP growth, broadly defined, can respond to the introduction of new (disembodied[1]) technologies, organisational improvements, resource reallocation, scale economies and so on.

Thus,

$$\dot{Y} = \dot{I} + M\dot{F}P.$$

Growth in inputs is equal to the share-weighted sum of growth in capital $(\dot{K})$ and labour $(\dot{L})$; that is,

$$\dot{I} = S_K \dot{K} + S_L \dot{L}$$

where $S_K$ and $S_L$ are the shares of capital and labour respectively in total payments to factors of production.

If ICT capital growth $(I\dot{C}T)$ and other capital growth $(O\dot{K})$ are separately identified within total capital growth, this equation can be written as:

$$\dot{Y} = S_L \dot{L} + S_{ICT}\, I\dot{C}T + S_{OK}\, O\dot{K} + M\dot{F}P. \qquad (1)$$

The sum of the shares, $S_i$, for each input i is equal to unity under assumptions of constant returns to scale.

Equation (1) provides the basis for assessing the contribution of the accumulation of ICT assets to output growth. The second term, the share-weighted growth in ICT input $(S_{ICT}\, I\dot{C}T)$, measures the extent to which growth in the use of computers and other ICT equipment accounts for output growth.

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1 Technological advances in ICTs are treated as embodied in equipment purchases through the use of hedonic price deflators (chapter 2).

## 3.2 Accounting for productivity growth

Accounting for productivity growth starts with a labour productivity relationship. Growth in labour productivity — the ratio of output to labour input — can be written as (see box 3.1 for derivation[2]):

$$\dot{\left(Y/L\right)} = S_K \dot{\left(K/L\right)} + M\dot{F}P$$

or

| | | | | |
|---|---|---|---|---|
| labour productivity growth | = | capital deepening | + | multifactor productivity growth |

where $\dot{\left(K/L\right)}$ is growth in the capital-labour ratio.

**Box 3.1 Decomposing growth in labour productivity**

The steps involved in deriving a decomposition equation for labour productivity are most readily seen with a Cobb-Douglas specification of an aggregate production function:

$$Y = K^{\alpha}.L^{1-\alpha}\ MFP$$

where, as in the text, Y = output, K = capital input, L = labour input and MFP = multifactor productivity. The parameter $\alpha$ is the output elasticity with respect to capital. Under the assumption of constant returns to scale, the output elasticity with respect to labour is equal to (1-$\alpha$).

Dividing both sides by L:

$$Y/L = \left(K/L\right)^{\alpha}.MFP$$

Taking logs, differentiating and expressing in proportional change form; and assuming competitive markets ensure that factors are rewarded according to their marginal products (so that $\alpha = S_K$):

$$\dot{\left(Y/L\right)} = S_K \dot{\left(K/L\right)} + M\dot{F}P$$

---

[2] Alternatively, the expression can be derived from equation (1)

If ICT capital is separately identified, the equation becomes:

$$\left(\dot{Y/L}\right) = S_{ICT}\left(\dot{\frac{ICT}{L}}\right) + S_{OK}\left(\dot{OK/L}\right) + M\dot{F}P \qquad (2)$$

A further step in the analysis of the contribution of ICTs might be to decompose the growth in MFP. There may be MFP gains in the production of ICT equipment.

In this case,

$$M\dot{F}P = W_{ICT}\ M\dot{F}P_{ICT} + W_{OI}\ M\dot{F}P_{OI} \qquad (3)$$

where $M\dot{F}P_{ICT}$ is MFP growth in the production of ICTs, and $M\dot{F}P_{OI}$ is MFP growth in other industries. The weights, $W_i$, reflect the relative sizes of the ICT production sector and other industries in the economy.[3] Equation (3) can obviously be substituted into equation (2).

Thus, ICTs can have three effects on productivity growth:

- increases in labour productivity growth through capital deepening (equation (2));
- increases in MFP growth through the production of ICTs ($M\dot{F}P_{ICT}$ in equation (3)); and
- efficiency gains in using industries, which would show up as part of $M\dot{F}P_{OI}$ in equation (3).

The capital deepening effect derives from increases in the ICT-intensity of production. For example, relatively cheaper ICTs would induce businesses to substitute ICTs for other types of capital and for labour. Benefits are captured by the owners of ICT assets in income flows (which are reflected in the income shares, $S_{ICT}$).

Efficiency gains in using industries are sometimes referred to as ‘spillovers’ gains since, in principle, they involve some positive externality, for example, through network economies. However, these increments to $M\dot{F}P_{OI}$ would be mixed in with other productivity gains from industry-specific technology or other sources of productivity improvements in these industries. The available studies have not attempted to disentangle ICT-related productivity gains in other industries from

3 If sectoral MFP growth is estimated with a gross output measure, Domar weights (the ratio of industry gross output to aggregate value added) are normally used. See, for example, Gullikson and Harper (1999).

gains from other sources. Whilst an increase in $M\dot{F}P_{OI}$ may be consistent with ICT spillovers, it does not necessary establish the existence of such spillovers.

However, there are certain assumptions and measurement issues that cloud the allocation of ICT gains to capital deepening and MFP growth and the further allocation of ICT-related MFP growth to production and use effects. These are discussed in section 3.4.

## 3.3 Capturing quality changes

The standard growth accounting framework, as just outlined, has been applied in the range of studies of the ICT contribution to output and productivity. However, variations in the definition of labour and capital inputs can also influence results. In particular, estimates can reflect differences in definitions and treatment of capital inputs.

### Labour composition or quality

Some studies take account of changes in the composition of labour, more commonly referred to as labour 'quality'.[4] This is common in US studies, given the availability of official data from the Bureau of Labor Statistics (BLS). There are not sufficient data available for labour composition effects to be separately identified in the Australian case.

Where labour composition can be identified, total input of labour becomes a function of both quantity (hours worked) and composition. That is:

$$\dot{L} = \dot{L}_H + \dot{L}_C \qquad (4)$$

where $L_H$ = an index of hours worked and $L_C$ = an index of labour composition.

The labour composition variable is introduced to reflect the fact that an hour of work is not equally productive throughout the workforce. Differences in skill and experience, for example, are key distinguishing features.

The BLS measures changes in labour composition by first establishing the hours worked by different groups, identified by employment experience, education and gender. It then weights the hours worked by these different groups to form the aggregate measure of labour input (L), where the weights are based on the average

[4] Gordon (2000a) makes a persuasive case to use the term composition, rather than quality.

wage rates paid to each of the groups. The implicit assumption is that workers in each group are paid according to their marginal product.

The labour composition component ($\dot{L}_c$) is then the difference between total labour input growth ($\dot{L}$) and growth in total hours worked ($\dot{L}_H$).

The introduction of the labour composition measure effectively ‘factors out’ this component from measured MFP growth. MFP growth can be thought of as the amount of output growth that is not accounted for by input growth. Looking at equation (4) and assuming labour composition shifts toward higher productivity workers, measured MFP growth will be lower if labour input is measured as the sum of growth in hours worked and growth in labour quality. Or, to put it another way, labour quality would ‘explain’ an amount equal to $L_c$ of MFP growth when labour input is measured according to an hours worked measure.

Similarly, if an Australian measure of MFP growth (which uses only an hours worked measure of labour input) is to be compared with a US measure of MFP growth, the change in the US labour composition component should be added back into the US rate of MFP growth to improve the comparability of estimates between the two countries.

The US estimates suggest that the explicit allowance for labour composition effects does not have a very large impact on productivity assessments. Annual average rates of change in US labour composition have been of the order of 0.3 per cent.

## Capital quality

Two dimensions of quality of capital input can be considered:

- one makes allowance for the decline in efficiency of installed assets over time through a ‘capital services’ measure; and
- one makes allowance for the incorporation of technological and other improvements in new assets that become available and are purchased over time.

### *Capital services*

Traditionally, productivity and growth-accounting analyses have proceeded on the assumption that capital assets deliver economic services in proportion to the size of the installed capital stock (net of depreciation).

But different types of capital deteriorate at different rates unrelated to wealth depreciation. Some assets produce a fairly even delivery of effective services over their economic lives, with little deterioration. Computers are a reasonably good example — they continue to work for quite a time (nearly) as well as they did when first installed. Other assets (for example, motor vehicles) tend to deteriorate more evenly throughout their economic lives.

The measurement of capital input has been upgraded in a number of countries in recent times, to measure capital services, rather than rely on the net capital stock assumption.

Statisticians use age-efficiency profiles to capture the different rates of loss of economic efficiency of different asset types. These profiles are quite distinct from rates of financial depreciation of assets. For example, say the humble light bulb has an economic life of two years. Straight line financial depreciation would see the wealth value of the light bulb decline proportionately over the 2 years. However, the light bulb would provide equally effective services (no loss in economic efficiency) in each of the two years of its economic life.

The volume of capital, adjusted for efficiency losses according to the relevant age-efficiency profile, defines the productive capital stock of an asset over time. The productive capital stock of each asset type is weighted and summed to form an aggregate capital services measure. (Asset types identified in Australian Bureau of Statistics (ABS) procedures are listed in table 3.1.)

The weights used in the summation are based on the rental prices for the different asset types. Rental prices can be thought of as estimates of the rates each asset type would attract if the assets were leased in a commercial arrangement[5]. The underlying assumption in the use of rental prices as weights is that the rental price reflects the marginal product of an asset; and so more productive assets are given higher weights in forming the capital services measure. In this sense, there are parallels between the construction of labour quality and capital quality measures.

5 Rental prices have to cover: the opportunity costs of investing elsewhere, represented by the interest rate, r; the loss in market value of the good due to ageing, d; and the capital gains or losses due to asset price inflation/deflation, i. Thus, the rental price for an asset of price q would be (ignoring taxes and subsidies): q(r+d-i). See appendix B.

Table 3.1 **Asset types used by the ABS in constructing a capital services measure for the market sector**

**General assets**

- Non-dwelling construction
  - Buildings
  - Other structures (roads, railway, bridges, etc)
- Equipment
  - Transport equipment
    - * Road vehicles
    - * Other transport equipment
  - Other machinery and equipment
    - * Computers
    - * Electrical equipment
    - * Industrial machinery
    - * Other equipment
- Land
- Software
- Inventories

**Industry-specific assets**

- Livestock (specific to Agriculture)
- Mineral exploration (Mining)
- Artistic originals (Cultural & recreational services)

Computers and related ICT equipment tend to figure more prominently in a capital services measure than in a wealth measure (that is, net capital stock based on financial depreciation). There are two reasons:

- The economic efficiency of computers is taken to decline moderately over their economic lives (and is in fact assumed to be constant in some studies[6]) so that a computer is taken, in at least some analyses, to deliver at only a moderately-declining rate of productive service throughout its economic life.
- Rental price weights for computers and related equipment are relatively high. The economic life of a computer is relatively short (compared with a building, say), and expected capital losses on resale/retirement are high (implying high rates of depreciation). A leasing agent would have to charge a relatively high rent (per dollar invested) to cover all costs and make a satisfactory rate of return on a computer.

[6] See, for example, Whelan (2000). Some efficiency loss is assumed, however, in the ABS's procedures for Australia (see appendix B).

These factors mean that a switch in the investment mix toward ICTs, all other things equal, will produce faster growth in a capital services measure than in a net capital stock measure.

In these circumstances, the use of a capital services measure will raise the rate of (capital) input growth (compared with a net capital stock measure) and produce commensurately lower estimates of MFP growth.

*Hedonic prices*

The other aspect of quality — highly relevant in the case of computers — is the incorporation of technical improvements. The capital services quality aspect dealt with the rate of delivery of service from an asset over its economic life (for example, a computer of a given generation). However, different vintages of the same asset type (and especially ICT equipment) embody improvements in technical characteristics.

The use of hedonic prices to capture improvements in technical characteristics was discussed in chapter 2. Hedonic price indexes are used to deflate nominal expenditures on new investment. This effectively treats technical improvements as 'embodied' changes, raising the volume of output in ICT production and the volume of investment and capital input in using industries, compared with estimates compiled without the use of hedonic prices (box 3.2).

## 3.4 Capturing the gains from ICTs in theory and practice

The nature of the gains from ICTs and how they are manifest in growth accounting estimates has not been thoroughly examined and discussed in the available studies. There could be a gap between theory and practice that could render the growth accounting framework somewhat unreliable or at least imprecise in its characterisation of the gains from ICTs.

The growth accounting framework outlined above identified three avenues through which ICTs can influence labour productivity gains. In principle, three types of gains can be neatly allocated to the three avenues:

- MFP gains in ICT production capture the ability of producers to generate more computing power and other characteristics of ICTs per unit of input.

**Box 3.2 MFP growth in ICT production reflects advances in computer power**

The statistical treatment of ICTs has implications for the interpretation of the industry sources of MFP gains. As outlined in chapter 2, hedonic price indexes are used to ensure that the volumes of ICTs produced and purchased reflect the rapid rate of quality improvements — advances in processing speed, memory, peripheral devices and so on. Since the price of equipment has remained relatively constant (or even declined) in current terms, the rapid advance in quality means that the price of ICT characteristics has declined rapidly in relative and absolute terms.

This treatment has two implications:

- Advances in ICT characteristics are captured as rapid growth in the real output, and therefore rapid growth in MFP in ICT production industries. The operation of Moore's Law (that the power of semiconductors doubles every 18 months to 2 years), for example, has a strong positive effect on the measurement of the volume of output in the production of computers and, especially, semiconductors. Since advances in the production of additional computer power are possible without any or many additional resource inputs, MFP in ICT production also shows strong growth.
- From the users' point of view, advances in technology are treated as being embodied in new purchases of ICT equipment and are therefore counted as (relatively rapid) increases in the volume of capital inputs in using industries. Capital input is measured in terms of the computer power and capacity available and not in terms of expenditure or number of computer 'boxes' available. More rapid growth in capital input means (for a given growth in output) slower MFP growth in using industries.

This treatment calls for movements in hedonic prices to be accurate. In the presence of both production and use, errors will affect the size of the MFP gains (through the production output effect) and their division between production and using sectors (through the combination of production output and capital input effects).

Jorgenson and Stiroh (2000a) showed the sensitivity of their results to price deflators. In their view, the official Bureau of Economic Analysis (BEA) price deflators understate the (constant-quality) price declines in software and communications equipment. With alternative scenarios assuming faster price declines, their estimates show a reduction in total MFP growth (the capital input effect outweighs the production output effect). Moreover, more MFP growth is attributed to ICT production in the alternative scenarios, and MFP growth in non-ICT industries is turned negative (from a 0.55 percentage point contribution over 1995-98 in the base case).

- The capital deepening component captures gains to the direct users of ICTs. The gains are reflected in the income stream attributable to ICTs and would cover all benefits to ICT owners. These would include cost savings from substituting ICTs for other inputs as ICTs become cheaper. The sceptical view of the benefits from ICTs acknowledges only this form of gain. ICTs are seen as just another production input. Demand for ICTs is driven primarily by price and, conceptually, producers respond to relative price changes by shifting to a different point on the production function. In principle, the ICT income stream would also include the internalised gains from development of new products and new processes of production, distribution and exchange, based on ICT.

- MFP gains in using industries are basically externality benefits. According to the 'new economy' enthusiasts, ICTs can bring network economies, increasing returns and spillovers, which would be captured in MFP gains in using industries. They are gains generated by producers and some users of ICTs but are not internalised by them. They are transmitted to others. For example, network economies derive from any increased value of a network (for example, Internet or local purchasing network for e-commerce) to existing members when new members join.

However, in practice, there are several implementation issues that undermine such a neat allocation and frustrate interpretation, particularly of a finding of MFP growth in using industries.

The measurement of MFP gains in ICT production depends crucially on the accuracy of measurement of hedonic prices. In the presence of both production and use of ICTs, mismeasurement of deflators would affect both the size of the aggregate MFP gains and the allocation of MFP gains between ICT production and ICT use (box 3.2). Incorrect measurement of prices could see advances in the technical characteristics of ICTs show up in MFP gains in using industries, or some MFP gains from use incorrectly allocated to ICT production.

Correct measurement of prices also has implications for the measurement of MFP gains in ICT production for another reason. MFP gains in ICT production are equated with reductions in equipment prices (box 3.3). Errors in prices will therefore be translated into errors in MFP gains in ICT production.

The allocation of gains between capital deepening and MFP can be influenced by a number of factors. First, there is an issue of whether technological advances in ICTs bring any 'new' qualities to production — whether there are technological spillovers from producers to users. Two possible circumstances can be envisaged. First, the diffusion of a general purpose technology such as IT could reach a threshold at which more substantial gains become possible. Second, some new feature associated with IT, such as the advent of the Internet, could bring new gains.

**Box 3.3 Measurement of MFP gains in ICT production**

The measurement of prices for ICTs has a further implication for the measurement of productivity growth in ICT production. The conventional method of measurement of MFP growth draws on data on output and input quantities. However, data on the quantity of capital input are not available at the level of industry disaggregation of ICT hardware and software. The US studies have therefore used a 'price-dual' method, in which the extent of productivity growth is taken to be equal to the extent of output price declines, taking into account any input cost changes. It is assumed that any productivity gains are passed on in lower prices. This method is quite defensible, according to duality theory, although in practice it requires accurate price measures and the assumption of competitive markets in ICTs, or at least no changes in the size or distribution of economic rents, normally associated with the use of market power. Thus, if there had been some reduction in market power of US microprocessor and computer manufacturers and the prices they could charge, estimates of their productivity gains could be overstated.

Oliner and Sichel (2000) considered this issue. They noted that an international glut of semiconductors developed in the late 1990s and intensified downward pressure on prices. On the other hand, their examination of the aggregate profit margin across US semiconductor producers showed a rise, rather than a fall. Discussions with 'seasoned observers' suggested that an increased rate of innovation in the US enabled producers to weather the difficult market conditions.

Jorgenson (2001) also notes an acceleration in the IT price reduction occurred in 1995, following sharper semi-conductor price falls in 1994. He traced this to a reduction in the product cycle for semiconductors from three years to two years, following intensified competition.

Some unease about the precision of the price dual approach must remain, although the degree of error may not be very large. It seems that the rate of innovation did increase. But, on pricing, the counterfactual is unknown. The unanswered issue is whether more of the productivity gains were passed on than is usual because of the difficult market conditions.

The growth accounting framework cannot pick up any 'new' qualities as part of the internalised returns to IT investors. To see why, consider two cases: one involving a doubling of the volume of ICTs of given technology, and the other involving a doubling of the power of a given number of ICT units.[7] The capital services delivered in each case is the same. But if the more technologically advanced option

[7] In both cases, the capital-labour ratio is the same. The ICT cost share is the same because it is derived from the volume of capital available and a constructed rental price.

is more useful and productive than the other, output growth and MFP gains in using industries will be greater.[8]

Brynjolfsson and Hitt (2000) pinpoint another practical issue affecting the allocation of gains between capital deepening and MFP growth. They note that the gains reflected in capital deepening are constrained by the assumption that asset holdings are in equilibrium and therefore earn a common 'normal' rate of return (after asset-specific taxes, depreciation and allowance for capital gains or losses). If in reality ICTs earn super-normal returns, the additional gains would show up in MFP growth — even though they are gains internalised by ICT investors.

Brynjolfsson and Hitt found evidence of high returns to ICT investments at the firm level. They considered that ICTs could generate high returns not only in a short-run adjustment phase, but more importantly also in the long-term if other complementary changes were made in firm organisation. They saw these high long-term gains as comprising the direct benefits from ICTs — as reflected in capital deepening — plus the indirect benefits from ICTs and (intangible and uncosted) complementary investments in organisational change — as reflected in MFP growth.

Brunker (2001) presented a theoretical case to suggest that gains from ICTs are misallocated between production and use. In his view, some gains could be allocated to MFP growth in using industries (rather than to ICT production) through quasi-fixities or incomplete adjustment in ICT holdings to rapidly declining prices.[9]

Thus, whilst the allocation of ICT benefits in the growth accounting framework is reasonably straightforward in principle, the practice is much less straightforward. Moreover, the interpretation of a finding of MFP gains in using industries is clouded. It cannot be taken as necessarily establishing the presence of ICT spillovers. In practice, the growth accounting framework is not well tuned to make fine distinctions between the different types of gains from ICTs and to quantify precisely any 'special' properties of ICTs.

[8] In principle, the greater value of the technological advance in use should be captured in the hedonic price. But this is most unlikely to happen in practice. Hedonic deflators are based on technical characteristics, and not on productivity in use.

[9] Correction for this would presumably encounter the same practical issue raised in footnote 8.

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# 4 The US evidence

The US has been the main 'laboratory' for analysing the effects of information and communications technologies (ICTs) on output and productivity growth. As shown in chapter 2, the production and use of ICTs is very well advanced in the US. It is in the US that any strong link between ICTs and output and productivity growth could be expected to be found.

Three studies have been particularly influential in the analysis of the role of ICTs in the US acceleration in output and productivity growth — Oliner and Sichel (2000), Jorgenson and Stiroh (2000a) and the more sceptical view of Gordon (2000b).

Jorgenson and Stiroh consider three related factors to be prominent in the relationship between ICTs and US growth and productivity performance.

- There have been rapid advances in multifactor productivity (MFP) in the production of ICTs — especially through the production of more powerful semiconductors, with little or no more input requirements.
- These productivity advances have enabled relative and absolute price declines for ICT equipment — prices have declined by 18 per cent a year from 1960 to 1995 and by 27.6 per cent a year from 1995.
- Lower prices have helped to stimulate very strong demand for ICTs, especially in the second half of the 1990s.

These factors imply aggregate labour productivity gains via MFP gains in computer production and capital deepening in using industries as firms raise the ratio of ICT services to labour.

Jorgenson and Stiroh were unconvinced about the existence or importance of spillover gains from ICTs, which would show as MFP gains in using industries. Gordon was particularly strong in expressing the view that there have been no productivity gains from ICTs in using industries.

Because the three seminal studies have been much reviewed and compared (including in the studies themselves), this paper does not dwell on their details. But this paper does compare these studies with more recent estimates, including those from the Bureau of Labor Statistics (BLS) — the official source of US productivity estimates — and the 2001 *Economic Report of the President*. These and other sources provide growing evidence of MFP gains in ICT using industries. However, the source(s) of the gains are still uncertain.

The US studies restrict their analysis to ICT goods, covering the manufacture of computer hardware and software and communications equipment. The delivery of ICT services (for example, communications and Internet services) is excluded.

Analysis of growth in both output and labour productivity is reviewed in this chapter. However, more emphasis is given to labour productivity, reflecting the relative interest in examinations of US performance.

## 4.1 The contribution to US output growth

US output growth was very strong in the second half of the 1990s. The average rate of growth in the non-government sector was around 4.8 per cent a year (table 4.1).

A number of macroeconomic factors could have contributed to the strong US growth performance. For example, DeLong (2000) acknowledges the contribution of fiscal deficit reduction and the favourable investment climate it helped to create. He nevertheless views the production and heavy investment specifically in ICTs to have had significant macroeconomic effects in the US in the second half of the 1990s.[1]

Table 4.1 shows that ICTs formed a major part of the growth in capital input. According to the growth accounting studies shown, they accounted for 45 to 60 per cent of the growth in capital services after 1995.[2]

It follows that growth in ICT capital inputs accounted for a major part of the very strong output growth. Oliner and Sichel attribute 1.1 percentage points (nearly one quarter of output growth) to growth in ICT inputs, and Jorgenson and Stiroh attribute 0.9 of a percentage point[3] (or around one fifth of output growth).

[1] DeLong raises the interesting question (without offering an answer) as to whether the ICT boom could have come earlier, if the investment climate had been more favourable, or whether it required ICT-specific technology breakthroughs. Others have pointed to the acceleration in computer price reductions and the wider use of the Internet from 1995.

[2] The estimates from Jorgenson and Stiroh (2000a) are updated to 1999 in Jorgenson (2001).

[3] The ICT contribution to business capital input of 0.75 is added to the 0.19 contribution from computers and software to consumer durable services. Jorgenson and Stiroh separately identify outputs of investment and consumption goods (in order to capture substitutions between them). This encompasses investment in computer hardware, software and communications equipment, as well as consumption of computer hardware and software. The service flows from these assets are also counted as inputs. Jorgenson and Stiroh's output measure also includes housing.

Table 4.1 **Contributions to US output growth in the late 1990s[a]**
(per cent per year)

| | *Oliner and Sichel (2000)* | *Jorgenson and Stiroh (2000a)* |
|---|---|---|
| Period | 1996-99 | 1995-98 |
| 1. Output growth | 4.82 | 4.73 |
| 2a. Capital input contribution | 1.85 | 1.61 |
| • ICT | 1.10 | 0.75 |
| - hardware | 0.63 | 0.46 |
| - software | 0.32 | 0.19 |
| - communications equipment | 0.15 | 0.10 |
| • Other capital | 0.75 | 0.86 |
| 2b. Consumer durable services contribution[b] | | 0.56 |
| • Computers and software | | 0.19 |
| • Other | | 0.37 |
| 3. Labour input contribution | 1.81 | 1.57 |
| • Labour hours | 1.50 | 1.32 |
| • Labour composition (quality) | 0.31 | 0.25 |
| 4. MFP growth | 1.16 | 0.99 |

**a** Line 1 is equal to lines 2a+2b+3+4. **b** Jorgenson and Stiroh separately identify services from consumer durables. Total capital services, broadly defined, can be thought of as line 2a + line 2b.

The estimated contribution of ICTs to the *acceleration* in output growth over the 1990s is of a similar magnitude. Table 4.2 shows output growth was 2 percentage points higher in the second half of the 1990s, compared with the first half. Both studies attribute around 0.5 of a percentage point (or about a quarter of the output acceleration) to growth in ICTs. The contribution of ICTs is at least as large as the contribution from non-ICT assets — a contribution that is vastly out of proportion to the share of ICTs in the capital stock.

Growth in hours worked accelerated in the late 1990s, with increases in hours worked and labour force participation and falls in unemployment. However, effective labour input was reduced by changes in labour composition (usually referred to as labour ‘quality’) as increased employment of labour drew disproportionately on workers with lower marginal products. (See chapter 3 for an outline of labour composition methodology.)

There was also a marked acceleration in MFP growth in the second half of the 1990s — from rates around 0.33 per cent a year in the 1970s and 1980s to around 1 per cent a year or more in the second half of the 1990s. (This resulted in an acceleration of around two-thirds of a percentage point as shown in table 4.2.) As will be seen in the next section, more recent studies put MFP growth in the late 1990s even higher.

Table 4.2 **Contributions to the acceleration in US output growth in the late 1990s[a]**

Per cent per year

| | *Oliner and Sichel (2000)* | *Jorgenson and Stiroh (2000a)* |
|---|---|---|
| Period | 1991-95 to 1996-99 | 1990-95 to 1995-98 |
| 1. Output acceleration | 2.07 | 1.99 |
| 2a. Capital input contribution | 0.84 | 0.70 |
| • ICT | 0.53 | 0.35 |
| - hardware | 0.38 | 0.27 |
| - software | 0.07 | 0.04 |
| - communications equipment | 0.08 | 0.05 |
| • Other capital | 0.31 | 0.35 |
| 2b. Consumer durable services[b] contribution | | 0.27 |
| • Computers and software | | 0.10 |
| • Other | | 0.17 |
| 3. Labour input contribution | 0.55 | 0.39 |
| • Labour hours | 0.68 | 0.51 |
| • Labour composition (quality) | -0.13 | -0.12 |
| 4. MFP acceleration | 0.68 | 0.63 |

**a** Line 1 is equal to lines 2a+2b+3+4. **b** Jorgenson and Stiroh separately identify services from consumer durables. Total capital services, broadly defined, can be thought of as line 2a + line 2b.

## 4.2 The contribution to US productivity growth

*There was a strong acceleration in labour productivity growth in the 1990s*

It is common ground among studies that US labour productivity growth accelerated in the second half of the 1990s. Table 4.7 shows a number of estimates. There is general agreement that the acceleration was around 1 percentage point a year. This was supported by the BLS estimates released in early 2001. In the *Economic Report of the President*, however, the Council of Economic Advisers (CEA 2001) estimated that the acceleration was as much as 1.6 percentage points, out to the year 2000[4].

[4] The CEA infers productivity for the year 2000 from figures for the first three quarters. Output is averaged over production-side and income-side measures. Nordhaus (2001a) shows that, particularly in the second half of the 1990s, income-side data reveal greater output and therefore productivity growth than the production-side data used by the BLS and other studies.

Table 4.3 **Estimates of the 1990s acceleration in US labour productivity growth**

Per cent per year

| | *Oliner and Sichel (2000)* | *Gordon (2000b)* | *Jorgensen and Stiroh (2000a)* | *BLS (2001)* | *CEA (2001)* |
|---|---|---|---|---|---|
| Coverage | Non-farm business | Non-farm business | Private business plus service flows from consumer durables and housing | Private business | Private non-farm business |
| Labour productivity growth over periods | 1974-90 : 1.37<br>1991-95 : 1.53<br>1996-99 : 2.57 | 1972-95 : 1.42[a]<br>1995-99 : 2.75[b] | 1973-90 : 1.44<br>1990-95 : 1.37<br>1995-98 : 2.37<br>1995-99 : 2.58[c] | 1979-90 : 1.6<br>1990-95 : 1.5<br>1995-99 : 2.6 | 1973-95 : 1.39<br>1995-2000 : 3.01 |
| Cyclical adjustment | | 1995-99 : -0.50 | | | 1995-2000 : -0.04 |
| 1990s acceleration | 1.04 | 0.83[a] | 1995-98 : 1.0<br>1995-99 : 1.21[c] | 1.0 | 1.58 |

[a] Trend estimate. [b] Actual estimate. [c] Provisional estimate.

Estimates out to the year 2000 may, however, turn out to be overstated. The BLS revised its labour productivity growth estimates (quarterly series) in August 2001. The revisions affected the most recent years the most. Annual labour productivity growth in the private business sector was revised from 4.3 per cent to 3.1 per cent for 2000 and from 2.6 per cent to 2.5 per cent for 1999. Revisions to the annual MFP-based dataset (which is relied on in this study) have not been announced.

### *But perhaps not all of the measured acceleration is a trend shift*

There is some disagreement about the extent to which the measured acceleration represents an uplift in the underlying trend rate of growth or merely a transient or cyclical effect.

Robert Gordon believes that there is a sizeable cyclical component in the productivity acceleration and has made an adjustment to extract it (table 4.7). He believes that the extent of the reduction in unemployment and the increase in the current account deficit in the 1990s make the high rate of output and productivity growth unsustainable. Gordon’s treatment has attracted some controversy. But, on the other hand, most other studies do not explicitly consider the issue, and report measured productivity accelerations as though they are trend shifts.

The CEA drew on unpublished statistical analysis to say that the post-1995 acceleration does not appear to be associated with the normal business cycle variation in productivity.[5] Their cyclical adjustment is quite minor (table 4.7).

Figure 4.1 offers a perspective on the issue. The actual labour productivity series is plotted, along with a Hodrick-Prescott trend series. The common use of the Hodrick-Prescott filter has been criticised, particularly for the accuracy of trend calculations at the start and end of series. Too great a reliance should not be placed on it. But it can be reasonably used here to show that US labour productivity was below trend in 1995 and above trend in 1998 and 1999.

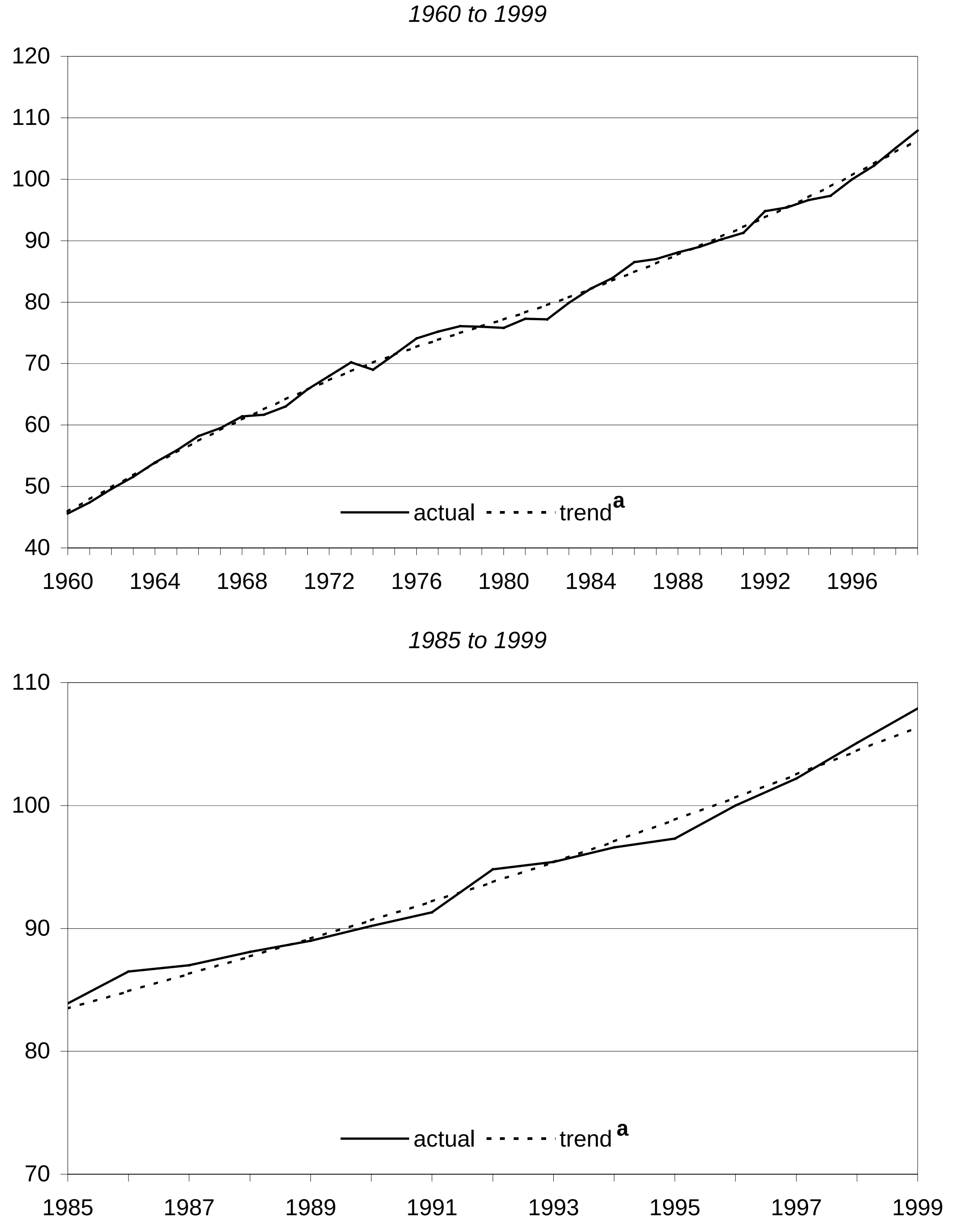
Another observation from the chart is that the post-1995 uplift in productivity does not yet stand out from other productivity increases in earlier periods, such as the early 1980s (see also Nordhaus 2001b, p. 10). But perhaps some of the significance of the 1990s productivity acceleration lies in its ‘surprise’ element, leading to much more favourable outcomes than forecast[6], rather than in whether the size of the acceleration is unprecedented.

[5] However, because it refers to the business cycle, this presumably relates to whether recovery from the 1991 recession still exerted some influence and not to whether there was a cyclical (labour productivity) component in the average growth from 1995.

[6] See DeLong (2000) and Jorgenson (2001).

Figure 4.1 **Private business sector labour productivity in the US, 1960 to 1999**

Index 1996 = 100




[a] Trend is based on the Hodrick Prescott filter (computed on the entire series from 1960).

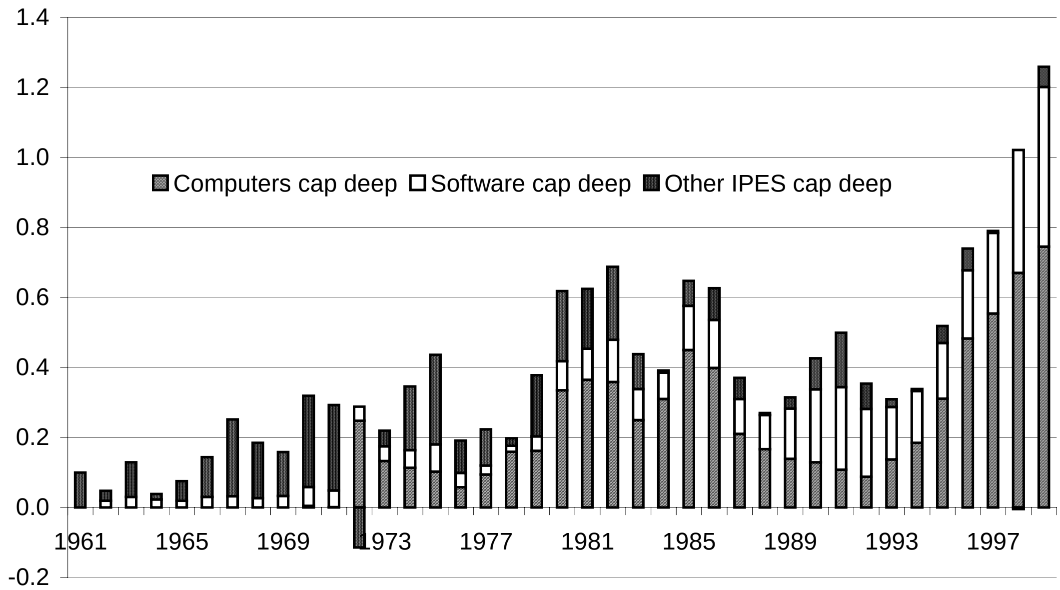
*Data source:* PC estimates based on Bureau of Labor Statistics data.

*Capital deepening through ICT investment and MFP growth from all sources have been major factors*

As outlined in chapter 3, labour productivity growth can be decomposed into contributions from capital deepening and MFP growth.

BLS data are used to show the year-by-year contribution of ICTs (defined by the BLS as information processing equipment and software — IPES). Figure 4.2 shows the very strong acceleration over the latter part of the 1990s — from 1995. However, again, it can be noted that the contribution in the early 1990s was down on contributions in the 1980s.

Figure 4.2 **IPES[a] contributions to labour productivity growth, 1961 to 1999**
Percentage points




**a** Information processing equipment and software.

*Data source:* PC estimates based on BLS data.

Table 4.2 shows the contributions to labour productivity growth in the second half of the 1990s — from 1995. The two 'academic' studies attribute a substantial contribution to capital deepening. Oliner and Sichel attribute about two-fifths (1.1 percentage points) and Jorgenson and Stiroh over one half. The table also shows strong contributions from MFP growth. Both the academic studies attribute around two-fifths of labour productivity growth to MFP growth.

Compared with the academic studies, the official BLS estimates show a lower contribution from capital deepening (0.9 of a percentage point as opposed to 1.1 or 1.3 percentage points). Less capital input growth in the BLS estimates also leaves more room for MFP growth — at a strong rate of 1.3 per cent a year. The BLS estimates attribute one half of labour productivity growth to MFP growth and about two-fifths to capital deepening.

Table 4.4 **Contributions to US labour productivity growth in the late 1990s[a]**

| | *Oliner and Sichel (2000)* | *Jorgenson and Stiroh (2000a)* | *BLS (2001)* | *CEA (2001)* |
|---|---|---|---|---|
| Period | 1996-99 | 1995-98 | 1995-99 | 1995-2000 |
| 1. Labour productivity growth | 2.57 | 2.37 | 2.6 | 2.97[c] |
| 2. Capital deepening | 1.10 | 1.31 | 1.0 | 1.09 |
| • ICT | 0.96 | | 0.9[b] | 1.03 |
| - hardware | 0.59 | | 0.6 | |
| - software | 0.27 | | 0.2 | |
| - communications equipment | 0.10 | | 0.1 | |
| • Other capital | 0.14 | | 0.1 | 0.06 |
| 3. Labour quality | 0.31 | 0.25 | 0.3 | 0.27 |
| 4. MFP growth | 1.16 | 0.99 | 1.3 | 1.59 |

[a] Line 1 is equal to lines 2+3+4. [b] Information processing equipment and software. [c] Business cycle effect of 0.04 percentage points removed.

The CEA found even higher labour productivity growth, but ascribe similar proportions as the BLS to the contributions of MFP growth and capital deepening to output growth — over a half and nearly two-fifths respectively.

*Growth in use of ICTs has accounted for nearly all of the capital deepening*

Increased use of ICTs has been by far the major factor in capital deepening. Oliner and Sichel attribute nearly 90 per cent of the capital deepening component to ICTs. A similar picture is evident in the BLS and CEA estimates.

*ICT capital deepening and MFP growth are also important in the 1990s labour productivity acceleration*

Table 4.5 assembles estimates of the contributions to the labour productivity *acceleration* in the second half of the 1990s (as identified in table 4.2). An update from Oliner and Sichel (2001) extends their estimates to 2000.

To a broad approximation, the studies attribute a little under a half of the labour productivity acceleration to ICT capital deepening. Very little, if any, is attributed to other capital deepening.

With the exception of Gordon, the studies attribute a somewhat stronger contribution to MFP growth than to capital deepening. Oliner and Sichel, Jorgenson and Stiroh and the BLS, attribute about two-thirds of the labour productivity acceleration to MFP growth. The CEA attributes around three-quarters. A reduction in the average productivity or 'quality' of labour was an offsetting factor.

Table 4.5 **Contributions to the acceleration in US labour productivity growth in the 1990s**[a]

| | *Oliner and Sichel (2000)* | *Oliner and Sichel (2001)* | *Gordon (2000b)* | *Jorgenson and Stiroh (2000a)* | *BLS (2001)* | *CEA (2001)* |
|---|---|---|---|---|---|---|
| 1. Labour productivity acceleration | 1.04 | 1.32 | 0.83[b] | 1.00 | 1.1 | 1.58 |
| 2. Capital deepening | 0.48 | 0.56 | | 0.49 | 0.5 | 0.38 |
| - ICT | 0.45 | 0.55 | 0.33 | | 0.5[c] | 0.62 |
| - Other | 0.03 | 0.02 | | | 0.0 | -0.23 |
| 3. Labour quality | -0.13 | -0.16 | 0.19[d] | -0.12 | -0.1 | 0.00 |
| 4. MFP growth | 0.67 | 0.91 | 0.29 | 0.63 | 0.7 | 1.19 |

**a** Line 1 is equal to lines 2 (or subsidiary components) +3+4. **b** Acceleration in trend — that is, actual adjusted for cyclical component. **c** Information processing equipment and software. **d** Includes adjustment for price measurement.

### *Productivity cycles — lower acceleration in trend productivity growth*

However, a different picture emerges when BLS data are used to analyse labour productivity growth over productivity cycles. Using peak-to-peak measurements over productivity cycles is one way of assessing underlying productivity trends. It is a method used by the Australian Bureau of Statistics and its use here not only helps to address the cyclical issue raised earlier, but also provides a sound basis for comparison later between US and Australian results.

Figure 4.3 shows contributions to labour productivity growth over labour productivity cycles. This peak-to-peak approach is not used by the BLS, but has been implemented from BLS data.[7]

The figure has a number of features (see also table 4.6) :

- the high rate of growth in, and contribution from, MFP in the 1960s;

[7] Productivity peaks were identified as points where the gap between the actual and trend series turned from increasing to decreasing. A Hodrick-Prescott filter was used to form the trend series.

- a high contribution from ICTs in periods prior to the 1990s, especially 1976 to 1986;
- the strong contribution of labour composition from 1986 to 1992; and
- the strong growth in MFP in the 1990s compared with other periods after 1973.

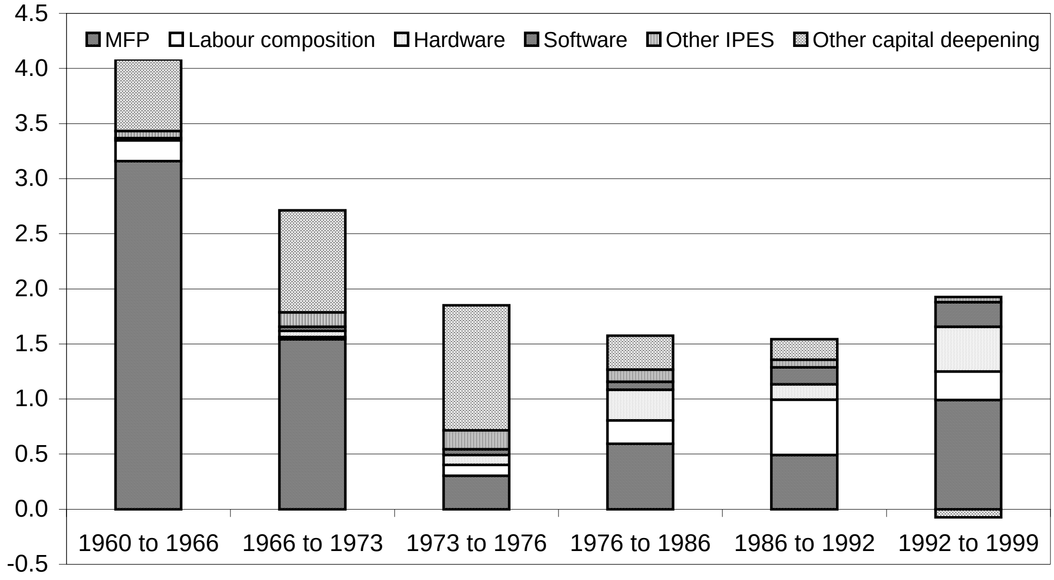
The figure again shows that the magnitude of labour productivity and MFP growth in the 1990s was not unprecedented. However, it is worth remembering that, in the 1980s and early 1990s, expectations of returning to the productivity growth rates of the 1960s, or even improving markedly on post-1973 growth rates, had been severely dented (Krugman 1992).

Labour productivity growth in the 1990s is found to be much more modest, according to this methodology, than in the other studies reviewed above. Rather than annual growth of 2.5 per cent or more, growth of less than 2.0 per cent is found.

The figure also shows that the 1990s growth in ICTs has come at the expense of growth in other capital. The contribution of capital deepening from non-ICT capital dwindled from the mid-1970s and actually turned negative in the 1990s. As ICTs have become cheaper, businesses have substituted increased use of ICTs for increased use of other forms of capital. The fact that capital deepening has changed little also suggests that growth in capital has not substantial for growth in labour.

Figure 4.3 **Contributions to growth in labour productivity for the United States over labour productivity cycles, 1960 to 1999**

Per cent




*Data source:* PC estimates based on BLS data.

Table 4.6 **Contributions to growth in labour productivity for the United States over labour productivity cycles, 1960 to 1999**

| | *1960 to 1966* | *1966 to 1973* | *1973 to 1976* | *1976 to 1986* | *1986 to 1992* | *1992 to 1999* |
|---|---|---|---|---|---|---|
| Labour productivity growth | 4.2 | 2.7 | 1.8 | 1.6 | 1.5 | 1.9 |
| Total capital deepening | 0.7 | 1.1 | 1.4 | 0.8 | 0.5 | 0.6 |
| • IPES[a] capital deepening | 0.1 | 0.2 | 0.3 | 0.5 | 0.4 | 0.7 |
| - Hardware | 0.0 | 0.1 | 0.1 | 0.3 | 0.1 | 0.4 |
| - Software | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 |
| - Other IPES | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.0 |
| • Other capital deepening | 0.7 | 0.9 | 1.1 | 0.3 | 0.2 | -0.1 |
| Labour composition (quality) | 0.2 | 0.0 | 0.1 | 0.2 | 0.5 | 0.3 |
| MFP growth | 3.2 | 1.5 | 0.3 | 0.6 | 0.5 | 1.0 |

[a] Information processing equipment and software.

*Source:* PC estimates based on BLS data.

Table 4.7 **Contributions to 1990s acceleration in labour productivity growth for the United States**

Per cent per year

| | *1990s cycle over previous cycle*[a] | *1990s cycle over long term*[b] |
|---|---|---|
| Labour productivity acceleration | 0.3 | 0.3 |
| Total capital deepening | 0.1 | -0.2 |
| • IPES capital deepening | 0.3 | 0.2 |
| - Hardware | 0.3 | 0.2 |
| - Software | 0.1 | 0.1 |
| - Other IPES | 0.0 | -0.1 |
| • Other capital deepening | -0.3 | -0.5 |
| Labour composition (quality) | -0.2 | 0.0 |
| MFP acceleration | 0.5 | 0.5 |

[a] Growth in 1992 to 1999 less growth in 1986 to 1992. [b] Growth in 1992 to 1999 less growth in 1973 to 1992.

*Source:* PC estimates based on BLS data.

Table 4.7 shows the contributions to the acceleration in labour productivity in the 1990s cycle, compared with earlier periods. Importantly, the BLS data shows a much more modest acceleration in labour productivity growth, of 0.3 of a percentage point over productivity cycles, compared with the 1.1 percentage point or more found in other studies. This acceleration is accounted for by capital deepening of a similar magnitude (0.2 to 0.3 of a percentage point). The substitution of ICTs for other forms of capital, leading to negative growth in other capital deepening of a similar magnitude, meant that there was very little overall contribution from capital deepening to trend labour productivity growth. This left MFP to account for the labour productivity acceleration (offset partially by the negative labour composition effect).

Communications equipment made little contribution to the growth and acceleration in US labour productivity in the 1990s (figure 4.2, table 4.4, table 4.6 and table 4.7). The exclusion of communications equipment from Australian estimates (chapter 5) may therefore have little adverse effect on comparisons between Australia and the US.

## The size and sources of MFP growth

### *Academic studies show ICT production has made a strong contribution to the MFP growth acceleration*

As pointed out in chapter 3, ICTs can make a contribution to MFP growth in two ways:

- through MFP gains in ICT production; and
- through MFP gains to ICT-using industries through the use of ICTs.

Chapter 3 also pointed to a number of practical issues that affect the measurement, allocation and interpretation of MFP gains. In practice, the measurement of MFP gains, their allocation to ICT production and use and their association with spillover effects may not be precise.

Table 4.8 assembles the results of studies that isolate the first factor. The second factor is not isolated from other non-ICT developments that could lift productivity growth in ICT-using industries.[8]

[8] The BLS does not publish estimates of MFP growth specifically in ICT production. However, it does publish MFP estimates for broader manufacturing industry groupings. MFP growth in Industrial machinery & equipment and Electronic and other electric equipment — the 'homes' of ICT equipment manufacture — were 7.6 per cent and 7.2 per cent a year respectively over 1995-98. The rates for manufacturing and the non-farm business sector were 2.5 and 1.3 per cent per year respectively (BLS 2001).

Table 4.8 **Contributions to the acceleration in US MFP growth in the 1990s**[a]

| | *Oliner and Sichel (2000)* | *(2001)* | *Gordon (2000b)* | *Jorgenson and Stiroh (2000a)* | *CEA (2001)* |
|---|---|---|---|---|---|
| 1. MFP acceleration | 0.67 | 0.91 | 0.29 | 0.63 | 1.19 |
| 2. ICT industries | 0.26 | 0.26 | | 0.19 | 0.18 |
| - Computers | | | 0.29 | 0.16 | |
| - Semiconductors | 0.27 | | | | |
| - Software | | | | 0.03 | |
| - Communications | | | | 0.00 | |
| 3. Other industries | 0.41 | 0.64 | 0.00 | 0.44 | 1.00 |

**a** Aside from rounding errors, line 1 is equal to line 2 (or subsidiary components) plus line 3.

Gordon stands alone in attributing all of the MFP gains to computer production. These are gains that come from the increased capacity and power of ICTs — especially microprocessors — that are produced with little or any more input requirements (box 4.1).

All other studies find stronger contributions from other industries than from ICT industries — especially in more recent Oliner and Sichel (2001) and CEA (2001) estimates. The CEA attributes over 80 per cent of its finding of much stronger MFP growth to industries outside of the ICT production sector.

In the Gordon view, there can be no overall gains in ICT use, because he finds no MFP growth in other industries, outside of ICT production. However, as noted above, Gordon's view on the extent of MFP gains appears to be on the low side. Moreover, even zero MFP growth for the 'Other industries' aggregate does not necessarily rule out MFP gains in individual ICT-intensive user industries that are offset by trends in other industries (Jorgenson and Stiroh 2000, p. 183).

The CEA estimates in particular — but also the other studies, apart from Gordon — provide scope for the use of ICTs to bring MFP gains in non-ICT producing industries. How much scope cannot be directly gauged, except for taking MFP growth in 'Other industries' as the upper limit.

Box 4.1 **MFP gains in ICT production: Advances in Moore's Law or a size effect?**

At first glance, the strength that the studies have given to the role of computer production in the late 1990s MFP *acceleration* appears odd. Advances in computer power play such a central part in productivity growth in ICT production and yet Moore's Law (that the capacity of microprocessors doubles every 18 to 24 months) has been in continuous operation for some years — not just in the second half of the 1990s.

The table below, drawn from Oliner and Sichel (2000), shows that two things seemed to have happened: there was an unexplained slowdown in productivity growth in semiconductor production in the early 1990s; and there was an acceleration in productivity growth from the long-term rate in the second half of the 1990s. The second factor tallies with observations that the time horizon in Moore's Law may have been reduced to around 12 months.

However, the contribution of MFP gains in computer production is also influenced by the growth in the size of the sector. The table shows that the output weights that apply to computer and especially semiconductor production have changed considerably. Consequently, while there has been a 50 per cent increase in the rate of MFP growth in semiconductors (from 30 to 45 per cent a year), the contribution from semiconductors to aggregate MFP growth has increased nearly five-fold (from 0.08 to 0.39 of a percentage point).

**MFP growth and output shares in industry sectors**

| | *1974-90* | *1991-95* | *1996-99* |
|---|---|---|---|
| *MFP growth* (per cent per year): | | | |
| Computer sector | 11.2 | 11.3 | 16.6 |
| Semiconductor sector | 30.7 | 22.3 | 45.0 |
| Other non-farm business | 0.13 | 0.20 | 0.51 |
| *Output shares* (per cent): | | | |
| Computer sector | 1.1 | 1.4 | 1.6 |
| Semiconductor sector | 0.3 | 0.5 | 0.9 |
| Other non-farm business | 98.9 | 98.9 | 98.7 |
| *MFP growth contribution (per cent per year)* | | | |
| Computer sector | 0.12 | 0.16 | 0.26 |
| Semiconductor sector | 0.08 | 0.12 | 0.39 |
| Other non-farm business | 0.13 | 0.20 | 0.50 |

*Source:* Oliner and Sichel (2000), table 4.

*There is growing evidence of productivity acceleration in using industries*

As noted at the outset of this chapter, Jorgenson and Stiroh (2000a) were unconvinced about the importance of MFP gains associated with ICTs in the non-ICT producing sectors — despite their results showing the highest MFP acceleration in other industries (outside ICT production) amongst the academic studies.

> A closer look at the data, however, shows that gains in [MFP] growth can be traced in large part to IT industries… The evidence is equally clear that computer-using industries such as finance, insurance, and real estate (FIRE) and other services have continued to lag in productivity growth. (p. 128)

Generally speaking, this position is shifting as more data and analysis becomes available. Stiroh (2001) himself has had another look at industry data and found that 'IT-use has been an important part of the US productivity revival in the late 1990s' (p. 2), and 'the most intensive [industry] users of IT experienced the largest productivity gains, consistent with the idea that IT has real economic benefits' (p. 2). Based on a detailed industry analysis, Stiroh found that IT-producing industries contribute about one-fifth of the aggregate labour productivity acceleration and IT-using industries contribute nearly all of the remainder.[9] Importantly, he found little acceleration in industries unrelated to the production or use of IT.

Nordhaus (2001b) found that his 'new economy' production industries (machinery, electrical equipment, telephone and telegraph, and software) contributed about one-half of the aggregate labour productivity acceleration from 1995 (compared with the long-term average from 1973), with the other half due to productivity growth in sectors outside of ICT production. He found that Durable manufacturing, Wholesale trade, Retail trade and Finance, insurance & real estate (FIRE) made much stronger contributions to aggregate productivity growth in the 1990s.

There is little readily-available evidence on the rate of MFP growth in the US at the industry level that can be used to compare MFP growth in the late 1990s with earlier periods. Jorgenson and Stiroh (2000a, 2000b) include industry estimates, but only for the period 1958 to 1996 and without period breakdowns. Oliner and Sichel (2000) and Gordon (2000b) do not provide any disaggregation of MFP growth among non-ICT industries. The BLS does not produce industry MFP estimates outside of the manufacturing sector.

Two other sources can be drawn on. The first is a comparison of US and Canadian productivity performance by the (Canadian) Centre for the Study of Living Standards (CSLS 2000), and the second is the 2001 *Economic Report of the*

9 Stiroh examined labour productivity (with an hours worked labour measure) in over 60 industries. However, he only presents results for his industry groupings (ICT production, ICT-using and other) and not for individual industries.

*President* (CEA 2001). The results of these studies, based on output per employed worker, are presented in table 4.10.

There is some weakness in the evidence from these studies. They show some differences in productivity estimates for some of the same industries, probably related in part to the different time periods used. They also measure labour productivity and not MFP, and labour input is measured in terms of numbers employed (which would understate labour productivity acceleration in industries in which there has been growth in part-time employment). An acceleration in labour productivity could reflect capital deepening, rather than necessarily MFP gains.

They nevertheless reveal a marked acceleration in productivity growth in certain industries, especially:

- Wholesale and retail trade (acceleration of 4-6 percentage points); and
- Financial intermediation (acceleration of 3-4 percentage points).

The CEA source also shows strong acceleration in labour productivity in Durable goods manufacture — the 'home' of ICT equipment production.

The productivity acceleration in ICT-using industries is also confirmed in separate work by the OECD (2000d).

Brynjolfsson and Hitt (2000) reviewed firm-level studies of ICT use and found evidence of very high returns to ICT investments. They considered that ICTs could generate high returns in the short term, but also in the long term if complementary changes in firm organisation were made.

Whilst this evidence has some qualifications and does not establish how much productivity growth is due to ICT use, it challenges the view that there has been *no* acceleration in productivity growth in ICT-using industries.

Table 4.9 **Acceleration in US output per employed worker over the 1990s**
Per cent per year

| | *CSLS (2000)* | *CEA (2001)* |
|---|---|---|
| | **1989-95 to 1995-98** | **1989-95 to 1995-99** |
| **Periods** | | |
| *Private industries* | 1.31 | 1.43 |
| *Goods sector:* | 0.59 | |
| Agriculture | 5.52 | 0.84 |
| Mining | -1.48 | -0.50 |
| Construction | 0.16 | -0.79 |
| Manufacturing | 0.36 | 1.16 |
| - Durable goods | | 2.51 |
| - Non durable goods | | -0.59 |
| *Services Sector:* | 1.88 | |
| Transportation and public utilities | -0.56 | |
| - Transportation | -0.49 | 0.76 |
| - Communications | -0.57 | -2.41 |
| - Electricity, gas, sanitation | -0.07 | -0.09 |
| Wholesale trade | 6.35 | 4.99 |
| Retail trade | 4.83 | 4.25 |
| Finance, insurance and real estate | 1.26 | 0.97 |
| - Finance | | 3.58 |
| - Insurance | | 0.72 |
| - Real estate | | 1.49 |
| Services (other) | 0.99 | 0.93 |
| - Personal services | | 2.55 |
| - Business services | | 1.85 |
| - Health services | | 1.26 |
| - Other services | | 0.01 |
| Government | 0.30 | |

## 4.3 Summary

There was strong growth in the production and use of ICTs in the US in the second half of the 1990s, coinciding with surprisingly strong and persistent growth in output and labour productivity. Increased use of ICTs accounted for about a quarter of the 2 percentage point acceleration in output growth.

The strong labour productivity acceleration of over 1 percentage point between the first and second halves of the 1990s can be attributed to:

- capital deepening (a little under a half), based predominantly on ICT capital deepening (as ICTs have substituted for labour and other forms of capital); and
- MFP growth (over a half).

However, a different picture emerges when labour productivity growth is measured in trend terms. The acceleration is a much less spectacular 0.3 of a percentage point. There is no overall increase in capital deepening — the increased use of ICT is offset by slow or even negative growth in other capital. Faster MFP growth accounts for the labour productivity acceleration.

A range of studies find production of ICT equipment has contributed a sizeable proportion (roughly a quarter) of total MFP gain in the second half of the 1990s. Robert Gordon stands alone in attributing all the MFP acceleration to ICT production. But the evidence that more productivity gains have also come from ICT-using industries is now becoming stronger. Wholesale and retail trade and financial intermediation appear to be prime cases. Indeed, one detailed study by Stiroh (2001) attributed most of the labour productivity acceleration to using industries and found no productivity gains outside of industries engaged in ICT production or intensive ICT use.

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# 5 Contribution of IT in Australia

This chapter explores the contribution of computer and related equipment to Australia's output and productivity growth.

The assessment is confined to the contribution of computer hardware and software — referred to in this chapter as IT. Communication equipment is not separately identified in the Australian Bureau of Statistics (ABS) capital services data, and therefore cannot be included.

Even so, the contribution of IT to Australia's output and productivity growth in the 1990s is found to be high. Indeed, the extent and timing of the contribution to labour productivity growth of IT capital deepening is remarkably close to that of the US — and, if anything, exceeds it. Australia also shows a stronger multifactor productivity (MFP) acceleration than the US, despite the absence of a sizeable ICT equipment production sector. Whilst Australia's MFP acceleration could be due to a range of factors, at least some of it can be attributed to IT use.

The chapter also examines contributions at the industry level. Associations between IT use and productivity acceleration are found in a number of industries. But a clear relationship across all industries is not found.

## 5.1 The growth of IT in Australia

This section presents some of the data from the Australian national accounts that are used in the contribution analysis. Details are provided in appendix B.

Computer hardware is defined as computing and office equipment, including peripherals. Computer software is defined as purchased software (customised or 'off-the-shelf'), in-house developed software, and large expenditures on database development or extensions.

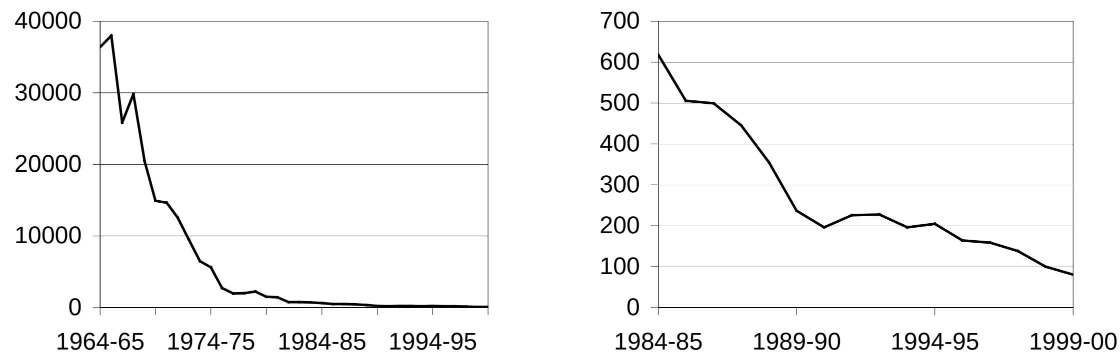
Estimates of the productive capital stock of hardware and software were formed from unpublished ABS data. The ABS provided data on productive capital stocks and rental prices by asset type and by industry. Productive capital stocks of assets were summed across industries and non-IT assets were aggregated, using rental price weights.[1]

The data and analysis in this chapter focus on IT contributions to production in the market sector of the economy. Investments by households are not included.

Falling IT prices have undoubtedly been an important influence on the growth in demand for IT. Falls in the quality-adjusted prices for hardware and software were discussed and displayed in chapter 2. These falls have contributed to massive falls in the relative rental prices, or user costs of capital, for IT compared with other assets (figure 5.1). However, there was no acceleration in the relative price decline over the 1990s.

Figure 5.1 **Rental price of IT relative to other capital, 1964-65 to 1999-00**
Index 1998-99 = 100

*1964-65 to 1999-00* *1984-85 to 1999-00*



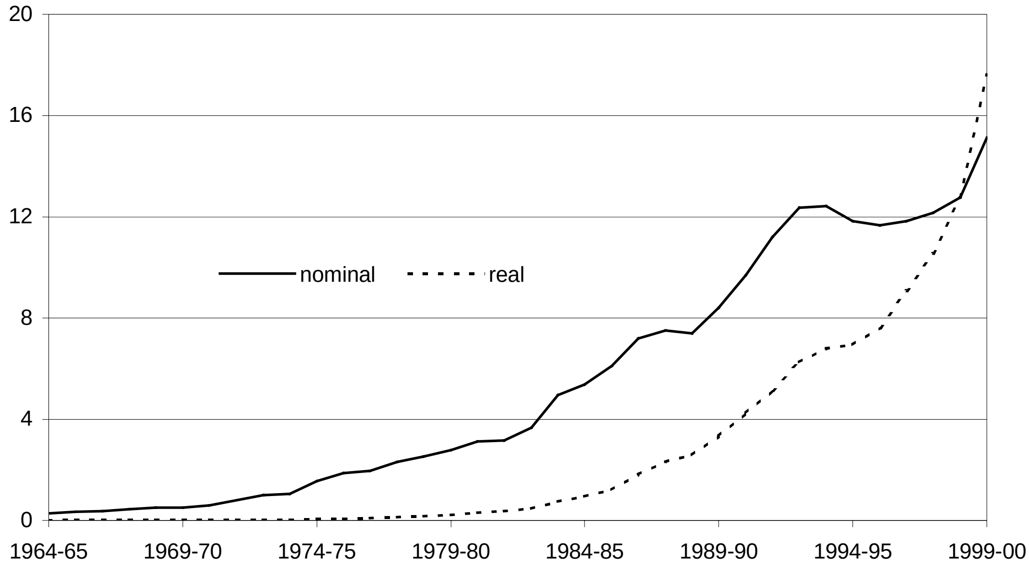

*Data source:* PC estimates based on unpublished ABS data.

Investment in IT only became a sizeable proportion of total investment from the mid 1980s (figure 5.2). Since then, the growth of investment has been very strong, especially in the 1990s, when investment in hardware grew by 35 per cent a year and software investment grew by 20 per cent a year in real terms (table 5.1). (High growth rates before the mid-1980s were off a very small base.) Investment in IT in 1999-00 represented nearly 18 per cent of annual market sector investment in real terms or 15 per cent in nominal terms (figure 5.2). (IT is a higher proportion in volume terms because of its declining hedonic price.)

[1] There were minor discrepencies between the ABS capital services measure and the equivalent measure built up from the disaggregated data. This appears to be due to the fact that the ABS uses weights based on gross operating surplus and these differ from weights based on rental payments.

## Figure 5.2 **IT share of real and nominal gross fixed capital formation for the market sector in Australia, 1964-65 to 1999-00**

Per cent




*Data source:* PC estimates based on unpublished ABS data.

## Table 5.1 **Annual average growth in real gross fixed capital formation for the market sector in Australia, selected periods**

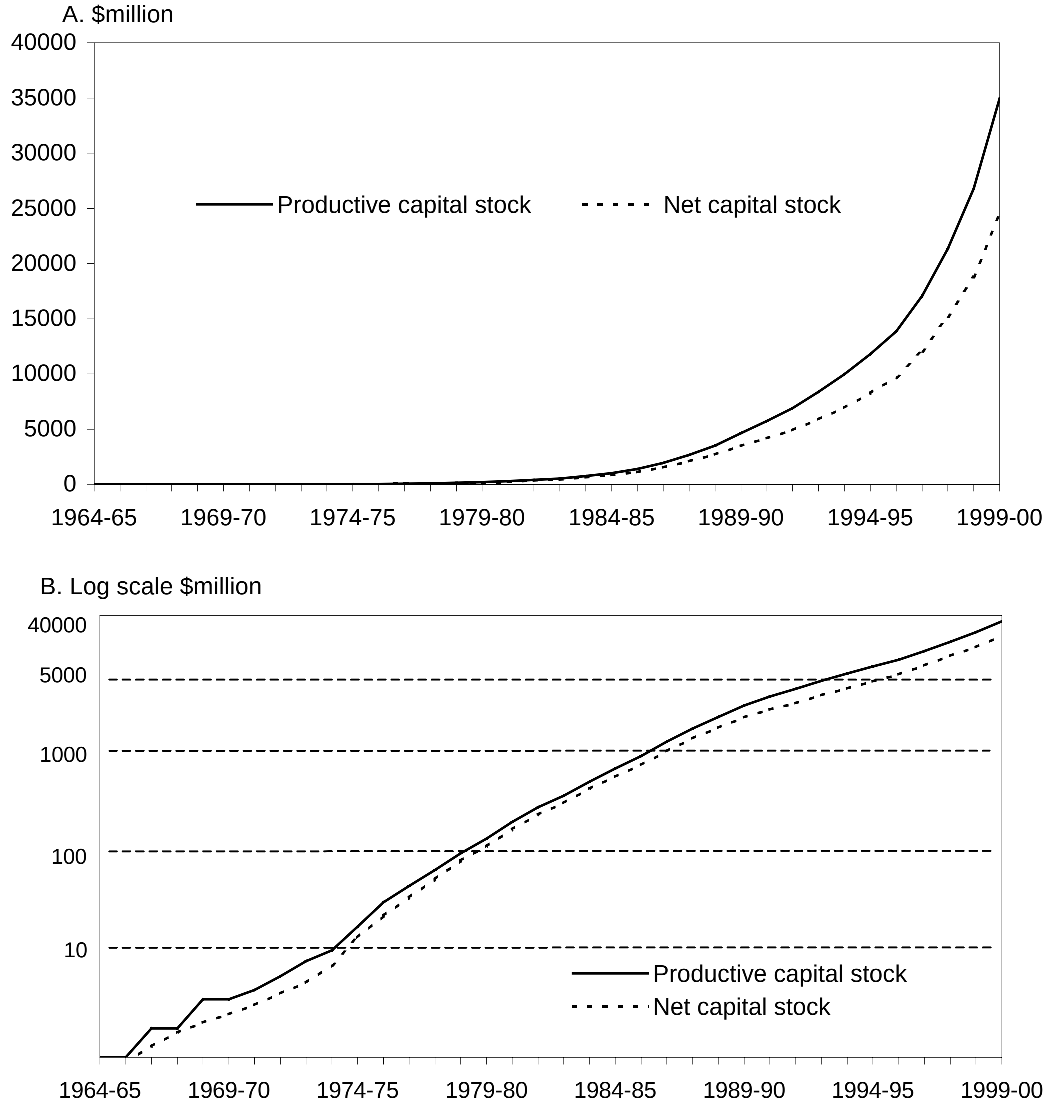
Per cent per year

| | *1964-65 to 1973-74* | *1973-74 to 1984-85* | *1984-85 to 1988-89* | *1988-89 to 1993-94* | *1993-94 to 1999-2000* | *1964-65 to 1999-00* |
|---|---|---|---|---|---|---|
| Computers | 34.5 | 37.7 | 35.0 | 17.9 | 35.1 | 33.1 |
| Software | 17.6 | 52.0 | 34.9 | 21.7 | 20.5 | 30.7 |
| Combined | 25.2 | 44.9 | 34.9 | 20.4 | 26.1 | 31.6 |
| | | | | | | |
| Other Capital | 4.0 | 3.0 | 4.5 | -1.6 | 5.4 | 3.1 |
| Total | 4.0 | 3.1 | 5.0 | -0.8 | 7.6 | 3.7 |

*Source:* PC estimates based on unpublished ABS data.

The growth in investment, of course, led to very strong growth in the productive IT capital stock — that is, the capital stock adjusted for efficiency loss (see chapter 3). Figure 5.3, shows the enormous growth in the productive IT capital stock from the late 1980s. The second part of the figure with the same data drawn on a log scale, indicates a virtually constant rate of growth through the period, with a slight slowdown in rate of growth in the 1990s.

## Figure 5.3 **Productive capital stock and net capital stock of IT assets in the Australian market sector, 1964-65 to 1999-00**




*Data source:* PC estimates based on unpublished ABS data.

The very strong growth in the productive IT capital stock raised the share of capital income attributable to IT (table 5.2). Growth in IT capital overshadowed the decline in IT rental prices, meaning that real IT capital income (the multiple of productive capital stock and rental price) not only grew strongly, but also grew as a proportion of total capital income (appendix B).

Table 5.2 **Share of capital income for the market sector, selected years**
Per cent

| | *1974-75* | *1981-82* | *1984-85* | *1988-89* | *1993-94* | *1999-00* |
|---|---|---|---|---|---|---|
| Hardware | 1.2 | 1.4 | 2.1 | 3.4 | 4.5 | 6.5 |
| Software | 0.4 | 1.5 | 2.2 | 3.0 | 6.0 | 5.8 |
| Other capital | 98.4 | 97.1 | 95.7 | 93.7 | 89.5 | 87.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*Source:* PC estimates based on unpublished ABS data.

The share of IT in total income (that is, payments to factors of production) has also grown markedly (table 5.3). As shown in chapter 3, IT's income share enters directly into the calculation of IT's contribution to output and productivity growth. The increase in the share over time therefore has a positive influence on the size of the calculated contributions.

Table 5.3 **Income shares for the market sector, selected years**
Per cent

| | *1974-75* | *1981-82* | *1984-85* | *1988-89* | *1993-94* | *1999-00* |
|---|---|---|---|---|---|---|
| Capital | 35.0 | 34.0 | 37.0 | 40.0 | 41.0 | 41.0 |
| - Hardware | 0.4 | 0.5 | 0.8 | 1.3 | 1.8 | 2.7 |
| - Software | 0.1 | 0.5 | 0.8 | 1.2 | 2.5 | 2.4 |
| - Other | 34.4 | 33.0 | 35.4 | 37.5 | 36.7 | 36.0 |
| Labour | 65.0 | 66.0 | 63.0 | 60.0 | 59.0 | 59.0 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*Source:* PC estimates based on unpublished ABS data.

## 5.2 Contribution to output growth

The IT contributions to output growth are assessed over output cycles, which are defined as periods between peaks in output growth. The peaks are defined as points where the gaps between the actual and a trend output series turn from increasing to decreasing.

The use of output cycles is one method for defining and examining underlying trends in output growth. A number of studies, including those reviewed in chapter 4, have compared growth rates for the second half of the 1990s with earlier periods. The use of 1995 as the dividing point between these periods may be defensible in terms of delineating the acceleration in investment in ICTs from 1995. But these periods are essentially arbitrary with respect to productivity growth and would only accidentally reveal underlying trends for analysis in the growth accounting framework. (Comparisons of contributions in the two halves of the 1990s are nevertheless presented for Australia below.)

Contributions are displayed in table 5.4 and in chart form in figure 5.4.[2] The IT contribution reached nearly 30 percent of the output growth in the 1990s (strictly, from the late 1980s). The contribution from hardware is slightly stronger than the software contribution. As in the US, the increase in IT contribution came at the expense of growth in other capital.

Table 5.4 **Contributions to Australia's output growth[a] in the market sector**

Per cent per year and (per cent)

| | *1964-65 to 1973-74* | | *1973-74 to 1981-82* | | *1981-82 to 1989-90* | | *1989-90 to 1999-00* | | *1964-65 to 1999-00* | |
|---|---|---|---|---|---|---|---|---|---|---|
| Output growth | 4.8 | (100) | 2.1 | (100) | 3.2 | (100) | 3.4 | (100) | 3.4 | (100) |
| Capital contribution[b] | 2.3 | (47) | 1.4 | (64) | 1.6 | (51) | 1.7 | (50) | 1.8 | (51) |
| - Hardware capital | 0.0 | (0) | 0.2 | (8) | 0.3 | (10) | 0.6 | (16) | 0.2 | (7) |
| - Software capital | 0.0 | (0) | 0.1 | (6) | 0.3 | (11) | 0.5 | (13) | 0.2 | (7) |
| - Other capital | 2.3 | (47) | 1.1 | (50) | 1.0 | (30) | 0.7 | (20) | 1.3 | (37) |
| Hours worked contribution[b] | 1.3 | (26) | -0.2 | (-8) | 1.2 | (36) | 0.3 | (9) | 0.6 | (19) |
| MFP growth | 1.3 | (27) | 1.0 | (44) | 0.4 | (13) | 1.4 | (41) | 1.1 | (30) |

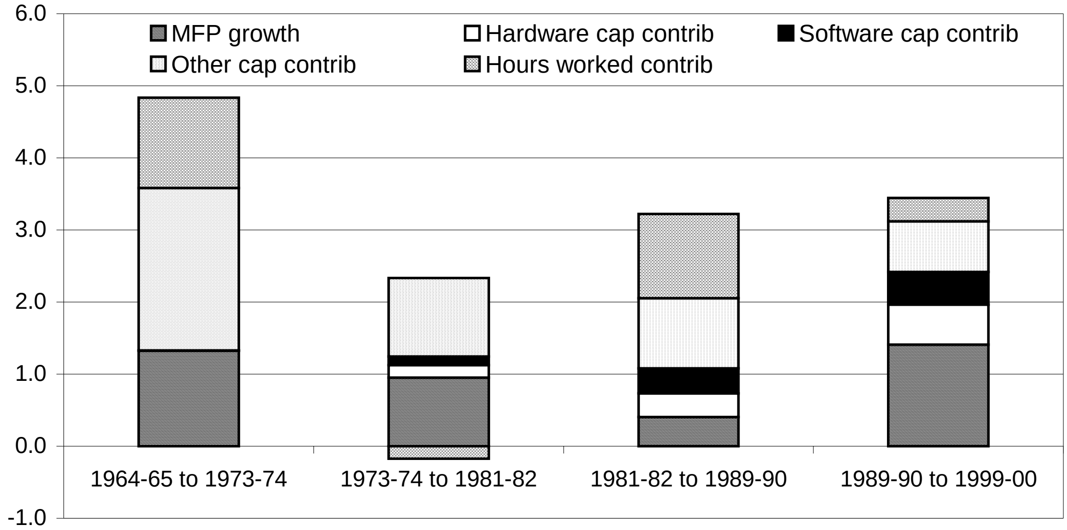
[a] Numbers in brackets are percentage contributions to output growth. Factor income shares, used in calculating contributions, are averaged over the periods indicated. [b] Contributions from factors are their rates of growth multiplied by their respective factor income shares.

*Source:* PC estimates based on unpublished ABS data.

[2] The output, capital contribution, hours worked contribution and MFP growth all accord with published ABS estimates. As noted in footnote 1, there was some discrepancy between published capital services estimates and the data used to separate out the growth in hardware, software and other capital. These discrepancies were allocated to the 'other capital' category. They were of only minor size — registering negligible differences in growth rates in most cases and of the order of 0.1 to 0.2 percentage points in a few cases.

Figure 5.4 **Contributions to market sector output growth for Australia, 1964-65 to 1999-00**

Per cent per year




*Data source:* PC estimates based on unpublished ABS data.

IT was also important in the changing sources of output growth from the 1980s to the 1990s (table 5.5). IT added 0.3 of a percentage point and MFP growth added a further 1 percentage point to the acceleration in output growth. However, these accelerating factors were offset to a large extent by lower growth in other capital and labour. IT growth made a stronger contribution to the long-term output acceleration — that is, growth in the 1990s compared with growth over the 1970s and 1980s.

Table 5.5 **Contributions to the 1990s acceleration in market sector output growth**

Percentage points

| | *Over the previous cycle*[a] | *Over the long term*[b] |
|---|---|---|
| Output growth acceleration | 0.3 | 0.8 |
| Capital contribution[c] | 0.1 | 0.2 |
| - Hardware capital | 0.2 | 0.3 |
| - Software capital | 0.1 | 0.2 |
| - Other capital | -0.3 | -0.3 |
| Hours worked contribution[c] | -0.8 | -0.2 |
| MFP acceleration | 1.0 | 0.7 |

[a] Annual growth over 1989-90 to 1999-00 less growth over 1981-82 to 1989-90. [b] Annual growth over 1989-90 to 1999-00 less growth over 1973-74 to 1989-90. [c] Factor contributions are their growth accelerations multiplied by their respective factor income shares.

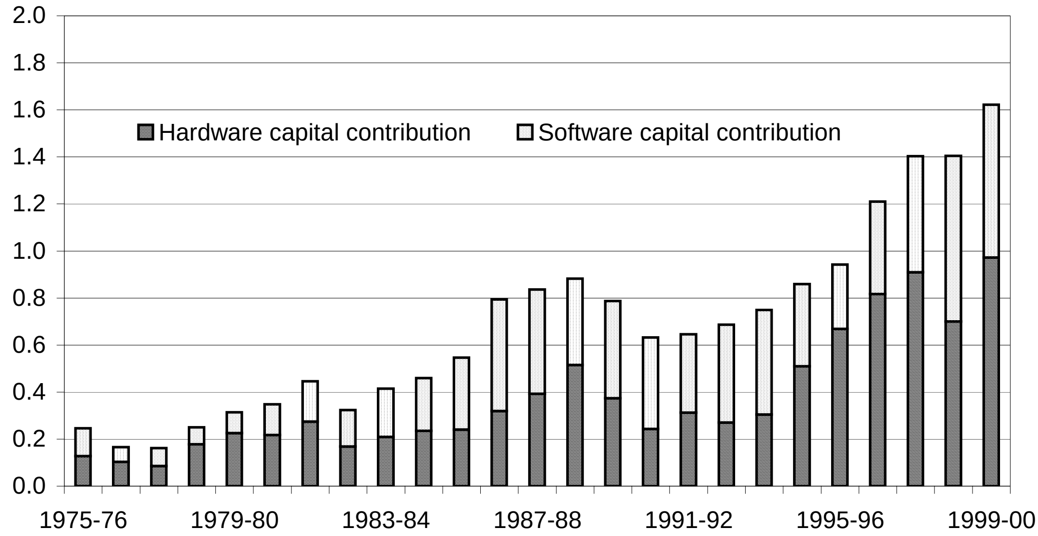
*Source:* PC estimates based on unpublished ABS data.

Figure 5.5 shows the annual contributions of IT capital to output growth. This shows that the IT contribution stepped up from 1995-96.

As noted above (and in chapter 4), US studies have compared the IT contributions to output growth in the first and second halves of the 1990s. Australian estimates are presented on this same basis in table 5.6. Contributions are measured and compared between the periods (year ending 30 June) 1990 to 1995 and 1995 to 2000.

Figure 5.5 **Annual contributions of IT capital to output growth, 1975-76 to 1990-00**

Per cent




*Data source:* PC estimates based on unpublished ABS data.

Table 5.6 **Contributions to output growth in first and second halves of the 1990s**

| | *1989-90 to 1994-95* | *1994-95 to 1999-00* | *Acceleration* |
|---|---|---|---|
| | % pa | % pa | Percentage points |
| Output growth | 2.0 | 4.9 | 2.9 |
| Capital contribution | 1.3 | 2.2 | 0.9 |
| - Hardware | 0.3 | 0.8 | 0.5 |
| - Software | 0.4 | 0.5 | 0.1 |
| - Other | 0.5 | 0.8 | 0.3 |
| Hours worked contribution | -0.1 | 0.7 | 0.8 |
| MFP growth | 0.8 | 2.0 | 1.2 |

*Source:* PC estimates based on unpublished ABS data.

Compared with the trend estimates in tables 5.4 and 5.5, the results in table 5.6 show much greater output growth and acceleration in the second half of the 1990s. The results in table 5.6 should therefore be treated with caution. IT capital and MFP growth account for part of the greater output growth shown. But the biggest difference is the much stronger contribution from hours worked in the second half of the 1990s. Simon and Wardrop (2001) obtain similar results even though the years chosen differ slightly. They also state that MFP and hours worked are the main contributors to the acceleration in output growth.

Compared with the US results (tables 4.1 and 4.2), the Australian results in table 5.6 show:

- faster output growth and acceleration in the second half of the 1990s;
- a similar or slightly higher contribution from IT hardware and software;
- a similar contribution from other capital; and
- higher contributions from hours worked and MFP.

## 5.3 Contribution to productivity growth

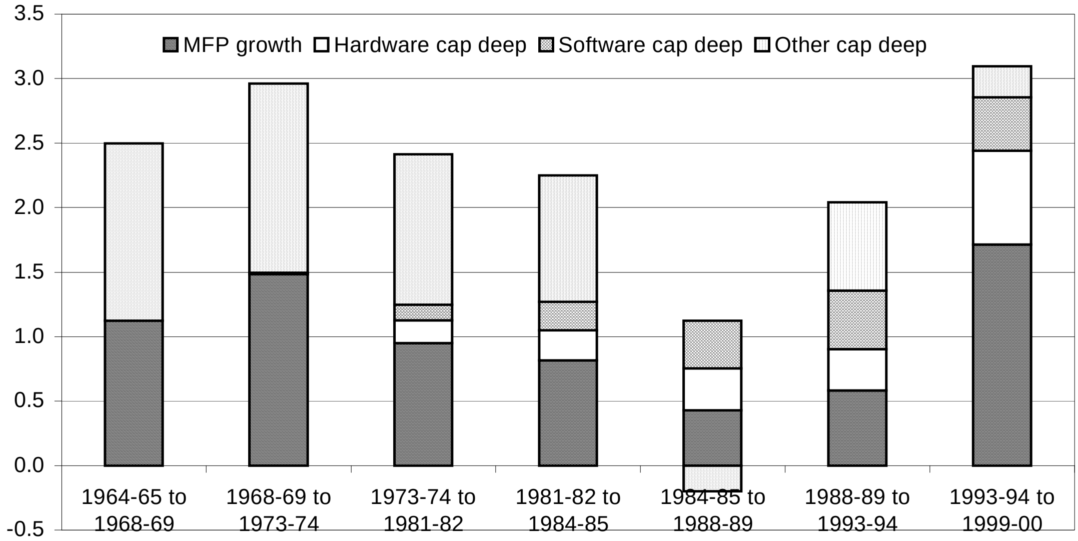
The contribution of IT to productivity growth is assessed over labour productivity cycles — that is, from peak to peak in labour productivity growth. The labour productivity cycles correspond to the MFP cycles identified by the ABS.

Figure 5.3 and table 5.7 show:

- Apart from the late 1980s cycle, the contribution of capital deepening was relatively constant — at around 1.4 per cent a year.
- The variation in labour productivity growth is mainly explained by variation in MFP growth.
- The importance of IT in capital deepening has increased since the mid 1970s.
- In the 1990s, IT capital deepening accounted for just over one third of the record-high labour productivity growth, and just over 80 per cent of all capital deepening.
  - Hardware capital deepening was more important than software capital deepening in the 1990s cycle, reversing the relative importance of each in the previous cycle.
- MFP growth accounted for over half of the growth in labour productivity in the 1990s.

Figure 5.6 **Contributions to market sector labour productivity growth for Australia, 1964-65 to 1999-00**

Per cent per year




*Source:* PC estimates based on unpublished ABS data.

Table 5.7 **Contributions to Australia's labour productivity growth[a] in the market sector**

Per cent per year

| | *1964-65 to 1973-74* | | *1973-74 to 1984-85* | | *1984-85 to 1988-89* | | *1988-89 to 1993-94* | | *1993-94 to 1999-2000* | | *1964-65 to 1999-00* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labour productivity growth | 2.7 | (100) | 2.4 | (100) | 0.9 | (100) | 2.1 | (100) | 3.1 | (100) | 2.4 | (100) |
| Capital deepening[b] | 1.4 | (52) | 1.5 | (61) | 0.5 | (54) | 1.5 | (72) | 1.4 | (45) | 1.3 | (56) |
| - Hardware | 0.0 | (0) | 0.2 | (8) | 0.3 | (35) | 0.3 | (16) | 0.7 | (23) | 0.2 | (9) |
| - Software | 0.0 | (0) | 0.2 | (7) | 0.4 | (40) | 0.5 | (22) | 0.4 | (13) | 0.2 | (10) |
| - Other capital | 1.4 | (52) | 1.1 | (46) | -0.2 | (-22) | 0.7 | (34) | 0.2 | (8) | 0.9 | (37) |
| MFP growth | 1.3 | (48) | 0.9 | (39) | 0.4 | (46) | 0.6 | (28) | 1.7 | (55) | 1.1 | (44) |

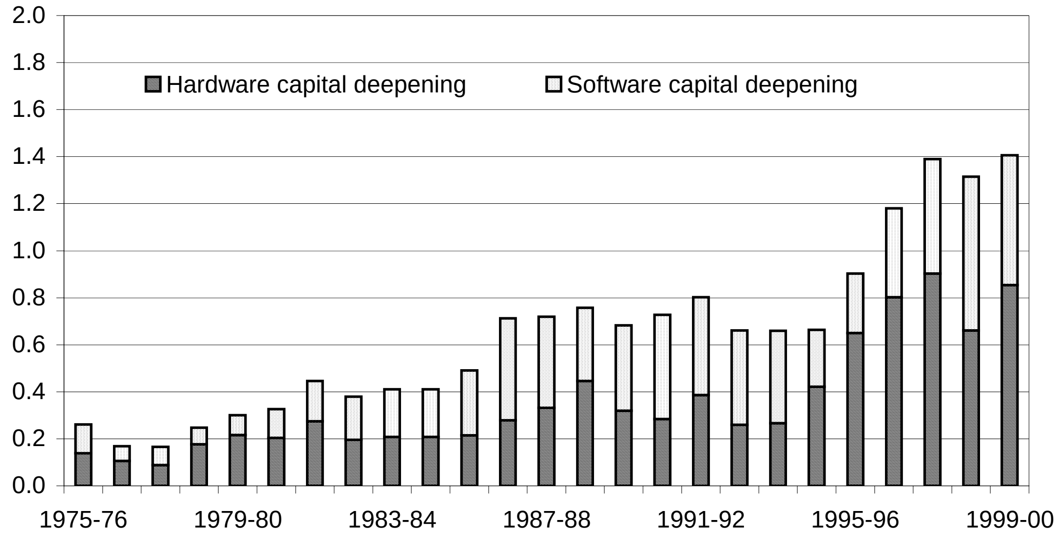
**a** Numbers in brackets are percentage contributions to labour productivity growth. Factor income shares, used in calculating contributions are averaged over the periods indicated. **b** Capital deepening is growth in the capital-labour ratio multiplied by the capital income share.

*Source:* PC estimates based on unpublished ABS data.

On year-to-year estimates, the strong contribution of IT capital deepening in the 1990s emerged in 1995-96 (figure 5.7). The timing and strength of this contribution is remarkably close to that of the US. If anything, the Australian contribution is slightly stronger than that of the US. This is explored further below.

Figure 5.7 **Contributions of IT capital deepening to market sector labour productivity growth, 1975-76 to 1999-00**

Percentage points




*Data source:* PC estimates based on unpublished ABS data.

Like the US, the increase in IT capital deepening in Australia co-existed with stronger MFP growth (although the MFP acceleration was greater in Australia). This association is investigated at an industry level in the next section.

Contributions to the 1990s labour productivity *acceleration* are shown in table 5.8. The 1990s growth in variables is compared with growth in the previous cycle (1988-89 to 1993-94) and with growth over the long term (1973-74 to 1993-94).

The increase in hardware capital deepening was more important than software capital deepening in the labour productivity acceleration. Hardware capital deepening accounted for about 40 per cent of the labour productivity acceleration, whereas software capital deepening barely increased in the 1990s period. However, IT capital deepening was offset by reductions in the ratio of other capital to labour. That is, growth in IT substituted for growth in those other forms of capital.

MFP growth was the major contributor to the labour productivity acceleration. While there was little net contribution from capital deepening, faster MFP growth accounted for virtually all of the labour productivity acceleration. Nevertheless, it is still theoretically possible that the IT capital deepening and MFP contributions to the labour productivity acceleration were linked.

IT's contributions to productivity growth have come from the use of IT, as evident in the IT capital deepening component, and potentially from (unspecified) links to

MFP gains in IT-using industries. Although it has not been explicitly examined in this study, the small size of Australia's IT production sector means that it is likely that IT production would have provided only a negligible contribution to aggregate MFP growth.

Table 5.8 **Contributions to the 1990s acceleration in market sector labour productivity growth**

| | *Over the previous cycle*[a] | *Over the long term*[b] |
|---|---|---|
| Labour productivity acceleration | 1.1 | 1.1 |
| Capital deepening (change in) | -0.1 | 0.1 |
| - Hardware | 0.4 | 0.4 |
| - Software | 0.0 | 0.1 |
| - Other capital | -0.4 | -0.4 |
| MFP acceleration | 1.1 | 1.0 |

[a] Growth in 1993-94 to 1999-00 less growth in 1988-89 to 1993-94. [b] Growth in 1993-94 to 1999-00 less growth in 1973-74 to 1993-94.

*Source:* PC estimates.

## Australian and US estimates compared

The above estimates of IT contributions to Australia's productivity growth, conducted in terms of underlying trends over productivity cycles, are most comparable with the US estimates presented in figure 4.3, table 4.5 and surrounding text — that is, where Bureau of Labor Statistics (BLS) data have been used to calculate and compare underlying trends over labour productivity cycles.

Comparing the US and Australian results on this similar basis reveals:

- The US labour productivity acceleration appears less impressive — 0.3 of a percentage point compared with 1.1 percentage points in Australia.
- The contribution of IT capital deepening is smaller in the US than in Australia — 0.2 or 0.3 of a percentage point in the US, compared with 0.4 or 0.5 of a percentage point in Australia.
- The contribution of MFP growth is smaller in the US than in Australia — 0.3 to 0.5 of a percentage point in the US, compared with 1.0 to 1.1 percentage points in Australia.

However, the US studies have all presented estimates of computers' contributions based on comparisons between the first and second halves of the 1990s. To facilitate comparisons with US estimates on this basis, the Australian numbers are reworked in table 5.9 to provide estimates for the first half and second half of the

1990s. Whilst these estimates facilitate comparison with US studies, they should not be interpreted as underlying trends.

Comparisons with tables 5.7 and 5.8 reveal that this approach produces similar, although slightly overstated, estimates of the contribution of IT capital deepening in Australia. However, the extent of labour productivity and, to a lesser extent, MFP accelerations are clearly overstated compared with the underlying trend estimates. The MFP acceleration of 1.1 percentage points shown in table 5.8 is a quite robust estimate of the 1990s MFP acceleration, being supported by estimates from a number of different methodologies (Parham and Kennett 2001).

Table 5.9 **Contributions to Australia's labour productivity growth over the 1990s**

Per cent per year

| | *1989-90 to 1994-95* | *1994-95 to 1999-00* | *Acceleration* |
|---|---|---|---|
| Labour productivity growth | 2.1 | 3.7 | 1.5 |
| Capital deepening | 1.3 | 1.7 | 0.4 |
| - Hardware | 0.3 | 0.8 | 0.5 |
| - Software | 0.4 | 0.5 | 0.0 |
| - Other | 0.5 | 0.4 | -0.1 |
| MFP growth | 0.8 | 2.0 | 1.2 |

*Source:* PC estimates based on unpublished ABS data.

The estimates for the first and second halves of the 1990s are quite sensitive, however, to period selection. This is shown when comparisons are made between 1990-91 to 1995-96 and 1995-96 to 1999-00.[3] Sensitivity is further demonstrated in work undertaken by the Reserve Bank of Australia (RBA). Gruen (2001) reported Australian estimates which compared IT contributions over 1990-91 to 1994-95 and over 1995-96 to 1998-99. These periods have been selected to correspond to periods used in Oliner and Sichel (2000).[4] The IT capital deepening contributions are quite similar in the RBA analysis (0.4 per cent a year for hardware capital deepening and zero for software capital deepening), but the labour productivity and MFP accelerations are overstated (at 2.0 per cent a year and 1.4 per cent a year respectively), compared with table 5.2. The OECD (2001) has reproduced the RBA results.

[3] With the alternative periods mentioned, the IT capital deepening contribution is similar to that shown in table 5.9, but the labour productivity and MFP accelerations are much lower.

[4] Most US studies have used the periods 1990-95 and 1995-99 or 1995-2000. Oliner and Sichel (2000), however, use the periods 1991-95 and 1996-99.

Wilson (2000) and Toohey (2000) have used the same periods as the RBA — that is, years ended 30 June, 1991-95 and 1996-99. Their results are similar to the RBA's on labour productivity growth. However, they attribute less importance to IT capital deepening and more to other capital deepening; and show an even greater (and overstated) contribution from MFP to the labour productivity acceleration of 1.6 percentage points. The lower attribution to IT capital deepening is due to the use of a capital stock measure, rather than a capital services measure (see chapter 2).

Work by the International Monetary Fund ((IMF) Gruenwald, Cardanelli and Dell'Ariccia 2001) includes comparisons between the first and second halves of the 1990s. However, their results do not accord with any other results presented here, and cannot be reproduced from ABS data.[5]

The key point is that period selection has considerable bearing on the results — not so much on the IT capital deepening contribution, but very much so on the labour productivity acceleration to be decomposed, and the size of the MFP contribution. Periods therefore need to be carefully selected and justified. For this reason, the trend assessments presented for Australia in tables 5.7 and 5.8 are preferred.

Compared with results for the US (tables 4.4 and 4.7), the Australian estimates in table 5.9 show a higher acceleration in labour productivity and MFP, and a similar — slightly higher — contribution from IT capital deepening. This conclusion is qualitatively similar to the above 'trend' comparisons.

Australia and the US had similar rates of increase in use of IT and related equipment in the 1990s. However, the fact that Australia has had stronger MFP growth suggests that:

- to the extent that MFP gains are associated with IT use, Australian firms have generated stronger MFP gains, perhaps because they had further scope to catch up to their US counterparts; and/or
- Australia has benefited more than the US from non-ICT contributions to MFP growth.

The gains from either or both of these factors have more than offset the absence of MFP gains from an ICT production sector in Australia.

The similarity in rates of IT capital deepening does mask some differences between the two countries. Table 5.10 compares IT capital deepening in Australia with US estimates based on BLS data. It shows that, while IT capital deepening was stronger

[5] The IMF results show less output growth in the second half of the 1990s than shown in any other study. The extent of labour productivity and MFP growth and acceleration in the IMF study is therefore lower.

in Australia, the growth in IT was stronger in the US, particularly in hardware. However, stronger growth in labour hours in the US and a higher IT income share[6] in Australia had a counteracting effect on IT capital deepening.

Table 5.10 **IT capital deepening in Australia and the US**

| | *US 1995-99* | *Australia 1994-95 to 1998-99* |
|---|---|---|
| IT capital deepening (% pa) | 0.9 | 1.2 |
| - Hardware | 0.6 | 0.8 |
| - Software | 0.3 | 0.4 |
| IT capital growth (% pa) | | |
| - Hardware | 42.8 | 34.5 |
| - Software | 17.9 | 16.8 |
| Labour hours (% pa) | 2.2 | 0.7 |
| IT income share[a] (%) | | |
| - beginning year | 2.9 | 4.5 |
| - end year | 3.8 | 5.2 |

[a] Simon and Wardop (2001) obtain similar results for their IT income shares for Australia.

*Source:* PC estimates based on BLS and ABS data.

## 5.4 Industry perspective

IT use at the industry level is now examined to determine whether there are clear relationships between IT use and productivity growth at the industry level.

### Growth in IT use

The productive IT capital stock grew rapidly in all industries in the late 1980s and through the 1990s (appendix B).

However, some industries have become more intensive IT users than others. Table 5.11 shows the proportion of IT in each industry's productive capital stock. Industries which have had higher growth in IT and have substituted more IT for other forms of capital show higher IT intensity in their productive capital stocks.

Finance & insurance stands out as having the highest IT proportion (over 11 per cent) in its productive capital stock in 1999-00. Other industries with proportions

[6] The higher IT income share in Australia is surprising and warrants some further investigation. Industry composition effects — higher proportion of IT-intensive service industries in the Australian economy — could be playing some role.

over 4 per cent are: Construction, Wholesale trade, Retail trade, and Cultural & recreational services. Generally speaking, the change in the IT share since 1993-94 was also above average in these industries.

Intensity of IT use can also be viewed with respect to total input use. The share of IT in total factor payments by industry is presented in table 5.12. A similar list of prominent IT using industries is evident, although Electricity, gas & water assumes greater prominence in this view of total input costs. This is likely due in part to its reduction in labour input over the 1990s. IT is also a relatively high proportion of total input costs in Communication services.[7]

Table 5.11 **Share of IT productive capital stock in industry productive capital stock**

| | *1981-82* | *1984-85* | *1988-89* | *1993-94* | *1999-00* | *Change over 1993-94 and 1999-00* |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | Percentage points |
| Agriculture | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.2 |
| Mining | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 | 0.2 |
| Manufacturing | 0.0 | 0.1 | 0.4 | 1.1 | 3.1 | 2.0 |
| Electricity, gas & water | 0.0 | 0.1 | 0.7 | 0.2 | 1.5 | 1.3 |
| Construction | 0.1 | 0.2 | 0.7 | 1.7 | 4.9 | 3.2 |
| Wholesale trade | 0.1 | 0.2 | 0.6 | 1.7 | 4.4 | 2.7 |
| Retail trade | 0.1 | 0.2 | 0.3 | 1.7 | 4.8 | 3.1 |
| Accom., cafes & restaurants | 0.0 | 0.1 | 0.4 | 0.9 | 2.5 | 1.6 |
| Transport & storage | 0.1 | 0.2 | 0.7 | 1.2 | 2.5 | 1.3 |
| Communications | 0.1 | 0.2 | 1.4 | 1.7 | 3.8 | 2.1 |
| Finance & insurance | 0.3 | 0.5 | 1.4 | 3.2 | 11.3 | 8.1 |
| Cultural & rec. services | 0.1 | 0.3 | 1.0 | 2.2 | 4.8 | 2.6 |
| Market sector | 0.1 | 0.1 | 0.4 | 1.0 | 3.0 | 2.0 |

*Source:* PC estimates based on unpublished ABS data.

[7] A number of sectors, such as Construction and Communications have had their share of IT productive capital stock increase substantially (table 5.11), but their IT income shares have not changed much at all (table 5.12). This is because the rental price has decreased faster than the rise in productive capital stock.

Table 5.12 **IT income shares by industry, selected years**

| | *1981-82* | *1984-85* | *1988-89* | *1993-94* | *1999-00* | *Change over 1993-94 and 1999-00* |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | Percentage points |
| Agriculture | 0.2 | 0.2 | 0.3 | 0.8 | 1.2 | 0.4 |
| Mining | 0.2 | 0.3 | 0.5 | 0.9 | 0.9 | 0.0 |
| Manufacturing | 0.5 | 1.0 | 1.8 | 3.6 | 3.8 | 0.3 |
| Electricity, gas & water | 0.7 | 1.5 | 2.1 | 1.3 | 7.7 | 6.3 |
| Construction | 0.5 | 0.9 | 1.9 | 2.8 | 2.7 | -0.1 |
| Wholesale trade | 1.3 | 2.0 | 3.2 | 4.7 | 4.6 | -0.1 |
| Retail trade | 0.6 | 1.2 | 2.4 | 4.5 | 3.5 | -1.0 |
| Accom., cafes & restaurants | 0.5 | 1.0 | 1.6 | 2.4 | 3.2 | 0.8 |
| Transport & storage | 1.1 | 1.6 | 2.6 | 5.0 | 3.6 | -1.4 |
| Communication serv | 1.5 | 6.1 | 4.7 | 8.0 | 9.0 | 1.0 |
| Finance & insurance | 3.7 | 6.1 | 10.6 | 13.2 | 14.8 | 1.6 |
| Cultural & rec. services | 1.6 | 2.4 | 4.2 | 5.3 | 5.9 | 0.5 |
| Market sector | 1.0 | 1.6 | 2.5 | 4.3 | 5.0 | 0.7 |

*Source:* PC estimates based on unpublished ABS data.

There are other possible indicators of IT use (appendix B). However, they are correlated in broad fashion with the rankings evident in the proportion of IT in the productive capital stock (table 5.11) or total input costs (table 5.12).

## Contributions to productivity growth

The contributions of IT to industry productivity growth in the 1990s are shown in table 5.13.

A very strong contribution from IT capital deepening is evident in Finance & insurance (3.5 percentage points or about 50 per cent). Electricity, gas & water had a strong IT capital deepening contribution due to a combination of growth in IT and reduction in labour. Cultural & recreational services and Communication services also showed relatively strong IT capital deepening contributions (above the market sector average). But others among the more intensive IT users — Wholesale trade and Retail trade — showed below-average contributions from IT capital deepening.

Strong MFP contributions are also evident among the high IT users. These include Wholesale trade, Finance & insurance, and Communications. However, some high IT users have below average MFP growth (for example, Retail trade and Cultural & recreation services).

Table 5.13 **Contributions to labour productivity growth by industry sector, 1993-94 to 1999-00**

| | *Labour productivity growth* | | *Capital deepening* | | | | *MFP growth* | |
|---|---|---|---|---|---|---|---|---|
| | | | *IT* | | *Other* | | | |
| | % | % | % | % | % | % | %pa | % |
| Agriculture | 2.2 | (100) | 0.2 | (10) | -0.5 | (-20) | 2.5 | (111) |
| Mining | 6.2 | (100) | 0.3 | (4) | 5.2 | (83) | 0.8 | (12) |
| Manufacturing | 2.1 | (100) | 1.0 | (47) | 0.6 | (30) | 0.5 | (22) |
| Electricity, gas & water | 7.2 | (100) | 2.6 | (36) | 3.6 | (50) | 1.0 | (14) |
| Construction | 1.3 | (100) | 0.6 | (48) | -0.6 | (-50) | 1.3 | (102) |
| Wholesale trade | 6.9 | (100) | 1.0 | (15) | 0.2 | (3) | 5.6 | (81) |
| Retail trade | 2.0 | (100) | 1.0 | (49) | 0.1 | (7) | 0.9 | (44) |
| Accom., cafes & restaurants | 1.0 | (100) | 0.7 | (68) | -0.1 | (-13) | 0.5 | (46) |
| Transport & storage | 2.4 | (100) | 0.6 | (25) | -0.3 | (-11) | 2.1 | (86) |
| Communications | 5.9 | (100) | 1.6 | (27) | 0.9 | (16) | 3.3 | (57) |
| Finance & insurance | 6.8 | (100) | 3.5 | (52) | -0.4 | (-5) | 3.7 | (54) |
| Cultural & rec. services | -1.1 | (100) | 1.5 | | 1.9 | | -4.1 | |
| Market sector | 3.1 | (100) | 1.1 | (37) | 0.2 | (8) | 1.7 | (55) |

*Source:* PC estimates based on unpublished ABS data.

## Relationships between IT use and productivity growth

The relationships between IT use and productivity growth are now examined in more detail. IT use would have a positive influence on labour productivity if it generated more capital deepening and/or more MFP growth. These relationships are explored in appendix B. The investigation of links between IT use and MFP growth is reported here.

Comparisons are made between the first and second halves of the 1990s. This highlights the increased use of IT in the second half. However, as previously noted, productivity estimates over these periods will only accidentally reflect underlying trends. Consequently, trend MFP estimates are relied on for comparisons. Trend series are formed with a Hodrick-Prescott filter (table 5.14).

Table 5.14 **MFP growth by industry in the first and second halves of the 1990s**

Per cent per year

| | *1988-89 to 1993-94* | | *1993-94 to 1999-00* | | *Acceleration* | |
|---|---|---|---|---|---|---|
| | *Actual* | *Trend* | *Actual* | *Trend* | *Actual*[a] | *Trend*[b] |
| Agriculture | 4.3 | 2.4 | 2.5 | 3.0 | -1.8 | 0.6 |
| Mining | 1.9 | 2.2 | 0.8 | 0.6 | -1.1 | -1.5 |
| Manufacturing | 1.8 | 1.4 | 0.5 | 1.1 | -1.3 | -0.3 |
| Electricity, gas & water | 4.0 | 3.5 | 1.0 | 2.1 | -3.0 | -1.4 |
| Construction | -0.4 | -0.1 | 1.3 | 1.3 | 1.6 | 1.3 |
| Wholesale trade | -2.1 | 0.9 | 5.6 | 3.3 | 7.7 | 2.4 |
| Retail trade | 0.5 | 0.0 | 0.9 | 0.9 | 0.4 | 0.9 |
| Accom., cafes and restaurants | -2.0 | -2.0 | 0.5 | -0.4 | 2.4 | 1.6 |
| Transport & storage | 0.6 | 1.3 | 2.1 | 1.8 | 1.5 | 0.5 |
| Communications | 6.3 | 5.1 | 3.3 | 4.2 | -3.0 | -0.9 |
| Finance & insurance | 0.0 | 1.2 | 3.7 | 2.4 | 3.7 | 1.2 |
| Cultural & rec. services | -1.7 | -2.3 | -4.1 | -3.4 | -2.4 | -1.1 |

[a] Growth over 1993-94 to 1999-00 less growth over 1988-89 to 1993-94. [b] Acceleration over the same periods. Trend series formed with a Hodrick-Prescott filter.

*Source:* PC estimates based on ABS data.

There are two forms of comparison:

- comparison in levels — industry IT use in the second half of the 1990s is compared with trend industry MFP growth over the same period; and
- comparison in changes — change in industry IT use between the first and second halves of the 1990s is compared with the acceleration in MFP growth between the first and second halves.

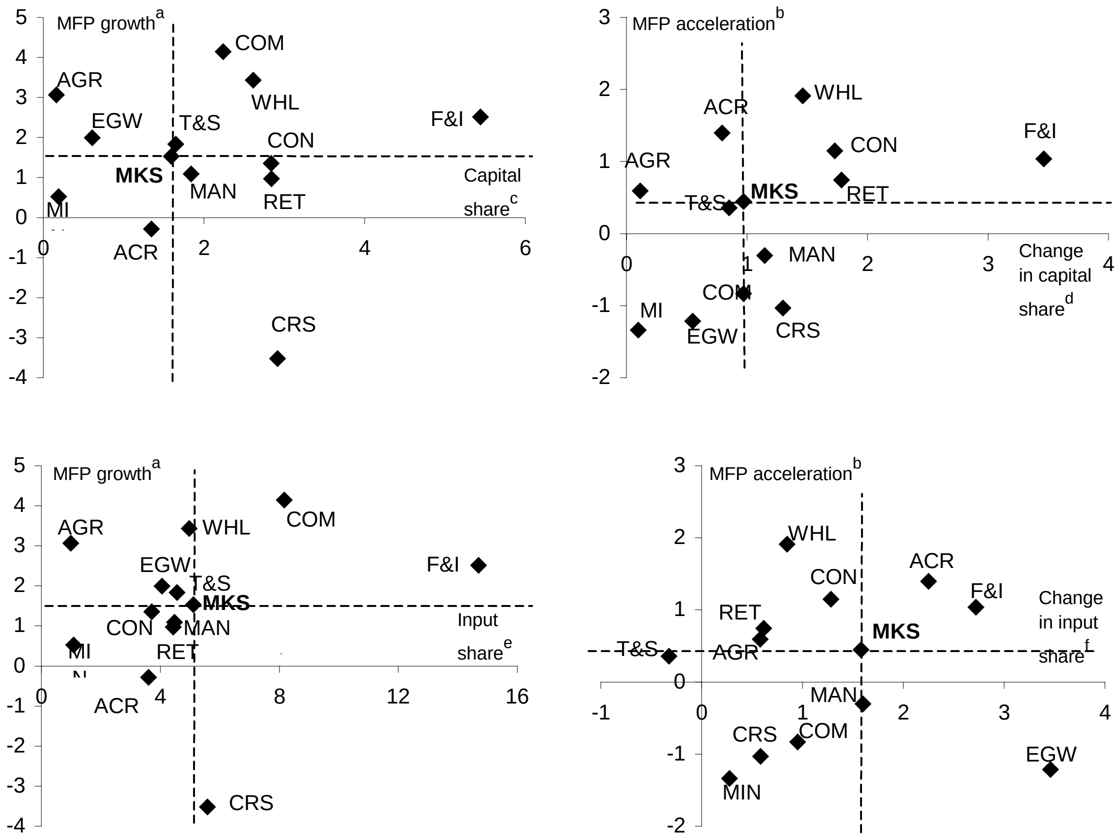
Scatter diagrams showing these comparisons are presented in figure 5.8 for the two measures of IT use — IT share in capital input and IT share in all inputs.

A strong positive correlation between IT use and MFP across all industries is not apparent. Broadly speaking, a positive correlation is strongest between change in IT use (both measures) and MFP acceleration. Regression lines (not shown) are flat in the two ‘levels’ cases, but show some slope and a better fit in the ‘changes’ cases (but only when Electricity, gas and water is excluded from the change in total inputs regression). Some specific features of note are:

- A positive relationship between IT use and MFP in Finance & insurance is apparent on all measures.
- There is also a positive relationship in Wholesale trade when IT use is measured in terms of intensity in capital inputs (but not in total inputs).

## Figure 5.8 IT use and MFP growth in Australian industries in the 1990s

Per cent and per cent per year




| | | | |
|---|---|---|---|
| AGR | Agriculture | ARC | Accomm., cafes & restaurants |
| MIN | Mining | T&S | Transport & storage |
| MAN | Manufacturing | COM | Communications |
| EGW | Electricity, gas & water | F&I | Finance & insurance |
| CON | Construction | CRS | Cultural & recreational services |
| RET | Retail trade | MKS | Market sector |
| WHL | Wholesale trade | | |

**a** Trend MFP growth 1994-95 to 1999-00. **b** Change in trend MFP growth between 1989-90 to 1994-95 and 1994-95 to 1999-00. **c** Share of IT in total productive capital stock (capital services), averaged over 1995-96 to 1997-98 . **d** Change in IT share in total productive capital stock between the average of 1991-92 and 1992-93 and the average of 1996-97 and 1997-98. **e** Share of IT in total payments to inputs, averaged over 1995-96 to 1997-98. **f** Change in IT total payments to inputs between the average of 1991-92 and 1992-93 and the average of 1996-97 and 1997-98.

*Data source:* PC estimates based on unpublished ABS data.

- Other industries show a positive relationship in only some measures — Communications, Construction, Retail trade, and Accommodation, cafes & restaurants.
- Community & recreational services tends to be above average in IT use, but is well below average on MFP measures. Electricity, gas & water had a large

increase in IT as a share in total inputs, but showed a deceleration in MFP growth.

Thus, the relationship between IT use and MFP at the industry level is not a simple, strong one. It undoubtedly reflects the fact that IT use is not the only factor affecting industry MFP growth. To take just one example, it is highly unlikely that an increase in IT use led to a deceleration in MFP growth in Electricity, gas & water in the second half of the 1990s. It is much more likely that the deceleration reflects the fact that other factors (including government business enterprise reforms) promoted very strong MFP growth in the 1980s and early 1990s.

An earlier study by Productivity Commission staff (Johnston et al. 2000), offers an insight into why large efficiency gains may not be related solely to increased IT use. The study of Australia's wholesale and retail trade showed that IT can facilitate quite fundamental industry restructuring and thereby promote strong MFP growth, without commensurate increases in IT intensity. In some areas, new IT systems — in particular barcoding and scanning — enabled wholesalers to transform operations from a storage-based system to a fast flow-through system, more responsive to consumer demands. Efficiencies have come from less inventory holding and less handling, thus reducing both capital and labour requirements.

Part of these gains could also be attributed to non-ICT factors. For example, the depth of restructuring and the resulting productivity gains were partly attributable to the reduction in demarcation problems and the introduction of split shifts.

Brynjolfsson and Hitt (2000) also pointed to the importance of complementary innovations in organisation, management and work practice for firms to gain the full potential of what IT can offer in production, supplier relationships and customer relationships. They state:

> As computers become cheaper and more powerful the business value of computers is limited less by computational capability and more by the ability of managers to invent new processes, procedures and organisational structures that leverage this capability. (p. 24)

They report evidence from firm level studies that show a clear positive relationship between IT investment and MFP, but also variation in firms' success with IT. They suggest that short-term returns represent the direct effects of IT investment, while larger long-term returns represent the direct effects of IT combined with related investments in organisational change.

Brynjolfsson and Hitt also suggest that high returns to IT investors are partly reflected in MFP gains, rather than solely in capital deepening. The MFP component could be above-normal returns in the short run or additional long-run returns that come through business restructuring.

Thus, the absence of a clear relationship between IT use and MFP growth across all industries may reflect the influence of non-IT factors. But there may also be more complex IT-related factors that require time to discover and implement complementary organisational changes.

The coincidence of industries in both the US and Australia that are both relatively high in IT use and productivity growth provides further circumstantial evidence of a link between IT use and productivity growth. However, that evidence also suggests that the positive influence of IT on productivity growth is — for the moment at least — narrowly-based on distributive trades and financial intermediation. This is turn is suggestive of gains from restructuring in these industries, rather than spillover gains that could be expected to be more broadly-based.

While the productivity gains appear to be narrowly-based, the benefits are enjoyed by a wider range of industries. Many services, including distribution and financial intermediation, are used extensively by manufacturing and other industries (Simon and Wardrop 2001). And these linkages can be driving the changes in the service industries. The study of the Wholesale industry provided the example of the passenger motor vehicle industry, which looked for productivity improvements in all areas of the 'value network' in production, distribution and marketing, in response to sharper competition from cheaper imported vehicles (Johnston et al 2000). The productivity gains in Wholesaling, even though very large, were passed on, with profit margins declining in the 1990s (Parham et al 2000).

## 5.5 Summary

There has been strong growth in investment in IT in Australia since the mid-1990s. IT investment reached over 15 per cent of total annual investment in the market sector in 1999-00.

The concomitant increase in the productive IT capital stock made a sizeable contribution to output and labour productivity growth over the 1990s.

- IT contributed nearly 40 per cent of market sector output growth (averaging 3.4 per cent a year) from 1989-90 to 1999-00.
- IT capital deepening contributed around 35 per cent of the record 3.1 per cent a year growth in labour productivity from 1993-94 to 1999-00.
- IT capital deepening contributed about 45 per cent of the 1.1 percentage point acceleration in labour productivity growth in the 1990s. However, this was offset

by negative capital deepening based on other types of capital. With no net contribution from overall capital deepening, faster MFP growth accounted for virtually all the faster labour productivity growth.

Compared with the US, Australia showed:

- a higher labour productivity and MFP acceleration; and
- a similar contribution to labour productivity growth from IT capital deepening, even without making allowance for the absence of communications equipment in the Australian estimates.

Australia has generated MFP gains from IT use and/or from non-ICT related factors that, in comparison with the US, have more than offset the absence of MFP gains from an ICT production sector.

There is no clear, strong relationship between ICT use and MFP growth across industries. In Finance & insurance, the relationship is clearly positive. Whilst the relationships are not as obvious in other industries, they may nevertheless be there. Evidence from other studies suggest that the direct gains from IT use are only part of the story. Complementary changes in organisation, management and work practices can be important in tapping the full efficiency gains that IT can offer over the long term. Non-IT factors can, of course, also be at work.

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# A Australia's production and use of ICTs

This appendix provides details and complementary information on Australia's production and use of information and communication technologies (ICTs) as reported in chapter 2.

The following tables are presented:

Table A.1 ICT Manufacturing and services in Australia, June 1995-96 and 1998-99

Table A.2 The structure of the ICT sector in Australia, June 1995-96 and 1998-99

Table A.3 Value-added in the ICT sector: an international comparison, 1997

Table A.4 Employment in the ICT sector: an international comparison, 1997

Table A.5 R&D in the ICT sector: an international comparison, 1997

Table A.6 ICT expenditure as a share of GDP in OECD countries

Table A.7 ICT expenditures as a proportion of GDP in 1997, annual average growth in ICT expenditure between 1992 and 1997 and contributions to growth over 1992 to 1997

Table A.8 The share of ICT investment in total investment in all industries

Table A.9 Proportion of households with a PC, selected OECD countries and years

Table A.1 **ICT Manufacturing and services in Australia, June 1995-96 and 1998-99**

| | *Businesses* | | *Employment* | | *Total income* | |
|---|---|---|---|---|---|---|
| | *1995-96* | *1998-99* | *1995-96* | *1998-99* | *1995-96* | *1998-99* |
| | number | | number | | million A$ | |
| Manufacturing | | | | | | |
| Computer and business machines | 237 | 122 | 5 755 | 2 461 | 1 935 | 1 146 |
| Telecommunication, broadcasting transceiving equipment | 134 | 68 | 7335 | 5 125 | 1 660 | 1 508 |
| Electronic equipment. | 57 | 77 | 836 | 1 959 | 99 | 345 |
| Cable and wire | 46 | 27 | 3 369 | 997 | 1 073 | 307 |
| *Total* | 473 | 294 | 17 295 | 10 542 | 4 766 | 3 306 |
| Wholesale trade | | | | | | |
| Computers | 2 326 | 1 575 | 26 599 | 27 212 | 12 255 | 15 748 |
| Business machines and electronic and electrical equipment | 653 | 602 | 13 030 | 12 725 | 5 071 | 7 004 |
| *Total* | 2 979 | 2 177 | 39 629 | 39 936 | 17 326 | 22 752 |
| Telecommunication services | 410 | 869 | 91 701 | 74 467 | 18 734 | 26 083 |
| Computer services | | | | | | |
| Data processing | 387 | 239 | 5 291 | 7 174 | 925 | np |
| Information storage and retrieval | 31 | 101 | 994 | 908 | 180 | 100 |
| Computer maintenance | 418 | 335 | 5 032 | 2 519 | 903 | np |
| Computer consultancy | 8 837 | 14 056 | 43 711 | 63 794 | 6 080 | 8 680 |
| *Total* | 9 673 | 14 731 | 55 028 | 74 395 | 8 088 | 10 474 |
| Total | 13 535 | 18 072 | 203 653 | 199 341 | 48 913 | 62 616 |

np not available for publication but included in totals where applicable, unless otherwise indicated.

*Source:* ABS (2000a).

## Table A.2 **The structure of the ICT sector in Australia, June 1995-96 and 1998-99**

Per cent

| | *Business* | | *Employment* | | *Total income* | |
|---|---|---|---|---|---|---|
| | *1995-96* | *1998-99* | *1995-96* | *1998-99* | *1995-96* | *1998-99* |
| Manufacturing | | | | | | |
| Computer and business machines | 1.8 | 0.7 | 2.8 | 1.2 | 4.0 | 1.8 |
| Telecommunication, broadcasting transceiving equipment | 1.0 | 0.4 | 3.6 | 2.6 | 3.4 | 2.4 |
| Electronic equipment. | 0.4 | 0.4 | 0.4 | 1.0 | 0.2 | 0.6 |
| Cable and wire | 0.3 | 0.1 | 1.7 | 0.5 | 2.2 | 0.5 |
| *Total* | 3.5 | 1.6 | 8.5 | 5.3 | 9.7 | 5.3 |
| Wholesale trade | | | | | | |
| Computers | 17.2 | 8.7 | 13.1 | 13.7 | 25.1 | 25.2 |
| Business machines and electronic and Electrical equipment | 4.8 | 3.3 | 6.4 | 6.4 | 10.4 | 11.2 |
| *Total* | 22.0 | 12.0 | 19.5 | 20.0 | 35.4 | 36.3 |
| Telecommunication services | 3.0 | 4.8 | 45.0 | 37.4 | 38.3 | 41.7 |
| Computer services | | | | | | |
| Data processing | 2.9 | 1.3 | 2.6 | 3.6 | 1.9 | np |
| Information storage and retrieval | 0.2 | 0.6 | 0.5 | 0.5 | 0.4 | 0.2 |
| Computer maintenance | 3.1 | 1.9 | 2.5 | 1.3 | 1.8 | np |
| Computer consultancy | 65.3 | 77.8 | 21.5 | 32.0 | 12.4 | 13.9 |
| *Total* | 71.5 | 81.5 | 27.0 | 37.3 | 16.5 | 16.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

np not available for publication but included in totals where applicable, unless otherwise indicated.

*Source:* ABS (2000a).

Table A.3 **Value-added in the ICT sector: an international comparison, 1997**

| | *Value-added in ICT* | *Share of country in total OECD*[g] | *Value-added / output value in ICT* | *Value-added in total business sector* | *Share of ICT value-added in total business sector* |
|---|---|---|---|---|---|
| | million ppp US$ | % | % | million ppp US$ | % |
| Australia[a] | 14 402 | 1.2 | 31.6 | 347 675 | 4.1 |
| Austria[b] | 9 379 | 0.8 | 32.3 | 138 266 | 6.8 |
| Belgium | 10 029 | 0.8 | 28.8 | 174 166 | 5.8 |
| Canada | 34 965 | 2.9 | 40.7 | 535 377 | 6.5 |
| Czech Republic[b] | 5 733 | 0.5 | 43.4 | 123 187 | 4.7 |
| Finland | 6 139 | 0.5 | 32.0 | 74 284 | 8.3 |
| France | 46 033 | 3.9 | 46.0 | 875 161 | 5.3 |
| Germany[c] | 89 154 | 7.5 | | 1 458 771 | 6.1 |
| Hungary [b] | 7 048 | 0.6 | 38.8 | 76 508 | 9.2 |
| Italy | 53 837 | 4.5 | 39.5 | 924 663 | 5.8 |
| Japan | 151 909 | 12.8 | 35.9 | 2 613 527 | 5.8 |
| Korea[c] | 62 722 | 5.3 | 48.1 | 585 273 | 10.7 |
| Netherlands[c] | 14 131 | 1.2 | 47.6 | 279 705 | 5.1 |
| Norway[d] | 3 670 | 0.3 | 51.0 | 57 783 | 6.4 |
| Portugal[b] | 6 155 | 0.5 | 36.4 | 109 616 | 5.6 |
| Sweden | 11 773 | 1.0 | 31.4 | 126 464 | 9.3 |
| United Kingdom | 81 919 | 6.9 | 35.6 | 979 441 | 8.4 |
| United States | 581 540 | 48.8 | 49.5 | 6 717 825 | 8.7 |
| G7[c] | 1 039 357 | 87.3 | 44.2 | 14 104 765 | 7.4 |
| European Union[e,f] | 328 549 | 27.6 | 37.8 | 5 140 536 | 6.4 |
| Total OECD[e,g] | 1 190 537 | 100.0 | 43.5 | 16 197 692 | 7.4 |

**a** Data is for 1998-99. **b** Including all of wholesale of machinery, equipment and supplies (ISIC 5150). **c** Excluding all of wholesale of machinery, equipment and supplies (ISIC 5150). **d** Data is for 1995. **e** Excluding Germany for value-added to output ratio. **f** Excluding Denmark, Greece, Ireland, Luxembourg and Spain. **g** Calculated for the 18 countries listed in table.

*Source:* OECD (2000b).

## Table A.4 Employment in the ICT sector: an international comparison, 1997

| | Employment in ICT | Share of country in total OECD[g] | Employ-ment in total business sector | Share of ICT employment in total business sector |
|---|---|---|---|---|
| | '000 | % | '000 | % |
| Australia[a] | 196 | 1.5 | 7 466 | 2.6 |
| Austria[b] | 165 | 1.3 | 3 364 | 4.9 |
| Belgium | 130 | 1.0 | 3 059 | 4.3 |
| Canada | 430 | 3.4 | 9 405 | 4.6 |
| Czech Republic[b] | 152 | 1.2 | 4 600 | 3.3 |
| Denmark | 96 | 0.8 | 1 879 | 5.1 |
| Finland | 88 | 0.7 | 1 579 | 5.6 |
| France | 681 | 5.3 | 16 964 | 4.0 |
| Germany[c] | 974 | 7.6 | 31 240 | 3.1 |
| Hungary[b] | 157 | 1.2 | 2 753 | 5.7 |
| Iceland[d] | 4 | 0.0 | 102 | 4.2 |
| Ireland[c] | 56 | 0.4 | 1 212 | 4.6 |
| Italy | 671 | 5.2 | 19 160 | 3.5 |
| Japan[c] | 2 060 | 16.1 | 60 121 | 3.4 |
| Korea[c] | 462 | 3.6 | 18 618 | 2.5 |
| Netherlands[c] | 199 | 1.6 | 5 265 | 3.8 |
| New Zealand | 31 | 0.2 | 1 498 | 2.1 |
| Norway[d] | 74 | 0.6 | 1 403 | 5.3 |
| Portugal[b] | 94 | 0.7 | 3 486 | 2.7 |
| Sweden | 174 | 1.4 | 2 784 | 6.3 |
| Switzerland[e] | 172 | 1.3 | 2 852 | 6.0 |
| Turkey[c] | 100 | 0.8 | 19 444 | 0.5 |
| United Kingdom | 1 112 | 8.7 | 23 057 | 4.8 |
| United States | 4 521 | 35.3 | 1 15 699 | 3.9 |
| G7 | 10 449 | 81.6 | 275 645 | 3.8 |
| European Union[f] | 4 441 | 34.7 | 113 049 | 3.9 |
| Total OECD[g] | 12 800 | 100.0 | 357 009 | 3.6 |

[a] Data is for 1998-99. [b] Including all of wholesale of machinery, equipment and supplies (ISIC 5150). [c] Excluding all of wholesale of machinery, equipment and supplies (ISIC 5150). [d] Data is for 1996. [e] Data is for 1998. [f] Excluding Greece, Luxembourg and Spain. [g] Calculated for the 24 countries listed in the table.

*Source:* OECD (2000b).

## Table A.5 R&D in the ICT sector: an international comparison, 1997

| | *R&D in ICT* | *Share of country in total OECD*[d] | *R&D/value added for ICT* | *R&D in total business sector* | *Share of ICT R&D in total business sector* |
|---|---|---|---|---|---|
| | million ppp US$ | % | % | million ppp US$ | % |
| Australia[a] | 822 | 0.7 | 4.9 | 3 065 | 26.8 |
| Belgium | 612 | 0.5 | 6.0 | 3 046 | 20.3 |
| Canada | 3 129 | 2.7 | 8.9 | 7160 | 43.7 |
| Czech Republic | 45 | 0.0 | 0.8 | 986 | 4.6 |
| Denmark | 329 | 0.3 | | 1558 | 21.1 |
| Finland | 962 | 0.8 | 15.7 | 1887 | 51.0 |
| France | 4 366 | 3.8 | 9.5 | 16559 | 26.4 |
| Germany | 5 653 | 4.9 | 6.3 | 28 131 | 20.1 |
| Greece | 76 | 0.1 | | 161 | 46.9 |
| Hungary | 34 | 0.0 | 0.5 | 299 | 11.3 |
| Iceland | 11 | 0.0 | | 49 | 21.8 |
| Ireland | 378 | 0.3 | | 792 | 26.5 |
| Italy | 1677 | 1.4 | 3.1 | 6 333 | 26.5 |
| Japan | 26 127 | 22.4 | 17.2 | 64 596 | 40.4 |
| Korea | 5 640 | 4.8 | 9.0 | 13 779 | 40.9 |
| Mexico | 1 | 0.0 | | 482 | 0.2 |
| Netherlands | 791 | 0.7 | 5.6 | 4033 | 19.6 |
| New Zealand | 38 | 0.0 | | 213 | 17.7 |
| Norway[b] | 324 | 0.3 | 6.3 | 1 111 | 29.2 |
| Poland | 61 | 0.1 | | 793 | 7.6 |
| Portugal | 50 | 0.0 | 0.8 | 213 | 23.5 |
| Spain | 551 | 0.5 | | 2 582 | 21.4 |
| Sweden | 1 427 | 1.2 | 12.1 | 5 123 | 27.9 |
| Turkey | 140 | 0.1 | | 644 | 21.7 |
| United Kingdom | 3 227 | 2.8 | 3.9 | 14 834 | 21.8 |
| United States | 59 916 | 51.5 | 10.3 | 157 539 | 38.0 |
| G7 | 104 095 | 89.4 | 10.0 | 295 152 | 35.3 |
| European Union[c] | 20 098 | 17.3 | 5.9 | 85 252 | 23.6 |
| Total OECD[d] | 116 384 | 100 | 9.7 | 335 988 | 34.6 |

[a] Australia's R&D to value added ratio (R&D intensity) is for 1998-99. [b] Norway's R&D to value added ratio (R&D intensity) is for 1995. [c] Excluding Austria and Luxembourg. Excluding also Denmark, Greece, Ireland and Spain for R&D to value added ratio. [d] Calculated for the 26 countries listed in the table.

*Source:* OECD (2000b).

Table A.6 **ICT expenditure[a] as a share of GDP in OECD countries**
Per cent

| | *1992* | *1993* | *1994* | *1995* | *1996* | *1997* |
|---|---|---|---|---|---|---|
| Canada | 6.6 | 6.6 | 6.9 | 6.9 | 7.1 | 7.5 |
| Mexico | 3.1 | 3.4 | 3.5 | 3.7 | 3.8 | 3.5 |
| United States | 7.2 | 7.3 | 7.4 | 7.6 | 7.7 | 7.8 |
| **Australia** | 6.9 | 7.5 | 7.6 | 7.4 | 7.4 | 8.1 |
| Japan | 5.5 | 5.2 | 5.1 | 5.3 | 6.4 | 7.4 |
| Korea | 4.7 | 4.7 | 4.7 | 4.9 | 6.1 | 6.1 |
| New Zealand | 9.0 | 8.5 | 8.5 | 8.3 | 7.9 | 8.6 |
| Austria | 4.9 | 5.1 | 4.5 | 4.6 | 4.7 | 5.1 |
| Belgium | 5.3 | 5.4 | 5.3 | 5.3 | 5.6 | 6.0 |
| Czech Republic | 5.6 | 5.5 | 5.4 | 6.0 | 5.8 | 6.5 |
| Denmark | 6.0 | 6.3 | 5.9 | 6.1 | 6.3 | 6.5 |
| Finland | 4.5 | 5.0 | 5.3 | 5.5 | 5.7 | 6.0 |
| France | 5.7 | 6.0 | 5.6 | 5.8 | 5.9 | 6.4 |
| Germany | 5.2 | 5.4 | 5.2 | 5.1 | 5.2 | 5.6 |
| Greece | 2.2 | 2.2 | 3.5 | 3.7 | 3.8 | 4.0 |
| Hungary | 3.6 | 4.1 | 4.3 | 3.8 | 4.2 | 4.4 |
| Ireland | 5.3 | 5.2 | 5.6 | 5.6 | 5.9 | 5.7 |
| Italy | 3.6 | 3.8 | 4.1 | 4.1 | 4.1 | 4.3 |
| Netherlands | 6.4 | 6.5 | 6.3 | 6.4 | 6.6 | 7.0 |
| Norway | 5.5 | 5.6 | 5.3 | 5.5 | 5.5 | 5.7 |
| Poland | 1.8 | 2.0 | 2.2 | 2.3 | 2.4 | 2.7 |
| Portugal | 2.6 | 2.7 | 4.2 | 4.5 | 4.8 | 5.0 |
| Spain | 3.8 | 3.9 | 3.7 | 3.7 | 4.0 | 4.1 |
| Sweden | 7.5 | 8.4 | 7.8 | 7.6 | 7.6 | 8.3 |
| Switzerland | 7.4 | 7.6 | 6.8 | 6.9 | 7.2 | 7.7 |
| Turkey | 2.6 | 2.2 | 2.5 | 1.6 | 2.5 | 2.6 |
| United Kingdom | 6.9 | 7.3 | 7.0 | 7.4 | 7.6 | 7.6 |
| European Union | 5.2 | 5.5 | 5.4 | 5.4 | 5.6 | 5.9 |
| **Total OECD** | **5.9** | **6.0** | **6.0** | **6.1** | **6.5** | **6.9** |

**a** Measured at current prices.

*Source:* OECD (2000e).

## Table A.7 ICT expenditures[a] as a proportion of GDP in 1997, annual average growth in ICT expenditure between 1992 and 1997 and contributions to growth over 1992 to 1997

Per cent and per cent per year

| | | | | | *Contributions to growth* | | |
|---|---|---|---|---|---|---|---|
| | *IT hardware* | *IT services & software* | *Telecom-munications* | *Average annual growth rate* | *IT hardware* | *IT services & software* | *Telecom-munications* |
| Canada | 1.3 | 3.5 | 2.7 | 1.8 | 0.6 | 0.6 | 0.7 |
| Mexico | 0.6 | 0.8 | 2.1 | 1.7 | 0.5 | 0.6 | 0.7 |
| United States | 1.7 | 3.4 | 2.7 | 1.2 | 1.1 | 0.2 | 0.0 |
| Australia | 1.4 | 2.5 | 4.2 | 2.3 | 1.0 | -0.1 | 1.4 |
| Japan | 1.1 | 2.7 | 3.6 | 4.3 | 0.2 | -0.2 | 4.3 |
| Korea | 1.7 | 0.9 | 3.6 | 3.8 | 1.2 | -0.4 | 3.0 |
| New Zealand | 1.3 | 2.9 | 4.4 | -0.7 | -0.1 | -1.4 | 0.8 |
| Austria | 0.9 | 2.2 | 2.0 | 0.5 | 0.6 | 0.3 | -0.3 |
| Belgium | 1.0 | 2.7 | 2.4 | 2.0 | 0.5 | 0.1 | 1.3 |
| Czech Republic | 1.5 | 2.4 | 2.5 | 2.1 | 0.2 | -0.3 | 2.1 |
| Denmark | 1.2 | 3.0 | 2.3 | 1.2 | 0.4 | 0.3 | 0.5 |
| Finland | 1.3 | 2.2 | 2.4 | 4.1 | 1.1 | 0.7 | 2.3 |
| France | 0.9 | 3.3 | 2.2 | 1.7 | 0.1 | 1.1 | 0.5 |
| Germany | 0.9 | 2.4 | 2.3 | 1.0 | 0.5 | 0.3 | 0.1 |
| Greece | 0.4 | 0.6 | 3.1 | 8.7 | 0.8 | 0.3 | 7.6 |
| Hungary | 1.1 | 1.7 | 1.6 | 2.8 | 0.3 | 1.3 | 1.1 |
| Ireland | 0.8 | 1.4 | 3.5 | 1.1 | -0.1 | -0.5 | 1.7 |
| Italy | 0.6 | 1.4 | 2.4 | 2.6 | -0.2 | 0.5 | 2.2 |
| Netherlands | 1.3 | 3.0 | 2.7 | 1.3 | 0.5 | -0.1 | 0.9 |
| Norway | 1.2 | 2.3 | 2.2 | 0.7 | 0.5 | 0.2 | 0.0 |
| Poland | 0.8 | 0.9 | 1.0 | 5.8 | 1.4 | 2.0 | 2.4 |
| Portugal | 0.6 | 0.9 | 3.4 | 10.1 | 1.0 | 0.2 | 8.9 |
| Spain | 0.7 | 1.1 | 2.4 | 1.2 | 0.1 | 0.1 | 0.9 |
| Sweden | 1.7 | 3.8 | 2.8 | 1.4 | 0.5 | 1.3 | -0.4 |
| Switzerland | 1.3 | 3.6 | 2.9 | 0.6 | 0.3 | 0.7 | -0.4 |
| Turkey | 0.4 | 0.3 | 1.9 | 0.1 | -0.8 | 0.4 | 0.6 |
| United Kingdom | 1.5 | 3.4 | 2.7 | 1.4 | 0.8 | 0.1 | 0.5 |
| Europen Union | 1.0 | 2.5 | 2.4 | 1.8 | 0.4 | 0.6 | 0.8 |
| **Total OECD** | **1.3** | **2.8** | **2.8** | **2.2** | **0.7** | **0.3** | **1.2** |

[a] Measured at current prices.

*Source:*OECD(2000e).

## Table A.8 The share of ICT investment in total investment in all industries

Per cent and per cent per year

| | France | Germany | Italy | Japan | Finland | U.S. | Australia |
|---|---|---|---|---|---|---|---|
| Share in non-residential GFCF[a] | | | | | | | |
| 1980 | 8.2 | 11.8 | 9.6 | 7.2 | 9.5 | 15.2 | 7.6 |
| 1990 | 9.8 | 14.0 | 13.7 | 12.4 | 14.9 | 22.5 | 13.7 |
| 1995 | 11.5 | 13.3 | 14.4 | 15.9 | 30.0 | 26.1 | 19.3 |
| 1999 | 16.0 | 16.2 | 16.3 | 17.9 | 36.0 | 31.7 | 20.8 |
| Average annual growth of expenditure at constant harmonised prices | | | | | | | |
| 1980-1990 | 13.0 | 12.1 | 13.1 | 20.0 | 15.3 | 12.2 | 18.4 |
| 1990-1999 | 15.5 | 11.1 | 10.2 | 9.7 | 14.3 | 17.7 | 14.8 |
| 1990-1995 | 10.1 | 8.1 | 6.5 | 8.7 | 9.4 | 13.3 | 13.9 |
| 1995-1999 | 22.2 | 14.8 | 14.8 | 11.0 | 20.5 | 23.2 | 15.8 |

**a** gross fixed capital formation (GFCF).

*Source:* OECD (2001).

## Table A.9 Proportion of households with a PCs, selected OECD countries and years

Per cent

| | 1990 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|
| Australia | | 38.7 | 42.6 | 45.3 | 49.9 |
| Canada | 16.2 | 36.4 | | | |
| Finland | 8.0 | 35.0 | 37.8 | 42.3 | |
| France | 9.1 | 16.0 | 19.0 | 23.0 | |
| Japan | 10.6 | 22.1 | 25.2 | 29.5 | |
| Netherlands | 21.0 | 47.0 | 55.0 | | |
| New Zealand | 11.6 | 27.6 | 32.9 | 37.5 | 42.8 |
| Norway | 20.0 | 50.0 | 57.0 | | |
| United States | 15.2 | 36.6 | 40.0 | | |

*Source:* OECD (2000e).

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# B IT use and productivity trends

This appendix outlines the IT-related data that are used in the national accounts procedures to estimate productivity trends for Australia. Because communications equipment is not separately identified as an asset type in the Australian national accounts, the measures are confined to IT hardware and software.

Hardware is defined as computers and peripherals and is one of the six major classes of machinery and equipment used in the national accounts. The three components of software capital are software developed in-house, purchases of customised software, and purchased 'off the shelf' software (ABS 2000a).

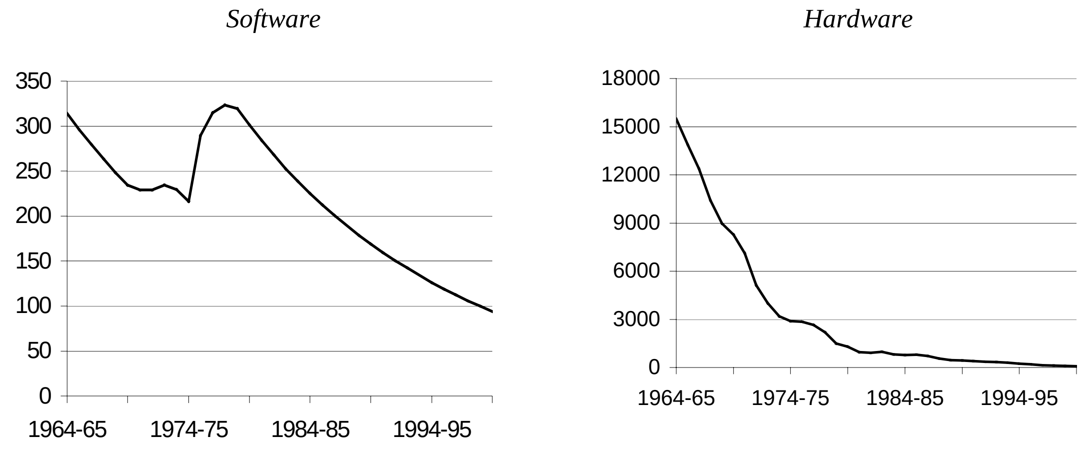
The appendix examines a number of measures, such as the price of IT capital, investment in IT, the productive capital stock of IT and income from IT capital. The appendix also examines various indicators of industry use of IT capital.

Finally, the appendix examines the relationships between IT use and productivity growth at the industry level.

## B.1 Prices

The two investment price indices for software and hardware are shown in figures B.1 and B.2. The software price index used by the Australian Bureau of Statistics (ABS) is based on a software price index developed by Statistics Canada, which declines by 6 per cent per year. This price index is based on the price of popular software. The hardware price index is based on the computer equipment price index developed in the United States by the Bureau of Economic Analysis. The US index is assumed to apply for Australia with a lag and adjusted for movements in the exchange rate between US and Australian dollars (ABS 2000a).

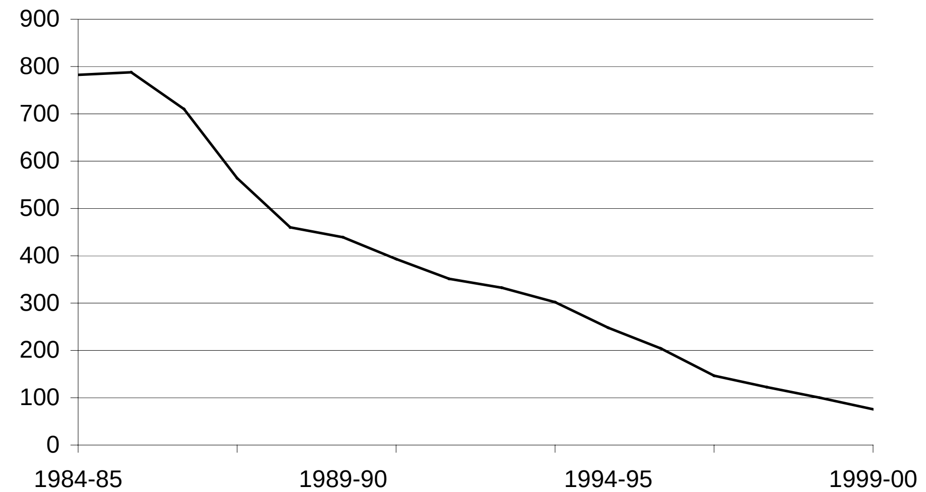
Figure B.1 **Investment price index for IT, 1964-65 to 1999-00**
Index 1998-99 = 100




*Data source:* PC estimates based on unpublished ABS data.

The investment price indexes for both software and especially hardware have fallen rapidly since the 1960s (figure B.1 and B.2).

Figure B.2 **Computer hardware investment price index, 1984-85 to 1999-00**
Index 1998-99 = 100




*Data source:* PC estimates based on unpublished ABS data.

The decline in the investment price is also reflected in the relative rental price of IT capital to other capital, which has shown a significant decrease (see Chapter 5, figure 5.1). The relative rental price is the ratio of the rental price of combined IT assets to the rental price of all other assets, the latter being the weighted sum of rental prices of individual assets and the weights reflect the relative size of the productive capital stock of each asset.

There are two opposing forces in forming rental prices, the real purchase price of an asset and its depreciation. As shown below, the rental price of an asset is equal to the depreciation of the asset plus returns to owners of the asset, less any revaluation of the nominal value of the asset due to inflation or other price changes. Thus, the higher the depreciation rate the higher the rental price, all other things being equal. However, in the case of computers, the lower real purchase price of computers has outweighed the rapid depreciation in the user costs of capital.

The lower relative rental price compared to other assets indicates that the relative user cost of IT has fallen, and thus forms part of the inducement to substitute IT for other types of capital. Note, however, that even though the relative rental price has fallen dramatically, the rental price on IT still remains higher than other asset's rental prices.

The rental price equation for each industry and asset type is defined as:

$$\text{Rental price} = p.(i+d-g)$$

where

p is the price deflator for new capital goods,
i is the nominal internal rate of return,
g is the capital gain/loss due to the revaluation of an asset, and
d is the depreciation rate.

The nominal internal rate of return is imputed for each industry and is constant across all asset types within that industry. This is in keeping with an assumption that asset holdings are in long-term equilibrium. The capital gain/loss is the change in the price deflator for a particular asset. The depreciation rate is the ratio of real economic depreciation (consumption of fixed capital) divided by the net capital stock. (ABS 2000)

The ABS (2000) includes an income tax parameter (T) and the effective average non-income tax rate on production (x) in its measure of rental prices. The rental price equation then becomes:

$$\text{Rental price} = T.p.(i+d-g) + p.x$$

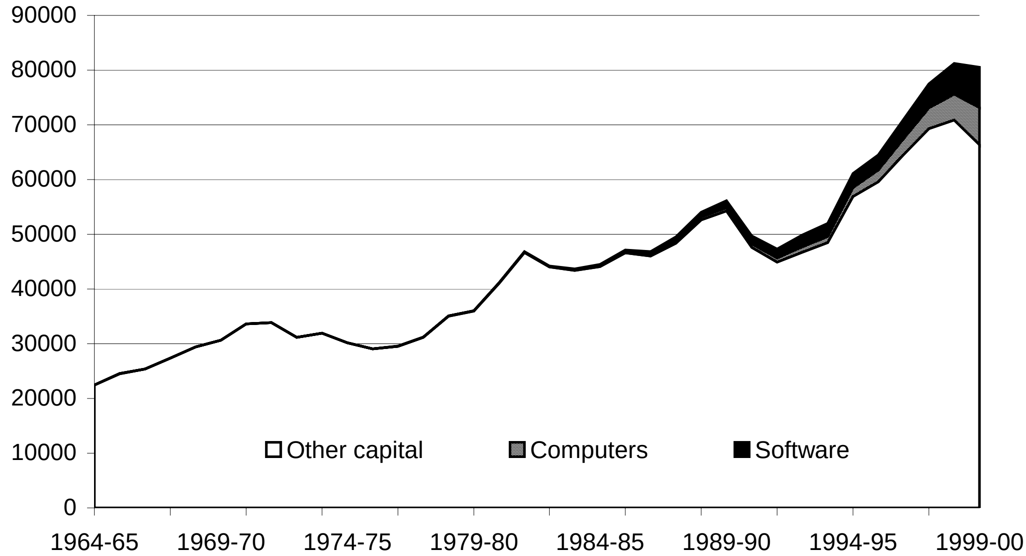
The income tax parameter is required because of the variations in income tax allowance across different industries and asset types. These allowances increase the after-tax returns and lower the rental price of capital. The inclusion of the income tax parameter is to reduce the distortions to the rental price due to the variations in allowances for different capital assets and industries over time. The non-income tax rate covers taxes such as land tax, local government authority taxes, motor vehicle registrations, stamp duties, and other miscellaneous taxes. (ABS 2000a)

## B.2 Growth in IT investment

IT investment has grown rapidly in importance, especially over the 1990s. Figures B.3 and B.4 highlight the growing importance of IT equipment as its volume share of total investment has increased substantially during the 1990s.

Figure B.3 **Annual real gross fixed capital formation for the market sector in Australia, 1964-65 to 1999-00**

$ million




*Data source:* PC estimates based on unpublished ABS data.

Table B.1 **Share of IT investment in real and nominal total investment in the market sector, Australia, selected years**

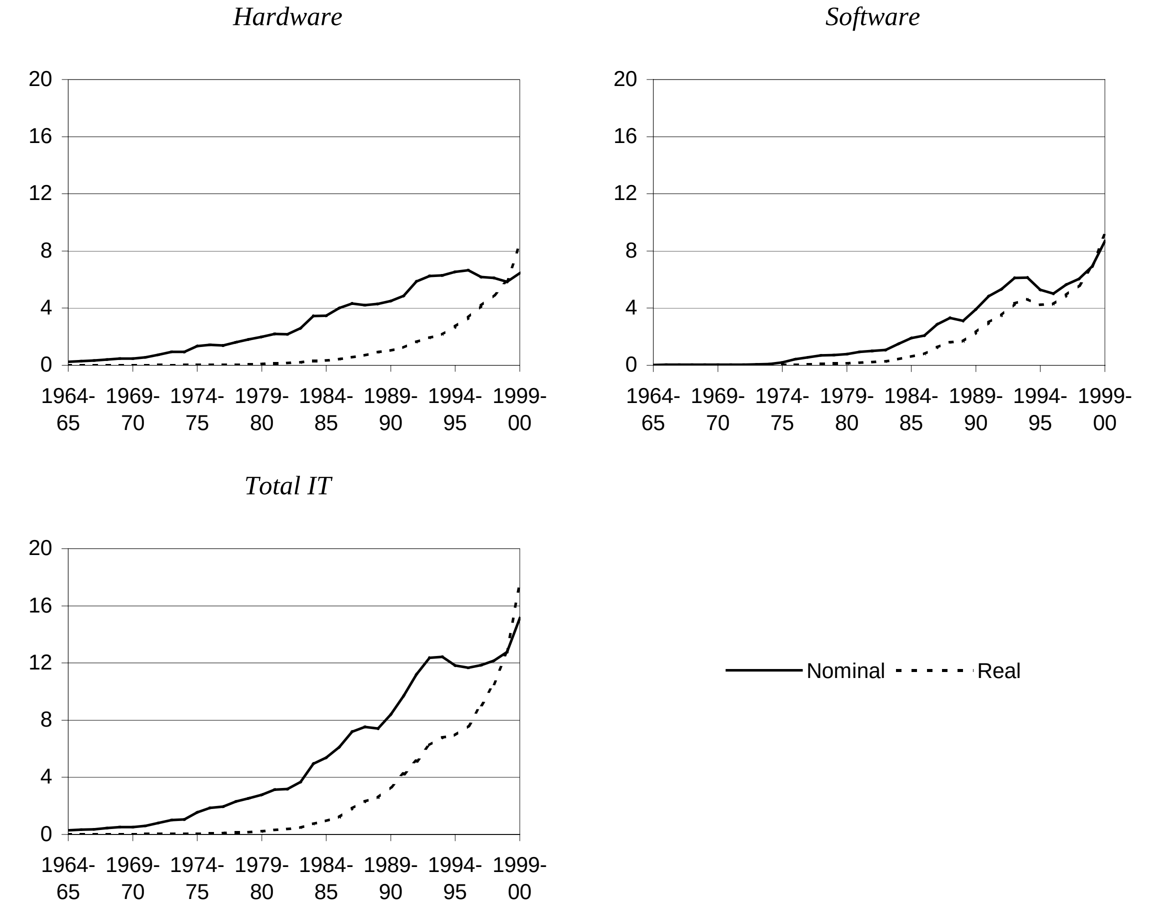
Per cent

| | *Computers* | | *Software* | | *Combined* | |
|---|---|---|---|---|---|---|
| | real | nominal | real | nominal | real | nominal |
| 1964-65 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.3 |
| 1973-74 | 0.0 | 1.0 | 0.0 | 0.1 | 0.0 | 1.0 |
| 1984-85 | 0.3 | 3.5 | 0.6 | 1.9 | 0.9 | 5.4 |
| 1988-89 | 0.9 | 4.3 | 1.7 | 3.1 | 2.6 | 7.4 |
| 1993-94 | 2.1 | 6.3 | 4.6 | 6.1 | 6.8 | 12.4 |
| 1999-00 | 8.4 | 6.4 | 9.2 | 8.7 | 17.6 | 15.1 |

*Source:* PC estimates based on unpublished ABS data.

Figure B.4 **IT share of real and nominal gross fixed capital formation for the market sector in Australia, 1964-65 to 1999-00**

Per cent




*Data source:* PC estimates based on unpublished ABS data.

Actual investment in the 1960s through to the early 1980s was very low (table B.1). In 1984-85 real investment in IT was only 0.9 per cent of total investment, climbing to 17.6 per cent for 1999-00. Growth in the share in nominal investment is lower than the share in real investment, reflecting the decline in absolute and relative prices of computer hardware and software.

## B.3 IT productive capital stock

Considerable growth in the productive capital stock and net capital stock for IT assets, occurred from around 1993-94 (see chapter 5, figure 5.4). The net capital stock is essentially a wealth measure (loss of earning capacity), whereas the productive capital stock forms the basis for the measure of capital services (loss of economic efficiency). Chapter 3 provides further discussion of productive capital stock.

Productive capital stock estimates are a measure of the productive capacity of an asset. Productive capital stock estimates are derived on the basis of an asset's decline in efficiency due to age. An age-efficiency profile is used to define how the flow of capital services declines over an asset's life. There are many possibilities for defining the age-efficiency profile, but a lack of data makes it difficult to determine the shape of the profile. The ABS uses hyperbolic functions to describe the age-efficiency profiles. A hyperbolic function means that the efficiency of an asset declines by a small amount at first and then the rate of decline increases as the asset ages. The hyperbolic age-efficiency function has the form:

$$E_t = \frac{M - A_t}{M - bA_t}$$

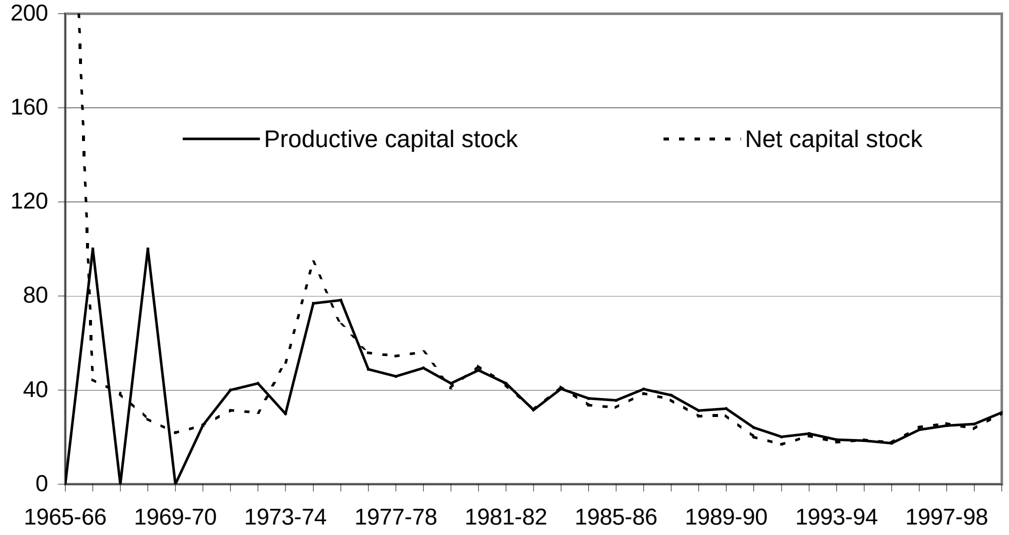
where $E_t$ is the efficiency of the asset at time t (as a ratio of the asset's efficiency when new).
M is the asset life.
$A_t$ is the age of the asset at time t.
b is the efficiency reduction parameter.

The efficiency reduction parameter is set to 0.5 for software, machinery and equipment and 0.75 for structures. The higher value for structures redistributes more of the efficiency loss to the end of the asset's life compared to that of machinery and equipment. For mineral exploration the efficiency reduction parameter is set to one, which implies that there is no efficiency decline in exploration knowledge. In contrast, the parameter is set to zero for artistic originals, implying a straight-line efficiency decline. (ABS 2000a)

Average annual growth rates of IT productive capital stock and net capital stock are shown in figures B.5 and B.6. Growth rates in the first half of the period are from a very low base.

**Figure B.5 Annual average growth in IT productive capital stock and net capital stock, 1965-66 to 1999-00**

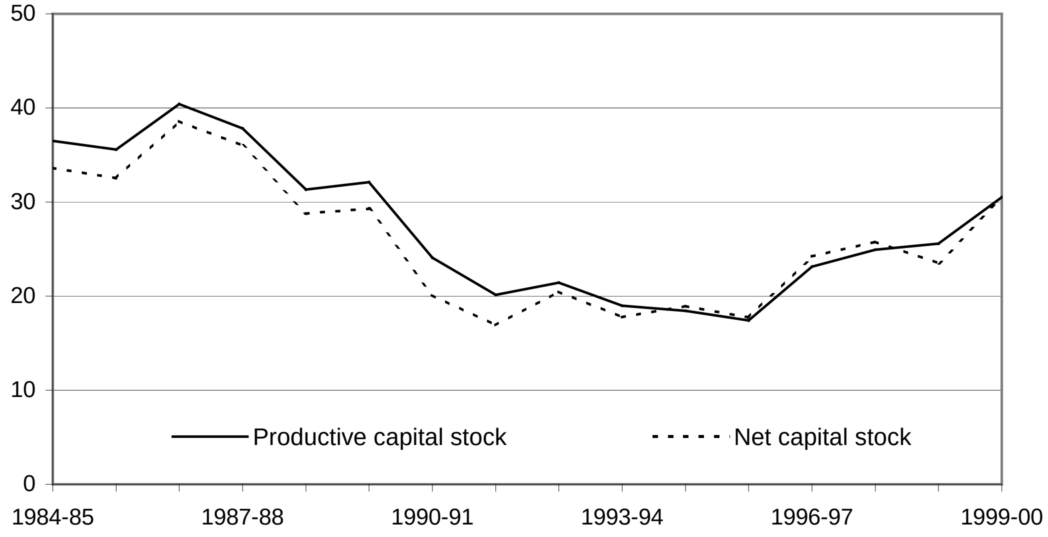
Per cent per year




*Data source:* PC estimates based on unpublished ABS data.

**Figure B.6 Annual average growth in IT productive capital stock and net capital stock, 1984-85 to 1999-00**

Per cent per year




*Data source:* PC estimates based on unpublished ABS data.

Table B.2 shows the high growth rates that have occurred in the IT productive capital stock since the early 1970s.

Table B.2 **Annual average growth in productive capital stock for the market sector in Australia, selected years**

Per cent per year

| | *1964-65 to 1973-74* | *1973-74 to 1984-85* | *1984-85 to 1988-89* | *1988-89 to 1993-94* | *1993-94 to 1999-00* | *1964-65 to 1999-00* |
|---|---|---|---|---|---|---|
| Computers | na | 48.9 | 30.8 | 20.8 | 32.3 | na |
| Software | 26.0 | 48.5 | 39.4 | 24.4 | 18.0 | 32.5 |
| Other Capital | 4.0 | 2.7 | 2.6 | 1.5 | 2.3 | 2.8 |
| Total | 4.0 | 2.8 | 2.6 | 1.7 | 2.6 | 2.9 |

na not applicable.

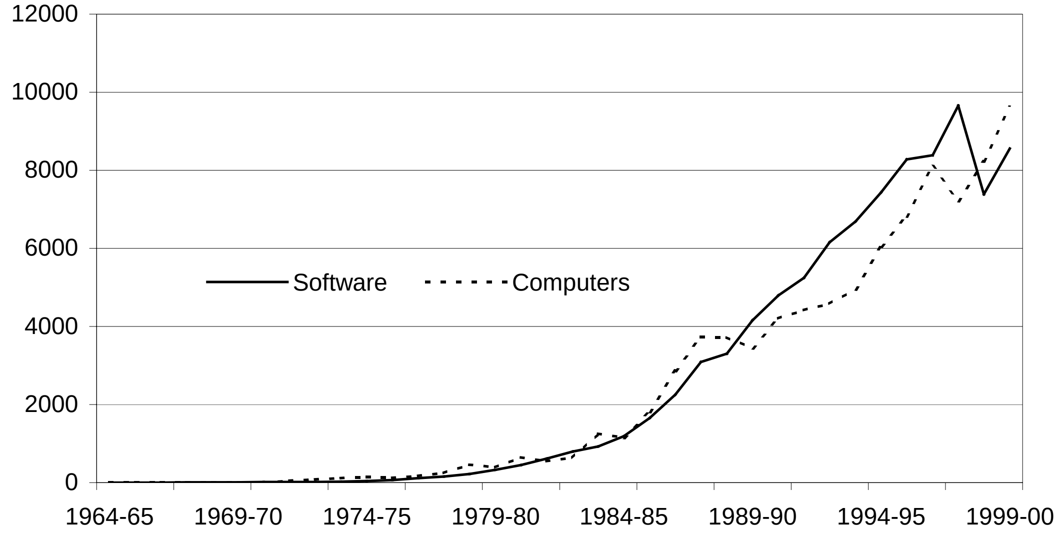
*Source:* PC estimates based on unpublished ABS data.

## B.4 Capital income

Capital income is defined in the national accounts as the rental price multiplied by the productive capital stock. Figure B.7 shows the capital income earned by IT assets has increased rapidly over the 1980s and 1990s. The increase in IT capital income is due to the increase in productive capital stock far outweighing the decrease in rental prices. IT capital income has followed a similar growth pattern to IT investment, although there does appear to be a slight lag.

Figure B.7 **Real capital income from IT assets for the market sector, 1964-65 to 1999-00**

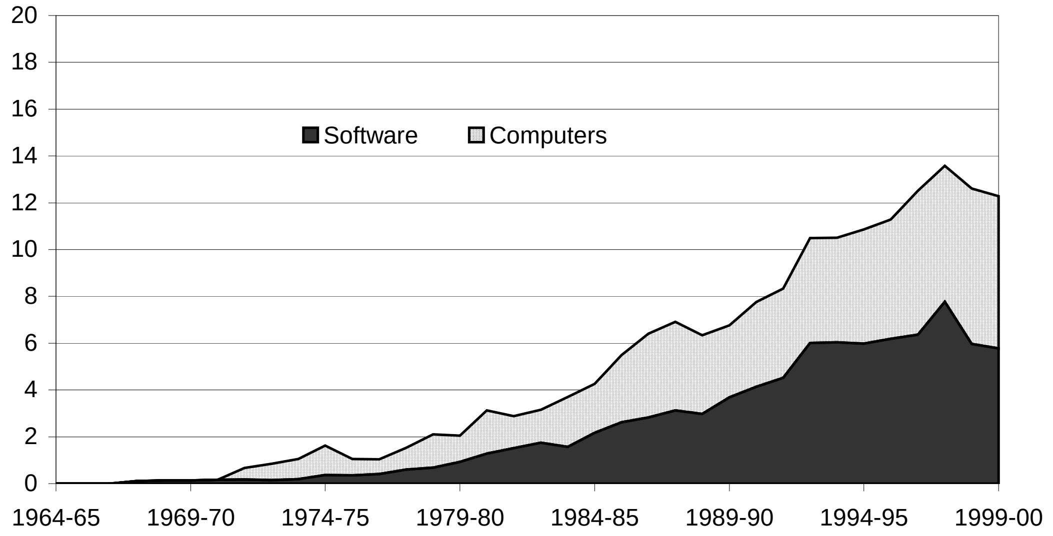
$ million




*Data source:* PC estimates based on unpublished ABS data.

Figure B.8 **Share of capital income by IT asset type in total capital income for the market sector, 1964-65 to 1999-2000**

Per cent




*Data source:* PC estimates based on unpublished ABS data.

Capital income earned from IT assets has increased its share of total capital income over the 1990s (figure B.8). That is, relatively more capital income is being earned from IT assets. More data is provided in table 5.4.

## B.5 Industry IT use

The intention in this section is to characterise IT use by industry so that any relationships between IT use and output and productivity outcomes can be explored. There are various indicators that can be used. An objective is to determine preferred measures. The indicators used in this section and summarised in table B.11 are:

- growth in IT investment;
- industry share of market sector IT investment;
- industry contributions to market sector growth in IT investment
- share of IT investment in total industry investment;
- growth in IT productive capital stock;
- share of industry IT productive capital in total industry productive capital stock; and
- share of income from IT assets.

Stiroh (2001) identifies IT intensity in a number of ways — share of IT capital in total capital, ratio of IT capital to output, or IT capital per worker. Stiroh prefers share of IT capital services in total capital services as this identifies those industries that are shifting their capital resources toward high-tech assets. As will be seen, this is one of the preferred measures used in this study. Another preferred measure is the share of income attributed to IT assets. This measure gives an indication of the growing importance of IT capital in relation to all inputs.

## Investment indicators

Although there is not a one-to-one relationship between investment and capital services, growth in IT investment can nevertheless indicate where there has been rapid uptake of IT at an industry level.

Table B.3 **Growth in IT investment, by industry sector**

Per cent per year

| | *1984-85 to 1988-89* | *1988-89 to 1993-94* | *1993-94 to 1999-00* | *Acceleration* | *Acceleration* |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (2)-(1) | (3)-(2) |
| Agriculture | 36.0 | 19.5 | 23.6 | -16.5 | 4.2 |
| Mining | 32.6 | 13.8 | 13.7 | -18.7 | -0.1 |
| Manufacturing | 37.1 | 22.8 | 23.6 | -14.3 | 0.8 |
| Electricity, gas & water | 10.1 | 19.7 | 43.8 | 9.5 | 24.1 |
| Construction | 38.6 | 20.0 | 22.2 | -18.6 | 2.2 |
| Wholesale trade | 35.9 | 22.3 | 21.1 | -13.6 | -1.2 |
| Retail trade | 38.5 | 23.6 | 24.9 | -14.9 | 1.3 |
| Accom., cafes & restaurants | 41.1 | 22.1 | 23.3 | -19.1 | 1.3 |
| Transport & storage | 30.4 | 10.3 | 66.9 | -20.1 | 56.6 |
| Communications | 32.7 | 22.0 | 17.9 | -10.7 | -4.1 |
| Finance & insurance | 37.3 | 17.2 | 29.4 | -20.0 | 12.2 |
| Cultural & rec. services | 36.3 | 22.5 | 30.2 | -13.8 | 7.7 |
| Market Sector | 34.8 | 20.3 | 26.9 | -14.5 | 6.5 |

*Source:* PC estimates based on unpublished ABS data.

There has been strong growth in IT investment across all industries (table B.3). There was some slower growth over the period 1988-89 to 1993-94 which included the recession. The Electricity, gas & water and Transport & storage sectors have significantly increased their rate of growth in IT investment over the 1990s. The higher rates of growth over the 1990s for these two industries reflect the fact that they were ‘catching up’ on lower growth rates in IT investment over previous periods. The Finance & insurance and Cultural & recreational services sectors also increased their rate of investment over the 1990s, at a rate faster than the market sector average. Only Mining, Wholesale trade and Communications saw the growth rate in IT investment fall over the 1990s compared to the 1980s.

Table B.4 **Industry share of IT investment, selected years**

Per cent

| | *1964-65* | *1981-82* | *1988-89* | *1993-94* | *1999-00* |
|---|---|---|---|---|---|
| Agriculture | 2.4 | 1.2 | 1.8 | 1.7 | 1.4 |
| Mining | 0.3 | 0.9 | 1.2 | 1.3 | 1.3 |
| Manufacturing | 25.2 | 11.7 | 13.9 | 16.0 | 14.0 |
| Electricity, gas & water | 2.1 | 13.4 | 4.0 | 3.6 | 6.7 |
| Construction | 3.1 | 3.7 | 6.4 | 6.0 | 4.8 |
| Wholesale trade | 6.5 | 9.2 | 9.4 | 10.9 | 9.4 |
| Retail trade | 5.8 | 6.0 | 9.3 | 11.4 | 9.8 |
| Accom., cafes & restaurants | 0.7 | 1.5 | 2.9 | 3.3 | 2.9 |
| Transport & storage | 8.2 | 6.6 | 7.9 | 7.4 | 10.4 |
| Communications | 18.1 | 12.2 | 10.1 | 11.1 | 7.0 |
| Finance & insurance | 26.6 | 32.1 | 31.1 | 24.7 | 29.4 |
| Cultural & rec. services | 1.0 | 1.4 | 2.2 | 2.5 | 3.0 |
| Market Sector | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*Source:* PC estimates based on unpublished ABS data.

Table B.4 shows which sectors are the relatively high investors in IT capital — Finance & insurance, Manufacturing and Transport & storage. The table shows that the relative importance has changed over time. The Transport & storage sector has increased its relative share over time, while the Manufacturing sector has decreased its share, even though it remains a larger IT investor than the Transport & storage sector.

Industry contributions to the growth in market sector investment depend on the growth in industry investment (table B.3) and the industry share in market sector investment (table B.4). The biggest industry contributions to market sector growth in IT came from the Finance & insurance sector and the Manufacturing sector (although this has declined over the 1990s). Other sectors which made relatively significant contributions were the Wholesale and Retail trade sectors (table B.5).

The changes in the contribution to growth in market sector investment should also be considered (table B.6). The Finance & insurance sector increased its contribution by 3.3 percentage points between the latter two periods. This sector was followed by the Transport & storage and Electricity, gas & water sectors with 2.3 and 2.0 percentage points respectively. Manufacturing did not feature prominently in the acceleration in industry contributions to market sector IT investment.

## Table B.5 **Industry contributions to market sector growth in IT investment, selected years**

Per cent per year and per cent

| | *1984-85 to 1988-89* | | *1988-89 to 1993-94* | | *1993-94 to 1999-00* | |
|---|---|---|---|---|---|---|
| Agriculture | 0.6 | (2) | 0.3 | (1) | 0.4 | (1) |
| Mining | 1.1 | (3) | 0.4 | (2) | 0.3 | (1) |
| Manufacturing | 5.6 | (16) | 3.7 | (18) | 3.9 | (14) |
| Electricity, gas & water | 0.6 | (2) | 0.6 | (3) | 2.6 | (9) |
| Construction | 2.2 | (6) | 1.2 | (6) | 1.2 | (5) |
| Wholesale trade | 4.2 | (12) | 2.7 | (13) | 2.2 | (8) |
| Retail trade | 3.6 | (10) | 2.4 | (12) | 2.8 | (10) |
| Accom., cafes & restaurants | 1.2 | (4) | 0.7 | (4) | 0.8 | (3) |
| Transport & storage | 0.7 | (2) | 0.2 | (1) | 2.5 | (9) |
| Communications | 3.6 | (10) | 2.5 | (12) | 1.6 | (6) |
| Finance & insurance | 10.6 | (30) | 4.9 | (24) | 8.2 | (30) |
| Cultural & rec. services | 0.9 | (3) | 0.6 | (3) | 0.9 | (3) |
| Market Sector | 34.8 | (100) | 20.3 | (100) | 26.9 | (100) |

*Source:* PC estimates based on unpublished ABS data.

## Table B.6 **Acceleration in industry contributions to market sector growth in IT investment, selected years**

Percentage points

| | *1984-85 to 1988-89 and 1988-89 to 1993-94* | *1988-89 to 1993-94 and 1993-94 to 1999-00* |
|---|---|---|
| Agriculture | -0.3 | 0.1 |
| Mining | -0.7 | -0.1 |
| Manufacturing | -1.9 | 0.2 |
| Electricity, gas & water | 0.0 | 1.9 |
| Construction | -1.0 | 0.1 |
| Wholesale trade | -1.5 | -0.4 |
| Retail trade | -1.2 | 0.3 |
| Accom., cafes & restaurants | -0.5 | 0.1 |
| Transport & storage | -0.5 | 2.3 |
| Communications | -1.1 | -0.9 |
| Finance & insurance | -5.7 | 3.3 |
| Cultural & rec. services | -0.3 | 0.3 |

*Source:* PC estimates based on unpublished ABS data.

Table B.7 **Share of IT investment in real industry gross fixed capital formation, selected years**

Per cent

| | *1964-65* | *1981-82* | *1988-89* | *1993-94* | *1999-00* |
|---|---|---|---|---|---|
| Agriculture | 0.0 | 0.0 | 0.4 | 1.1 | 3.4 |
| Mining | 0.0 | 0.1 | 0.5 | 0.9 | 1.5 |
| Manufacturing | 0.0 | 0.3 | 2.2 | 6.1 | 14.8 |
| Electricity, gas & water | 0.0 | 0.2 | 1.0 | 3.2 | 19.0 |
| Construction | 0.0 | 0.5 | 2.7 | 8.7 | 22.4 |
| Wholesale trade | 0.0 | 0.8 | 7.1 | 16.2 | 35.3 |
| Retail trade | 0.0 | 0.7 | 4.8 | 10.4 | 22.3 |
| Accom., cafes & restaurants | 0.0 | 0.4 | 1.6 | 8.1 | 14.5 |
| Transport & storage | 0.0 | 0.8 | 3.9 | 7.9 | 17.0 |
| Communications | 0.0 | 0.3 | 1.8 | 4.3 | 9.6 |
| Finance & insurance | 0.0 | 3.1 | 8.5 | 34.3 | 59.1 |
| Cultural & rec. services | 0.0 | 0.6 | 2.9 | 7.7 | 12.9 |
| Market Sector | 0.0 | 0.4 | 2.6 | 6.8 | 17.6 |

*Source:* PC estimates based on unpublished ABS data.

Table B.7 shows most sectors have shifted their mix of investment toward IT investment over time. This is consistent with IT investment substituting for investment in other forms of capital as it becomes cheaper. This is particularly so for the Finance & insurance sector, with its IT share of investment increasing rapidly, from 8.5 per cent in 1988-89 to 59.1 per cent in 1999-00. Between the years 1993-94 and 1999-00 there was a significant increase in the share of IT investment in a number of sectors.

Other sectors that have a significant share of investment in IT (above the market sector average) are Wholesale trade, Retail trade and Construction. The sharpest increases occurring between 1993-94 and 1999-00 were in the Finance & insurance, Wholesale trade, Construction, Electricity, gas & water, and Retail trade sectors (greater than the 11 percentage points increase that occurred for the market sector as a whole). Thus, while IT investment in Wholesale trade is declining (table B.3) over the 1990s, it represents a marked increased in the proportion of investment in that industry. The Electricity, gas & water sector's IT share of investment has increased sharply over the last few years from 3.2 per cent in 1993-94 to 19.0 per cent in 1999-00.

## Capital input indicators

Table B.8 shows the growth in the IT productive capital stock. It is growth in the productive capital stock that matters for output growth and productivity calculations. This is because growth in the productive capital stock means that there is growth in capital services input. The largest growth rate that occurred over the 1990s was in the Electricity, gas & water sector, which also had the biggest acceleration in growth in its IT productive capital stock. Other sectors that had growth rates greater than the market sector average over the period 1993-94 to 1999-00 were Agriculture, Finance & insurance and Cultural & recreational services.

Table B.8 **Growth in IT productive capital stock, by industry sector**

Per cent per year

| | *1984-85 to 1988-89* | *1988-89 to 1993-94* | *1993-94 to 1999-00* | *Acceleration* | *Acceleration* |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (2)-(1) | (3)-(2) |
| Agriculture | 35.9 | 22.0 | 23.3 | -13.9 | 1.3 |
| Mining | 38.2 | 24.7 | 20.7 | -13.4 | -4.0 |
| Manufacturing | 37.5 | 24.7 | 22.2 | -12.8 | -2.5 |
| Electricity, gas & water | 16.8 | 12.2 | 38.2 | -4.6 | 26.1 |
| Construction | 39.5 | 23.5 | 21.0 | -16.1 | -2.5 |
| Wholesale trade | 38.2 | 23.9 | 19.7 | -14.4 | -4.2 |
| Retail trade | 40.7 | 25.2 | 23.7 | -15.5 | -1.5 |
| Accom., cafes & restaurants | 43.6 | 25.2 | 22.9 | -18.4 | -2.3 |
| Transport & storage | 33.7 | 23.9 | 15.9 | -9.8 | -8.0 |
| Communications | 38.5 | 23.7 | 22.9 | -14.9 | -0.7 |
| Finance & insurance | 37.4 | 22.4 | 25.5 | -15.0 | 3.1 |
| Cultural & rec. services | 39.8 | 25.5 | 27.1 | -14.3 | 1.6 |
| Market Sector | 36.2 | 23.3 | 23.3 | -13.0 | 0.0 |

*Source:* PC estimates based on unpublished ABS data.

Even though Electricity, gas & water had the highest growth rates in IT productive capital stock, it is still low in its proportion of IT productive capital to its total productive capital stock. The Finance & insurance sector has the largest proportion of IT productive capital stock at 11.3 per cent in 1999-00 (table B.9). The Construction, Retail trade and Cultural & recreational service sectors have their IT productive capital stock at just under five per cent in 1999-00. The biggest increases between 1993-94 and 1999-00 occurred in these industries. These increases in shares in IT productive capital stock meant a large increase in the market sector's share from 1.0 per cent in 1993-94 to 3.0 per cent in 1999-00.

Table B.9 **Share of IT productive capital stock in industry productive capital stock**

Per cent

| | *1981-82* | *1984-85* | *1988-89* | *1993-94* | *1999-00* | *Change over 1993-94 and 1999-00* |
|---|---|---|---|---|---|---|
| Agriculture | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.2 |
| Mining | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 | 0.2 |
| Manufacturing | 0.0 | 0.1 | 0.4 | 1.1 | 3.1 | 2.0 |
| Electricity, gas & water | 0.0 | 0.1 | 0.1 | 0.2 | 1.5 | 1.3 |
| Construction | 0.1 | 0.2 | 0.7 | 1.7 | 4.9 | 3.2 |
| Wholesale trade | 0.1 | 0.2 | 0.7 | 1.7 | 4.4 | 2.7 |
| Retail trade | 0.1 | 0.2 | 0.6 | 1.7 | 4.8 | 3.1 |
| Accom., cafes & restaurants | 0.0 | 0.1 | 0.3 | 0.9 | 2.5 | 1.7 |
| Transport & storage | 0.1 | 0.2 | 0.4 | 1.2 | 2.5 | 1.3 |
| Communications | 0.1 | 0.2 | 0.7 | 1.7 | 3.8 | 2.2 |
| Finance & insurance | 0.3 | 0.5 | 1.4 | 3.2 | 11.3 | 8.0 |
| Cultural & rec. services | 0.1 | 0.3 | 1.0 | 2.2 | 4.8 | 2.6 |
| Market sector | 0.1 | 0.1 | 0.4 | 1.0 | 3.0 | 2.0 |

*Source:* PC estimates based on unpublished ABS data.

## Importance of IT inputs

Not only does growth in IT inputs matter, but growth in the importance of IT in total inputs also matters. The growth in the importance of IT inputs is measured by a sector’s share of income from IT assets in total factor income.

Table B.10 **IT share in total income by industry, selected years**
Per cent

| | *1981-82* | *1984-85* | *1988-89* | *1993-94* | *1999-00* | *Change over 1993-94 and 1999-00* |
|---|---|---|---|---|---|---|
| Agriculture | 0.2 | 0.2 | 0.3 | 0.8 | 1.2 | 0.4 |
| Mining | 0.2 | 0.3 | 0.5 | 0.9 | 0.9 | 0.0 |
| Manufacturing | 0.5 | 1.0 | 1.8 | 3.6 | 3.8 | 0.3 |
| Electricity, gas & water | 0.7 | 1.5 | 2.1 | 1.3 | 7.7 | 6.3 |
| Construction | 0.5 | 0.9 | 1.9 | 2.8 | 2.7 | -0.1 |
| Wholesale trade | 1.3 | 2.0 | 3.2 | 4.7 | 4.6 | -0.1 |
| Retail trade | 0.6 | 1.2 | 2.4 | 4.5 | 3.5 | -1.0 |
| Accom., cafes & restaurants | 0.5 | 1.0 | 1.6 | 2.4 | 3.2 | 0.8 |
| Transport & storage | 1.1 | 1.6 | 2.6 | 5.0 | 3.6 | -1.4 |
| Communications | 1.5 | 6.1 | 4.7 | 8.0 | 9.0 | 1.0 |
| Finance & insurance | 3.7 | 6.1 | 10.6 | 13.2 | 14.8 | 1.6 |
| Cultural & rec. services | 1.6 | 2.4 | 4.2 | 5.3 | 5.9 | 0.5 |
| Market sector | 1.0 | 1.6 | 2.5 | 4.3 | 5.0 | 0.7 |

*Source:* PC estimates based on unpublished ABS data.

Table B.10 shows each sector's share of income from IT capital. The data show that the income share of IT assets has increased over time for all sectors. A large part of this increase occurred over the 1990s. The sectors with the biggest increases over the 1990s were the Finance & insurance, the Electricity, gas & water, Communications, and the Accommodation, cafes and restaurants sectors, which all experienced a bigger increase in the income share from IT capital than the market sector. On the other hand some sectors experienced a decrease in their IT income share, most notable were the Retail trade sector and the Transport & storage sector.

## Assessment

In assessing the importance of IT use by industry a variety of indicators are available. Which indicator to use will depend on how the role of IT is viewed. If a general measure of IT use is to be examined, then either investment, or the better measure of growth in productive capital stock could be used. If it is the importance of IT in relation to other forms of capital, then the share of productive IT assets in total productive capital stock could be used. If it is the importance of IT in relation to all inputs then the share of income from IT assets could be used. The latter two measures are the ones considered to be the most important.

Table B.11 displays the industry rankings according to the various criteria of IT use. Generally, industries have been ranked if they were above the market sector average. The Finance & insurance sector ranks high on IT use across all indicators. The Electricity, gas & water and the Transport & storage sectors are also strong on use indicators, especially growth in investment, this is due to catching up to other sectors. The Wholesale and Retail trade sectors have average rankings in terms of the importance of their IT use. The Cultural & recreational services sector has high growth rates in IT use. The Manufacturing sector is high on the significance of its use of IT, but its relative importance is lessening.

The share of IT productive capital stock in total capital stock is the one favoured in this study. The indicators on investment influence the productive capital stock, and it is the changes in the productive capital stock that have most relevance to productivity measures. The Finance & insurance sector had the largest share of IT productive capital stock in 1999-00, and it also exhibited the biggest change since 1993-94. In addition the sector also saw an acceleration in the growth in productive capital stock over the second half of the 1990s. Other sectors with relatively high shares of IT productive capital stock, which also saw relatively high increase between 1993-94 and 1999-00 were Cultural & recreational services, Retail trade and Wholesale trade. The Communications and Manufacturing sectors had relatively high proportions of IT productive capital stock but only modest increases over the period between 1993-94 and 1999-00.

Another of the more important indicators of IT use is the share of income from IT assets. This indicates the importance in overall use of resources. Using this indicator, Finance & insurance is ranked as number one, followed by Communications and then Electricity, gas & water.

## Table B.11 **Industry rankings on use of IT**

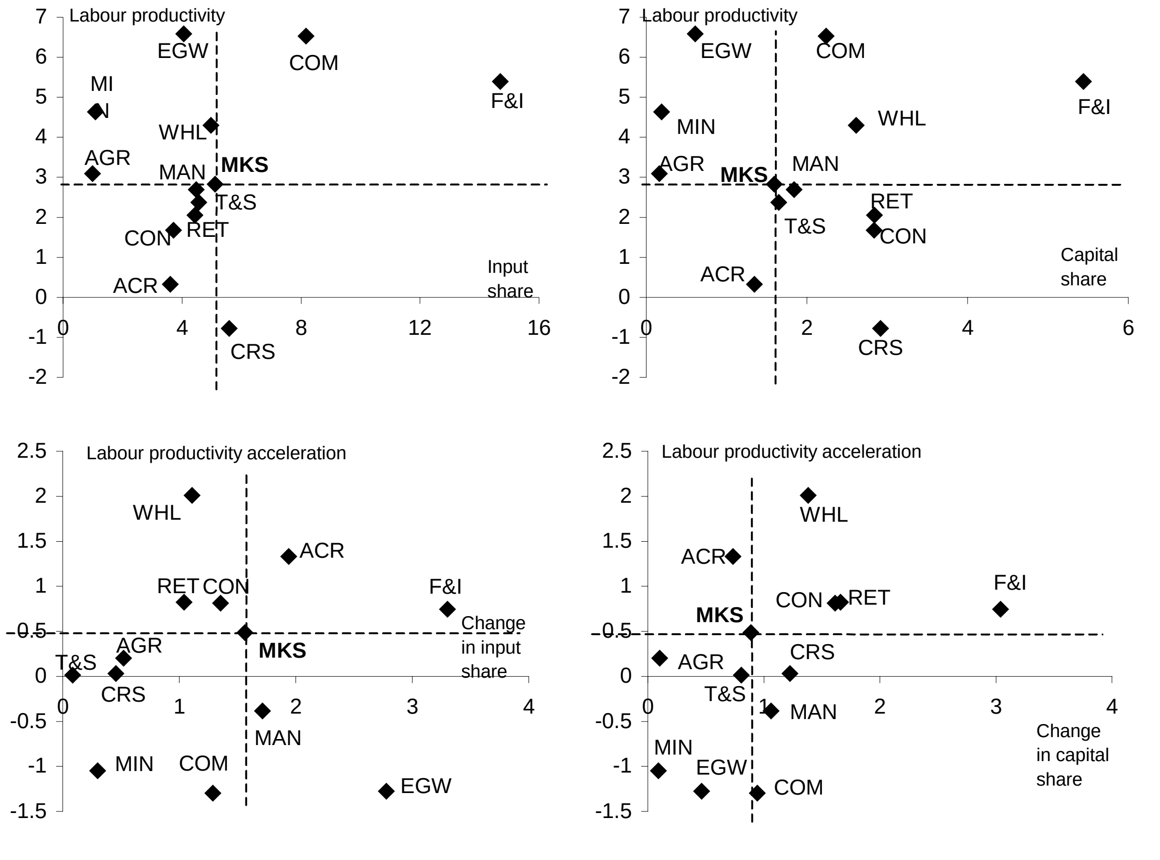
| | *IT Investment* | | | | | *IT Productive capital stock* | | |
|---|---|---|---|---|---|---|---|---|
| | *1990s growth (table B.4)* | *1990s acceleration (table B.4)* | *Share of market sector (table B.5)* | *Contrib to market sector 1990s growth (table B.6)* | *Share in industry invest (table B.7)* | *Growth (table B.9)* | *Share in ndustry total (table B10)* | *IT income share* |
| Agriculture | | | | | | 5 | | |
| Mining | | | | | | | | |
| Manufacturing | | | 2 | 2 | | | 7 | |
| Elect, gas & water | 2 | 2 | | 4 | 5 | 1 | | 3 |
| Construction | | | | | 3 | | 2 | |
| Wholesale trade | | | 5 | 6 | 2 | | 5 | 5 |
| Retail trade | | | 4 | 3 | 4 | 4 | 4 | |
| Accommodation, cafe & restaurants | | | | | | | | |
| Transport & Storage | 1 | 1 | 3 | 5 | | | | |
| Communication services | | | | | | | 6 | 2 |
| Finance & insurance | 4 | 3 | 1 | 1 | 1 | 5 | 1 | 1 |
| Cultural & recreational services | 3 | 4 | | | | 2 | 3 | 4 |

# B.6 Industry IT use and productivity growth

This section provides further detail on the examination of industry IT use and productivity growth presented in chapter 5.

Figure B.9 **IT use[a] and annual average growth in labour productivity[b] between 1994-95 and 1999-00**

Per cent and per cent per year



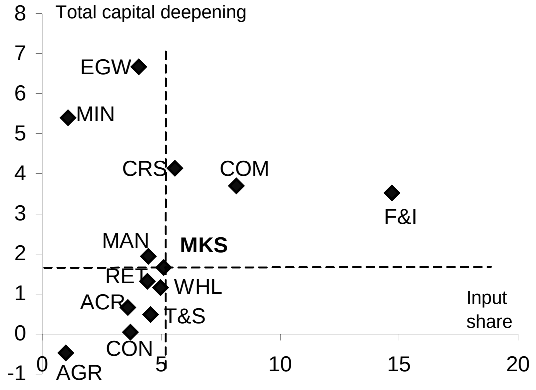

| | | | |
|---|---|---|---|
| ACR | Accommodation, cafes & restaurants | MAN | Manufacturing |
| AGR | Agriculture | MIN | Mining |
| COM | Communication services | MKS | Market sector |
| CON | Construction | RET | Retail trade |
| CRS | Cultural & recreational services | T&S | Transport & storage |
| EGW | Electricity, gas & water | WHL | Wholesale trade |
| F&I | Finance & insurance | | |

[a] Two estimates of IT use are input share and capital share. The input share is the income share of IT capital. The capital share is the share of productive capital stock to industry total productive capital stock. The average share is over the period 1995-96 to 1997-98. Changes in shares is the difference between the average share for 1990-91 and 1992-93 and the average share for 1995-96 and 1997-98. [b] The acceleration is the increase in the growth rate between the two periods 1989-90 and 1994-95 and 1994-95 and 1999-2000.

*Data source:* PC estimates based on ABS data.

## Figure B.10 **Average IT income share[a] and total industry capital deepening between 1994-95 and 1999-00**

Per cent and per cent per year




| | | | |
|---|---|---|---|
| ACR | Accommodation, cafes & restaurants | MAN | Manufacturing |
| AGR | Agriculture | MIN | Mining |
| COM | Communication services | MKS | Market sector |
| CON | Construction | RET | Retail trade |
| CRS | Cultural & recreational services | T&S | Transport & storage |
| EGW | Electricity, gas & water | WHL | Wholesale trade |
| F&I | Finance & insurance | | |

[a] The average share is over the period 1995-96 to 1997-98.

*Data source:* PC estimates based on ABS data.

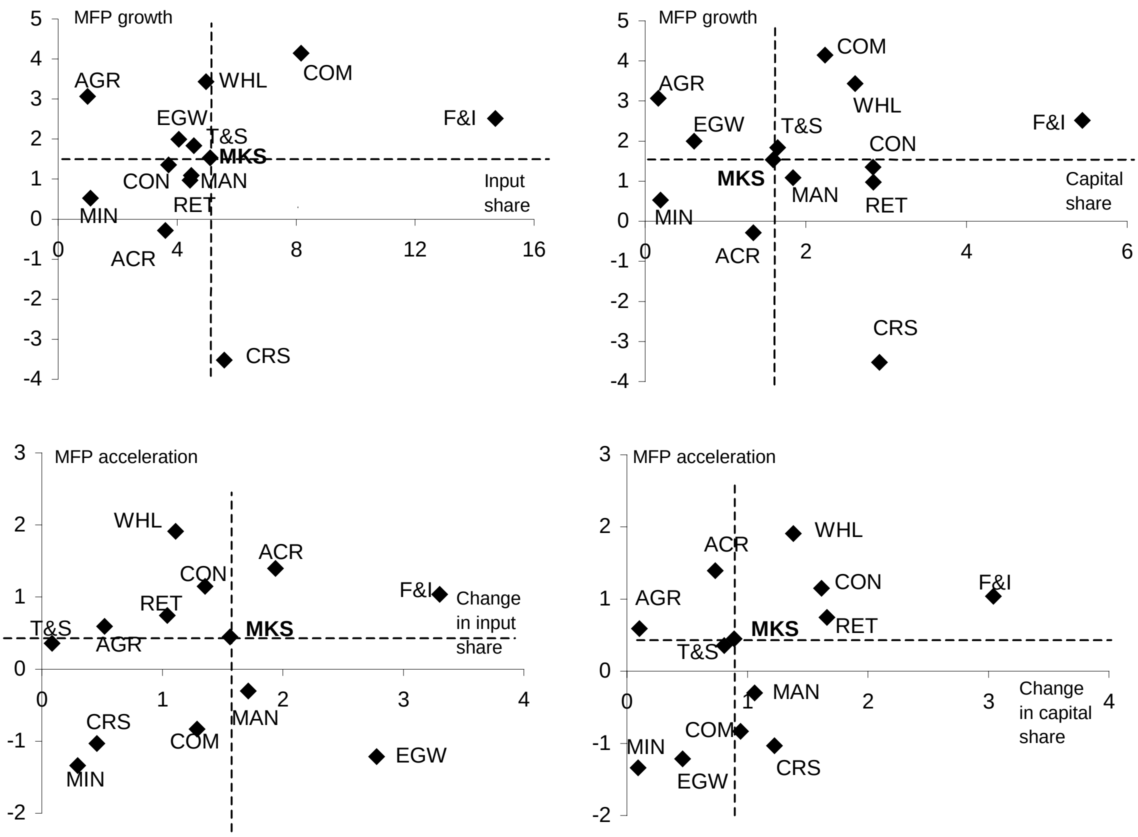
Figure B.9 displays scatter plots of IT use against labour productivity. The relationship between IT use and labour productivity would be positive if capital deepening occurred and/or there were gains in MFP. Overall capital deepening requires that an increase in IT capital does not substitute for other capital. Figure B.9 shows no clear relationship across industries.

Figure B.10 plots average IT income share against total capital deepening. The chart shows no clear relationship between IT income share and total capital deepening. Figure B.11 displays scatter plots of IT use against MFP growth by industry. The chart also shows no clear relationship between MFP and IT use.

The Finance & insurance, Wholesale trade and Communications are high users of IT or have increased their IT use over the second half of the 1990s. These industries have had better than average productivity responses, implying a link between IT use and productivity growth. However, for other sectors the relationship is not so clear. For instance, two sectors which are relatively big users of IT, Manufacturing and Retail trade, did not have better than average productivity growth, although Retail trade did show a better than average acceleration in productivity growth over the second half of the 1990s.

## Figure B.11 **IT use[a] and annual average growth in MFP[b] 1994-95 and 1999-00**

Per cent and per cent per year




| | | | |
|---|---|---|---|
| ACR | Accommodation, cafes & restaurants | MAN | Manufacturing |
| AGR | Agriculture | MIN | Mining |
| COM | Communication services | MKS | Market sector |
| CON | Construction | RET | Retail trade |
| CRS | Cultural & recreational services | T&S | Transport & storage |
| EGW | Electricity, gas & water | WHL | Wholesale trade |
| F&I | Finance & insurance | | |

**a** Two estimates of IT use are input share and capital share. The input share is the income share of IT capital. The capital share is the share of productive capital stock to industry total productive capital stock. The average share is over the period 1995-96 to 1997-98. Changes in shares is the difference between the average share for 1990-91 and 1992-93 and the average share for 1995-96 and 1997-98. **b** The acceleration is the increase in the growth rate between the two periods 1989-90 and 1994-95 and 1994-95 and 1999-2000.

*Data source:* PC estimates based on ABS data.

Table B.11 **Correlation coefficients between IT income shares, IT productive capital stock shares and labour productivity and MFP growth**

| | *Labour productivity* | *MFP* |
|---|---|---|
| Average IT income share [a] | 0.31 | 0.19 |
| Average IT productive capital stock share [a] | -0.05 | -0.02 |
| Change in average IT income share [b] | 0.05 | 0.15 |
| Change in average IT productive capital stock share [b] | 0.47 | 0.46 |

**a** Average IT share is for the period 1995-96 to 1997-98. Labour productivity and MFP growth is over the period 1994-95 to 1999-2000. **b** Change in average IT productive capital stock shares is the difference between the average share for 1990-91 and 1992-93 and the average for 1995-96 and 1997-98. For labour productivity and MFP it is the acceleration in the growth rates. The acceleration is the increase in the growth rate between the two periods 1989-90 and 1994-95 and 1994-95 and 1999-2000.

*Source:* PC estimates based on ABS data.

The charts show only a weak correlation between the use of IT and productivity growth. The correlation coefficients between the variables also suggest that there is only a weak link between IT use and productivity growth across all industries (table B.11).

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