Uptake and impacts of ICTs in the Australian economy:

Evidence from aggregate, sectoral and firm levels

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This paper presents part of the work in progress on a joint research project of the Productivity Commission, the Australian Bureau of Statistics, the Department of Industry, Tourism and Resources, and the National Office for the Information Economy. The joint project was set up to provide an Australian contribution to the set of country studies on ICT and Business Performance that is being facilitated and co-ordinated by the OECD.

The paper and the views expressed should be attributed to the authors and not to the participating agencies. On the other hand, it is stressed that the paper draws on the contributions of all members of the study team from the participating agencies and the guidance and scrutiny of Dr Trevor Breusch from the Australian National University.

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Key points

- The aggregate, sectoral and firm level evidence examined in this paper presents a picture of strong uptake of information and communication technologies (ICTs) in Australia in the 1990s which, in concert with restructuring of firms and production, has brought performance gains.
- The use of ICT equipment (hardware and software) has contributed to Australia's output and productivity performance through a modest increase in the rate of multifactor productivity (MFP) growth.
- The paper supports the general purpose technology view of ICTs — that is, that ICTs generate productivity gains by enabling restructuring, new products and new methods of production and operation.

ICT uptake

- Strong growth in ICT investment continued in Australia in the 1990s. Computer investment grew in real terms from around 3 per cent of total market sector investment in 1989-90 to around 19 per cent in 2000-01.
- Services industries featured very prominently in the uptake of computers, absorbing at least three-quarters of total market sector investment (about 10 percentage points more than their share of market sector output). The Finance & insurance sector stands out as the main area of uptake, with a 25 per cent share of investment. Manufacturing has also been a major user.
- Time-related developments — which could include the falling prices of equipment, lower adjustment costs and network effects — have had a significant influence on the uptake of ICTs and the Internet. Positive relationships with firm size and skill are also found. The earliest and most intensive users of ICTs and the Internet tended to be large firms with skilled managers and workers.
- The characterisation of the ICT uptake as a post-1995 phenomenon has been overstated. The uplift in ICT use began in some sectors before the 1990s. And there were also some cyclical and one-off factors in the 1990s trends. Nevertheless, there were some genuine post-1995 developments, including more rapid technological advances and price declines.

Performance effects

- In growth accounting terms, growth in ICT use accounted for a quarter of 1990s output growth of 3.4 per cent a year and, by raising the rate of ICT use per hour worked, accounted for a third of labour productivity growth of 3.0 per cent a year.
- However, increased ICT use has not affected the overall contribution of capital inputs to output and productivity growth. Rather, its increased use has been offset by slower growth in use of other forms of capital. This also means that the rate of substitution of capital for labour has remained unchanged.
- The net effect of ICTs on output and productivity performance depends on whether, and to what extent, they influence MFP growth. With little equipment production in Australia, there are no MFP gains of national significance from this source.
- Two approaches adopted in this paper suggest that the contribution from ICT use to Australia's aggregate MFP growth has been of importance, but not major — one or two

tenths of a percentage point of annual average growth. (Australia's underlying annual average MFP growth reached 1.8 per cent in the 1990s.)

- Sectoral evidence suggests that the performance effects have been concentrated in certain industries. The association between computer use and productivity growth is clearest in Finance & insurance. A somewhat weaker association appears in Wholesale trade.
- The firm-level analysis finds positive links between ICT use and productivity growth in all industry sectors examined. Significant interactions between ICT use and complementary organisational variables (eg skill and business restructuring) are also found in nearly all sectors. However, the strength of the links to ICTs, and the importance of complementary factors, varies across industries.
- The micro analysis has also highlighted dynamics and the importance of lags. Productivity growth effects taper over time, meaning that the ultimate productivity effect is a step up in levels, rather than a permanent increase in the rate of growth.
- Amongst other things, the paper points to the importance of management and employee skills in not only identifying the opportunities that ICTs present but also in transforming what businesses do and how they do it.

1 Introduction

Australia's productivity growth surged in the 1990s. Growth in both labour productivity and multifactor productivity more than doubled, compared with 1980s rates.

Whilst no single explanation for the productivity surge has emerged, the introduction of microeconomic policy reforms over the past 15 years or so has been identified as a major contributor (see, for example, PC 1999, OECD 2001a). Policy reforms have fostered productivity improvement through enhanced competitive incentives; greater openness to trade, investment and technology transfer; and increased flexibility for businesses to adjust their operations (Parham 2002a). More generally, they have encouraged and facilitated a process of economic restructuring that has invigorated Australia's catch-up toward the productivity levels of 'leader' economies (Parham 2002a).

Information and communications technologies (ICTs) are also considered to have played a role in Australia's surge, but through the use of ICT equipment, rather than the manufacture of ICTs (Parham 2002b). Australia is a small producer of ICT equipment — having the lowest ICT share in manufacturing value added among the countries covered in the OECD's *Science, Technology and Industry Scoreboard* (OECD 2001b). Consequently, MFP gains associated with the production of ICTs, found in other countries, have not been open to Australia. On the other hand, OECD comparisons show that Australia became a relatively high user of ICTs in the 1990s — reaching the third highest ICT share of business sector investment in 1999 on the OECD's *Scoreboard* (OECD 2001b). With low ICT trade barriers, Australian businesses have had the benefit of ready access to international advances in ICTs at competitive (and falling) prices.

In the absence of aggregate productivity gains through ICT manufacture, two other links between ICTs and Australia's productivity growth are possible: increased capital deepening (raising the ratio of capital to labour) as businesses step up investment in ICT; and MFP gains associated with ICT use. Whilst the capital deepening component is commonly recognised in the economics literature (see, for example, Jorgenson 2001), the existence and importance of an MFP component associated with use are more controversial.

There are two lines of argument about the possible effects of ICT use on MFP growth. The first looks upon ICTs as a general purpose technology that enables other productivity-enhancing changes. For example, ICTs could facilitate other actions such as the reorganisation of economic activity between firms and industries or they could provide an indispensable platform upon which further product or process innovations are based (Brynjolfsson and Hitt 2000). (The restructuring effects of ICTs in the Australian economy would then be reinforcing the catch-up restructuring in response to policy reforms.) The second line of argument looks to spillover effects, such as network economies, as sources of MFP gains. For example, an expansion in business via the Internet or 'closed' networks could reduce search and transactions costs for businesses.

This paper presents aspects of past and current research that explore the nature and importance of the links between ICTs and productivity gains in Australia. A broad indication of the importance of ICTs in Australia's improved economic performance can be obtained from output and productivity growth accounting at the aggregate and industry-sector levels. The next chapter provides an update of earlier work of this kind (Parham, Roberts and Sun 2001). However, such exercises provide a statistical accounting or decomposition and are suggestive, rather than

conclusive, on the nature and extent of the links between ICTs and output and productivity growth.

The view of ICTs as general-purpose, enabling technologies suggests that it is not just ICTs alone, but also other complementary factors (reorganisation of production and investments in associated innovations) that jointly determine the performance effects of ICTs. Since the incidence of complementary factors can vary across firms, even within the same industry, micro or firm-based analysis is needed to develop better understanding of the technological, organisational and policy influences — and their interaction — on restructuring and productivity growth.

Chapters 3 and 4 report econometric analysis of the use of ICTs at the firm level. Chapter 3 explores factors that have influenced the adoption of ICTs and chapter 4 explores the effects of ICTs on firm performance and the mechanisms through which these effects have been transmitted. A major objective of the analysis is to test the general-purpose/enabling technology view that ICTs are used jointly with other complementary factors to generate productivity gains.

Concluding remarks from the material presented in this paper are made in chapter 5.

The analysis in chapters 3 and 4 is work in progress from a research project being undertaken jointly by the Productivity Commission, the Australian Bureau of Statistics, the Department of Industry Tourism and Resources and the National Office for the Information Economy. The paper does not present final research outcomes or cover all aspects of the project. The firm-level analysis reported here is based on an existing firm-level dataset that has proved to be well suited to the project's needs. Another firm-level dataset that has been specially constructed for the project is also being analysed, but work on the second dataset is insufficiently advanced at the time of writing for it to be presented extensively in this paper. The project also covers a series of case studies, which have yet to be completed and documented.

2 Aggregate and sectoral evidence on uptake and performance effects

This chapter draws on national accounts data to illustrate the strong uptake of ICTs in the Australian economy during the 1990s and to assess the contribution of ICTs to Australia's economic performance. The material updates the estimates provided in Parham, Roberts and Sun (2001).

The chapter examines the contribution of information technology (IT), rather than ICT, to Australia's output and productivity growth. The Australian Bureau of Statistics (ABS) has adopted the major conventions of SNA93. However, unlike practice in a number of countries, current ABS practice is to treat communications equipment as electronic equipment, rather than to group it with computing equipment. The data used covers IT products (both hardware and software), but excludes IT services. This chapter is precise in referring to IT, but elsewhere in this paper the broader ICT term is mostly used.

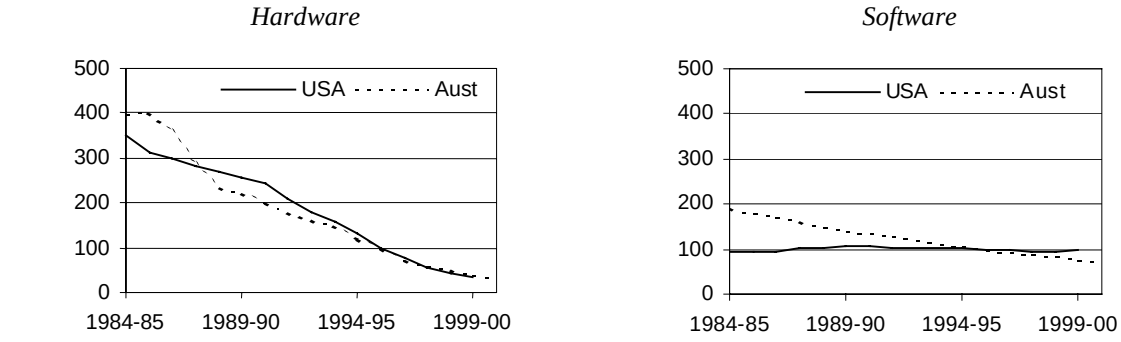
2.1 The uptake of IT

The ABS uses hedonic price deflators, which take account of improvements in the characteristics of products, to construct volume estimates of IT investment and usage.[1] The use of hedonic price deflators means that, to the extent that measurement is accurate, technological advances in hardware and software — including increases in processing speed, memory capacity and functions — are treated as embodied increases in the volume of IT purchased.

The price of IT products has fallen dramatically (figure 2.1).[2] Hardware prices fell 11 per cent annually over the 10 years to 1994-95 and by 19 per cent annually over the six years thereafter.

Figure 2.1 **Hedonic price deflators for IT, Australia and the USA, 1984-85 to 2000-01**

Index 1995-96 = 100



Data source: Unpublished ABS data and (US) Bureau of Labor Statistics.

1 There have been rapid advances in the quality of computers, but relatively little movement in their nominal prices. Therefore, if allowance is made for the substantial improvements in technical characteristics, the price of equipment has fallen rapidly. The ABS deflators for IT in Australia are based on the US price deflator for hardware (adjusted for exchange rate movements and a lag) and an assumed 6 per cent a year decline in software prices.

2 There has been a marked decline in prices since the 1960s (Parham, Roberts and Sun 2001).

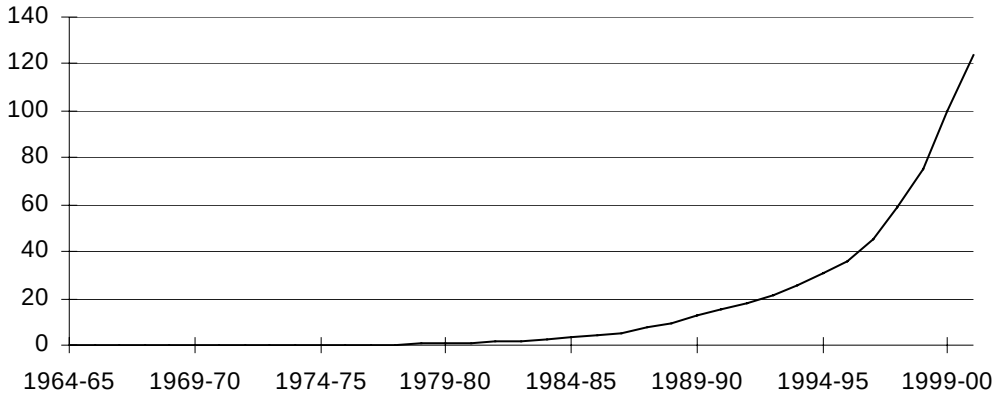
Falling IT prices have undoubtedly been a major reason for the rapid growth in investment in IT.[3] Real IT investment grew by 28 per cent a year in the second half of the 1990s (table 2.1) — sufficient to double the level of investment every three years. This was up on the rate in the first half of the 1990s, but not on the rate in the 1980s. However, IT investment became more prominent in total market sector[4] investment in the 1990s, growing from a 3 per cent share in 1989-90 to 19 per cent in 2000-01.[5]

Table 2.1 **Growth in investment in the market sector from the mid-1980s**
Per cent per year

	1984-85 to 1989-90	*1989-90 to 1994-95*	*1994-95 to 1999-00*
Information technology	35.1	17.3	28.0
- Hardware	31.3	24.0	36.1
- Software	36.5	14.8	23.4
Other capital	4.0	0.3	3.8
Total	**4.4**	**1.0**	**6.1**

Source: Productivity Commission estimates based on unpublished ABS data.

Figure 2.2 **IT capital services, 1964-65 to 2000-01**
Index (1999-2000 = 100)



Data source: ABS 5204.0.

[3] More correctly, the falling prices of IT *relative* to prices of other inputs (and output) is pertinent. For example, the rental price of IT also fell rapidly compared with the rental prices of other forms of capital (Parham, Roberts and Sun 2001).

[4] The market sector covers about 60 per cent of the measured economy and excludes industries (eg public administration, health, education, defence) for which output measures are inadequate for use in productivity analysis. A major difference between the market sector and the 'business sector' used in many other countries is the exclusion of business services from the Australian coverage. Business services are relatively intensive users of ICTs.

[5] The IT share in nominal investment grew from 8 per cent in 1989-90 to 18 per cent in 2000-01. The stronger increase in the IT share in real terms reflects the decline in relative prices of IT.

Naturally, the strong growth in IT investment led to strong growth in IT capital services input into production (figure 2.2).[6] IT capital services grew at 23 per cent a year through the 1990s. Growth was stronger in the second half of the 1990s (27 per cent a year) than in the first half (19 per cent a year). The share of IT in the total productive capital stock rose from 0.4 per cent in 1989-90 to 2.6 per cent in 1999-2000 (and to 3.1 per cent in 2000-01).

2.2 Contributions to aggregate output and productivity growth

This section assesses the contributions of IT and other factors to output and productivity growth in the market sector of the Australian economy. A standard growth accounting framework is used.

Contribution to output growth

Accounting for the contribution of IT capital inputs to output growth is straightforward in principle. As is well known, growth accounting attributes growth in output to: a contribution from growth in capital inputs; a contribution from growth in labour inputs;[7] and growth in multifactor productivity (the efficiency with which labour and capital inputs are combined to generate output). The capital contribution to output growth is decomposed into an 'IT' and an 'other-capital' contribution. The IT contribution is the share-weighted growth in IT capital services input, where the appropriate share is the proportion of total income payments attributed to IT.[8]

The IT contribution to output growth has increased substantially over the decades, but with short-term variations that suggest sensitivity to the business cycle (figure 2.3). The annual IT contribution has increased from around one-fifth of a percentage point in the late 1970s to around one and a quarter percentage points in the late 1990s. However, there were dips in the early 1980s and early 1990s in association with recessions. The IT contribution surged in the second half of the 1990s, consistent with the strong uplift in investment. Figure 2.3 also indicates that, in contrast with earlier periods, the hardware contribution grew faster than the software contribution from around 1994.

However, it appears that the strength of the post-1995 'boom' has been commonly overstated. First, the surge should be viewed partly in the light of the cyclical downturn in the first half of the 1990s. Second, the uncertainty about the Y2K bug may have spurred new IT investment late in the decade. A softening in IT capital deepening is evident in the 2000-01 rate. On the other hand, IT prices dropped more rapidly and Internet and other network opportunities and uses expanded after 1995.

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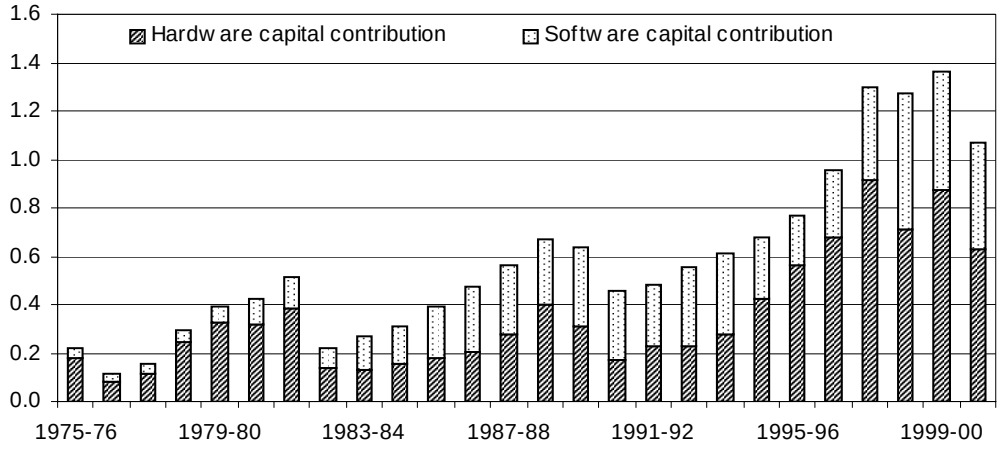
6 Conceptually, capital services are the flow of inputs into production from the productive capital stock, which is the volume of capital in operation, adjusted for efficiency loss over time.

7 The contribution of capital input is the product of the growth in capital input and the share of capital in total payments to factors of production. Similarly, the labour contribution is the share-weighted growth in labour input.

8 The share of IT in total income payments to factors increased from 2.1 per cent in 1989-90 to 4.5 per cent in 1999-2000.

Figure 2.3 **Contributions of IT capital to annual output growth, 1975-76 to 2000-01**

Percentage points

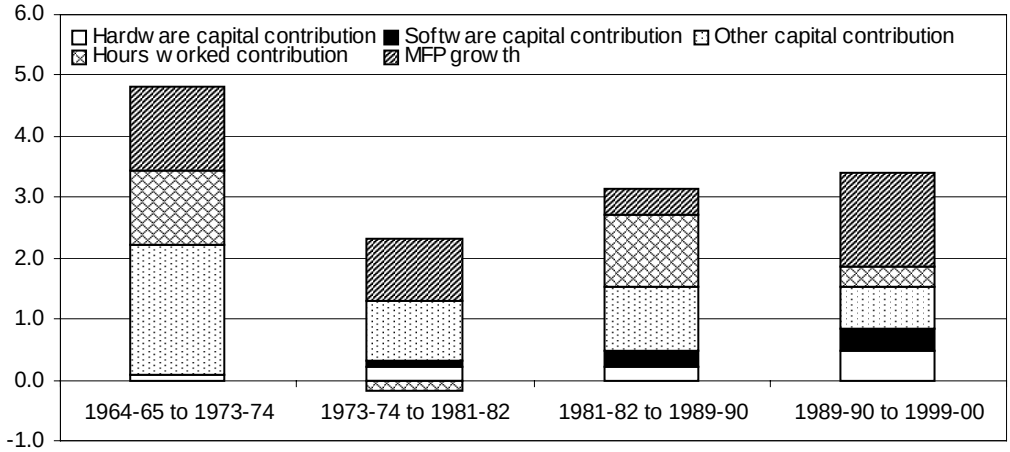


Source: Productivity Commission estimates based on unpublished ABS data.

IT became a major contributor to output growth in the 1990s. Figure 2.4 shows contributions to output growth over output cycles — from output peak to output peak. These periods control for cyclical effects which, as just seen, appear to exert important influence on IT use. The IT contribution increased from a relatively negligible level in the 1964-65 to 1973-74 period to become stronger than both the labour and the 'other capital' contributions in the 1990s cycle. IT accounted for a quarter of the output growth of 3.4 per cent a year between 1989-90 and 1999-2000[9] (table 2.2).

Figure 2.4 **Contributions to average annual output growth over output cycles, 1964-65 to 1999-00**

Percentage points



Source: Productivity Commission estimates based on unpublished ABS data.

However, slower growth in the use of other capital offset the contribution from increased use of IT. Table 2.2 shows that IT made a solid 0.3 of a percentage point contribution to the output

9 The year 1999-2000 was an output peak.

growth acceleration of 0.3 of a percentage point between the 1980s and the 1990s cycles. But the contribution of 'other capital' declined over the two cycles and its negative contribution to the output acceleration offset the entire IT contribution.[10]

Stronger MFP growth (a full percentage point higher) was the major contributor to the acceleration in output growth in the 1990s. The labour contribution was much weaker in the 1990s cycle, after the strong employment expansion in the 1980s.

Table 2.2 **Contributions to the acceleration in average annual output growth[a] in the 1990s**

Per cent per year, percentage points and (per cent)

	1981-82 to 1989-90		1989-90 to 1999-00		*Acceleration*
Output growth	3.1	(100)	3.4	(100)	0.3
Capital contribution[b]	1.5	(49)	1.5	(45)	0.0
- Information technology	0.5	(15)	0.8	(25)	0.4
… Hardware	0.2	(7)	0.5	(14)	0.3
… Software	0.2	(8)	0.3	(10)	0.1
- Other capital	1.1	(34)	0.7	(21)	-0.4
Hours worked contribution[b]	1.2	(38)	0.3	(10)	-0.8
MFP growth	0.4	(13)	1.5	(45)	1.1

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: Productivity Commission estimates based on unpublished ABS data.

It has been common in other studies to assess the contribution of IT and other factors to output growth in the first and second halves of the 1990s, without controlling for effects of the business cycle. Estimates based on this approach are presented in box 2.1 for the purposes of comparison with other studies. But they are not the preferred estimates.

Contribution to labour productivity growth

Growth in labour productivity can be decomposed into contributions from capital deepening — increases in the capital-labour ratio — and MFP growth. In principle, IT contributes to labour productivity growth through both capital deepening and MFP growth. The capital deepening part is assessed in the growth accounting framework by decomposing the total capital deepening contribution into an IT capital deepening component (the IT income share multiplied by the growth in the IT-labour ratio) and an other-capital deepening component. As discussed in chapter 1, the link between IT and MFP growth can come in principle through IT manufacture (although not in practice in Australia) or through use. However, there is no mechanism to explicitly link IT use and MFP growth in the growth accounting framework.[11]

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10 The relative contributions of IT and other capital depend on their relative rates of growth in capital services and income shares.

11 Studies of the USA (for example, Oliner and Sichel 2000) have been able to decompose the MFP contribution into separate contributions from the production of ICTs and other factors.

The pattern of year-on-year contributions from IT capital deepening (figure 2.5) closely follows that of the IT contribution to output growth (figure 2.3). The annual IT capital deepening contribution also increased from around one-fifth of a percentage point in the latter half of the 1970s to around one and a quarter percentage points in the latter half of the 1990s. There was also a pronounced uplift in the IT capital deepening contribution in the second half of the 1990s. However, the dampening effects of the early 1990s recession on IT capital deepening, whilst still evident, are not as pronounced as they were on the IT contribution to output growth. The recession would have brought cutbacks in labour as well as IT investment, muting any effect on the IT capital-labour ratio.

Box 2.1 IT contributions during the first and second halves of the 1990s

The results in this paper differ from those in other studies (eg Simon and Wardrop 2002), which have accounted for growth and its acceleration between the first and second halves of the 1990s. The periods used in this paper are preferred because they generate underlying rates of output and productivity growth that control for cyclical effects. However, since the comparison between the second half of the 1990s with earlier periods is so commonly used in other studies, it is included here for the sake of comparison. The tables below show the full extent of the IT contribution to output growth and the IT capital deepening contribution to labour productivity growth during their peak in the second half of the 1990s. However, not much emphasis should be placed on other estimates in the tables.

Contributions to the acceleration in output growth over the first and second halves of the 1990s

Per cent per year and percentage points

	1989-90 to 1994-95	*1994-95 to 1999-2000*	*Acceleration*
Output growth	2.0	4.8	2.7
Capital contribution	1.1	2.0	0.9
- Information technology	0.6	1.2	0.6
- Other capital	0.5	0.8	0.4
Hours worked contribution	-0.1	0.7	0.8
MFP growth	1.0	2.0	1.0

Contributions to the acceleration in productivity growth over the first and second halves of the 1990s

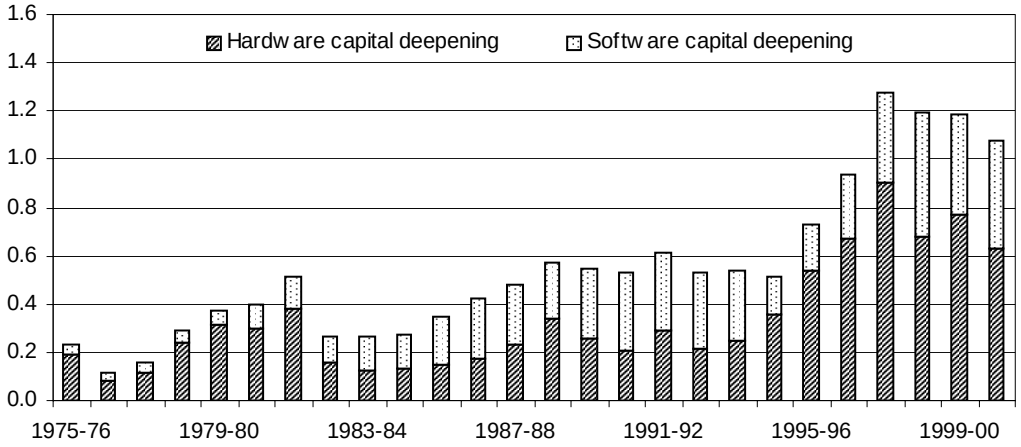
Per cent per year and percentage points

	1989-90 to 1994-95	*1994-95 to 1999-2000*	*Acceleration*
Labour productivity growth	2.2	3.5	1.3
Capital deepening	1.1	1.5	0.3
- Information technology	0.6	1.1	0.5
- Other	0.5	0.4	-0.1
MFP growth	1.0	2.0	1.0

Source: Productivity Commission estimates based on unpublished ABS data.

Figure 2.5 **Contributions of IT capital deepening to annual labour productivity growth, 1975-76 to 2000-01**

Percentage points

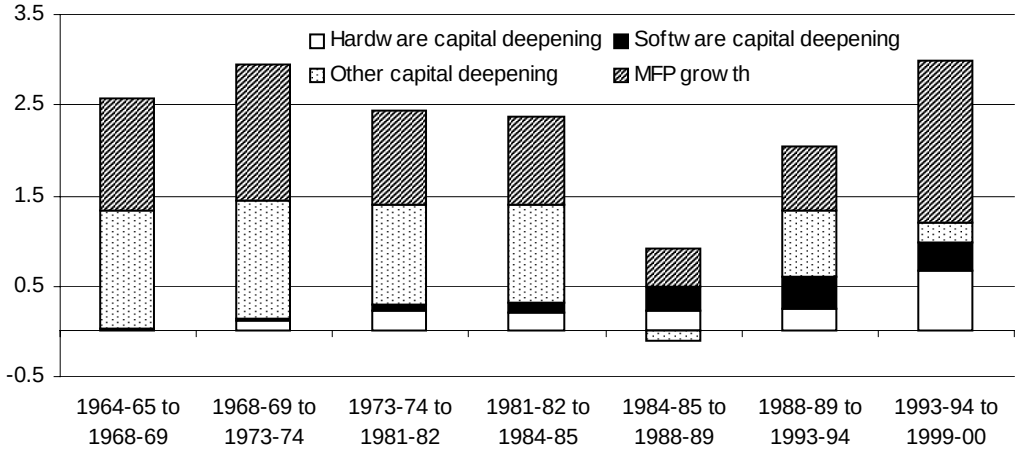


Source: Productivity Commission estimates based on unpublished ABS data.

IT's capital deepening contribution to labour productivity growth has increased steadily over time. Contributions to labour productivity growth over productivity cycles — from productivity peak to productivity peak — are illustrated in figure 2.6. The IT capital deepening contribution climbed to a very substantial proportion in the 1990s cycle (from 1993-94 to 1999-2000), when it accounted for a third of the very strong labour productivity growth of 3.0 per cent a year (table 2.3). IT capital deepening also made a strong contribution of 0.4 of a percentage point to the labour productivity acceleration of one percentage point between the last two productivity cycles (table 2.3).

Figure 2.6 **Contributions to average annual labour productivity growth over productivity cycles, 1964-65 to 1999-00**

Percentage points



Source: Productivity Commission estimates based on unpublished ABS data.

However, in an accounting sense, the larger IT capital deepening contribution has come at the expense of the other-capital deepening contribution. Again, controlling for cyclical effects, the faster growth in IT use has been offset by slower growth in use of other forms of capital. Figure 2.6 shows very little change in the overall rate of capital deepening — that is, no change in the rate of substitution of capital for labour — across productivity cycles (apart from the 1984-85 to 1988-89 cycle, during which there was strong employment growth). Table 2.3 confirms this offsetting effect over the last two cycles.

Table 2.3 **Contributions to the acceleration in average annual labour productivity growth[a] in the 1990s**

Per cent per year, percentage points and (per cent)

	1988-89 to 1993-94		*1993-94 to 1999-00*		*Acceleration*
Labour productivity growth	2.0	(100)	3.0	(100)	1.0
Capital deepening	1.3	(65)	1.2	(40)	-0.1
- Information technology	0.6	(30)	1.0	(33)	0.4
… Hardware	0.3	(12)	0.7	(23)	0.4
… Software	0.4	(17)	0.3	(10)	0.0
- Other capital	0.7	(35)	0.2	(7)	-0.5
MFP growth	0.7	(35)	1.8	(60)	1.1

a Numbers in brackets are percentage contributions to labour productivity growth. Factor income shares, used in calculating contributions are averaged over the periods indicated.

Source: Productivity Commission estimates based on unpublished ABS data.

MFP growth surged in the 1990s, to the extent that its acceleration fully accounted for the labour productivity acceleration (table 2.3). But, as noted earlier, there is no way of determining from the aggregate growth accounting whether, or to what extent, use of IT is associated with the acceleration in MFP growth. Comparison with the US experience suggests that one or two tenths of a percentage point of the MFP acceleration — up to a maximum of 0.3 of a percentage point — could be associated with IT use (box 2.2).

2.3 Uptake and performance effects at the sectoral level

Unpublished national accounts data on industry sectors show that the uptake of IT was not uniform across industry sectors. Moreover, the links between IT use and improved performance appear to be more prominent in certain industry sectors.

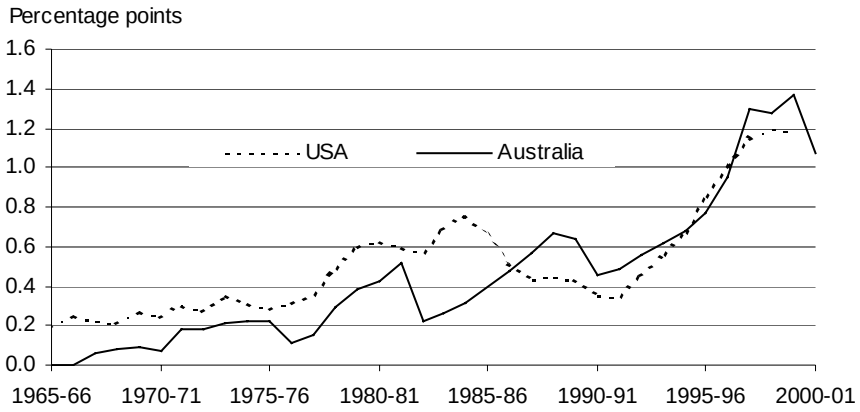
Growth in IT use

Services industries have dominated the uptake of IT since the mid-1980s, absorbing at least three-quarters of IT investment in the market sector (table 2.4). Mostly, this reflects the relative size of services industries, which account for about 65 per cent of market sector value added.

Box 2.2 The USA and Australia compared

There were strong similarities in the rate of uptake of IT in Australia and ICT in the USA. The figure below (which shows the I(C)T contribution — the share-weighted growth in I(C)T capital services — to annual output growth) suggests that the uptake was roughly the same in both countries, with a strong uplift in the second half of the 1990s.

Contributions of IT and ICT to annual output growth in Australia and the USA



Source: Productivity Commission estimates based on unpublished ABS data and (US) Bureau of Labor Statistics data

With a similar rate of uptake of ICT and its technological and productivity leadership, the USA can be used as a benchmark to assess the maximum productivity effects of ICT use in Australia. Controlling for cyclical effects in both countries, the maximum MFP acceleration that could be attributed to ICTs, as indicated by the US results in the table below, is 0.3 of a percentage point. (Other possible influences on the US productivity acceleration are assumed to be unimportant — see Parham 2002b). Some of this acceleration must be attributed to ICT production. Taking a number of factors into consideration, Parham (2002b) considered that 1 or 2 tenths of a percentage point, up to a maximum of 3 tenths of a percentage point, of productivity gains in the USA — and therefore Australia — can be associated with ICT use.

Contributions to labour productivity accelerations in the 1990s cycle in the USA and Australia

Per cent per year and percentage points

	USA[a]	*Australia*[b]
Labour productivity growth	**0.5**	**1.0**
Capital deepening	**0.2**	**-0.1**
- ICT capital	0.3	0.4
* Hardware	0.3	0.4
* Software	0.1	0.0
* Other	0.0	
- Other capital	-0.2	-0.5
MFP contribution	**0.3**	**1.1**

[a] Growth in 1992 to 2000 less growth in 1986 to 1992. [b] Growth in 1993-94 to 1999-00 less growth in 1988-89 to 1993-94.

Source: Productivity Commission estimates based on unpublished ABS data and (US) Bureau of Labor Statistics data.

The Finance & insurance sector has been the major sectoral destination for IT, absorbing at least a quarter of total IT investment — more than double its output share. By the end of the 1990s, 26 per cent of the total IT productive capital stock was in Finance & insurance.[12] The sector accounted for over two-fifths of the acceleration in IT capital services in the market sector between the last two productivity cycles (table 2.5).[13]

Manufacturing has also been prominent in the IT takeup. It has absorbed at least 15 per cent of market sector IT investment[14] (table 2.4) and contributed 1.2 percentage points of the 4.1 percentage point acceleration in market sector IT capital services in the 1990s (table 2.5).

Other industry sectors to feature in the IT uptake were Wholesale trade, Retail trade, Transport & storage and Communication services (all absorbing around 10 per cent of market sector investment). The above-mentioned six sectors together accounted for about 80 per cent of total IT investment.

Table 2.4 **Sectoral growth in real IT investment and proportion of market sector investment**

Per cent per year and per cent

	1984-85 to 1989-90		1989-90 to 1994-95		1994-95 to 1999-00	
	%pa	%	%pa	%	%pa	%
Agriculture	35	2	19	2	25	2
Mining	37	2	17	2	23	2
Manufacturing	37	15	18	16	28	17
Electricity, gas & water	13	4	28	4	28	4
Construction	35	5	19	6	22	5
Wholesale trade	36	11	17	11	25	10
Retail trade	37	9	21	10	25	10
Accom., cafes & restaurants	40	3	19	3	28	3
Transport & storage	36	10	16	10	23	8
Communication services	36	10	15	10	31	9
Finance & insurance	36	27	15	25	33	27
Cultural & rec. services	36	3	19	3	27	3
Market sector	35	100	17	100	28	100

Source: Productivity Commission estimates based on unpublished ABS data.

There was a strong acceleration in IT capital services in Electricity, gas & water in the 1990s. This contributed one fifth of the total market sector acceleration in IT use (table 2.5).

12 The sectoral percentages of total IT investment shown in the right-most column of table 2.4 happen to roughly approximate the sectoral percentages of total IT productive capital stock in 1999-2000.

13 Table 2.5 references growth rates to productivity cycles to facilitate later comparison to sectoral productivity growth (see chapter 5).

14 Manufacturing accounts for about 21 per cent of market sector value added.

Table 2.5 **Growth in IT capital services, by industry sector**

Per cent per year, percentage points and per cent

	1988-89 to 1993-94	1993-94 to 1999-00	Acceleration	Contributions to aggregate acceleration	
	%pa	%pa	pp	pp	%
Agriculture	20.4	27.4	7.0	0.1	2
Mining	20.6	25.0	4.4	0.1	2
Manufacturing	22.7	29.0	6.3	1.2	28
Electricity, gas & water	12.4	28.8	16.4	0.8	20
Construction	21.2	23.1	2.0	0.1	3
Wholesale trade	21.8	22.2	0.4	0.0	1
Retail trade	24.0	26.2	2.2	0.2	5
Accom., cafes & restaurants	24.2	28.6	4.5	0.1	3
Transport & storage	22.7	19.5	-3.2	-0.3	-8
Communications	22.9	22.5	-0.4	0.0	-1
Finance & insurance	20.5	26.8	6.4	1.7	43
Cultural & rec. services	23.6	26.2	2.6	0.1	2
Market sector	21.5	25.6	4.1	4.1	100

Source: Productivity Commission estimates based on unpublished ABS data.

Contributions to output growth

The relative importance of IT in each industry and the pattern of growth in IT use in each industry is illustrated in figure 2.7 by the contribution of IT to year-on-year sectoral output growth. The magnitude of the contributions reflects not only the growth in IT capital services but also the importance of IT in total production costs. In each panel, the sectoral IT contribution is compared with the market sector average.

Not surprisingly, given its dominance in uptake, the Finance & insurance sector stands out in terms of the contribution of IT to its output growth. It shows a much stronger contribution than other sectors, going back to the mid-1970s, as well as a much stronger uplift in the IT contribution in the 1990s.

The IT uptake has not just been a post-1995 phenomenon, at least in some sectors. Most industries show an increase in the IT contribution in the 1990s. However, it is also apparent that the IT contribution increased from the second half of the 1980s in Finance & insurance, Communication services and Cultural & recreational services.[15] (Larger firms are generally found in a review of ICT uptake in the next chapter to have been early adopters.)

15 Triplett and Bosworth (2002) found strong impacts of ICTs in US services industries and that the impacts were as strong pre-1995 as they were post-1995.

Figure 2.7 **Contribution of IT capital to annual output growth in industry sectors, 1984-85 to 2000-01**

Percentage points

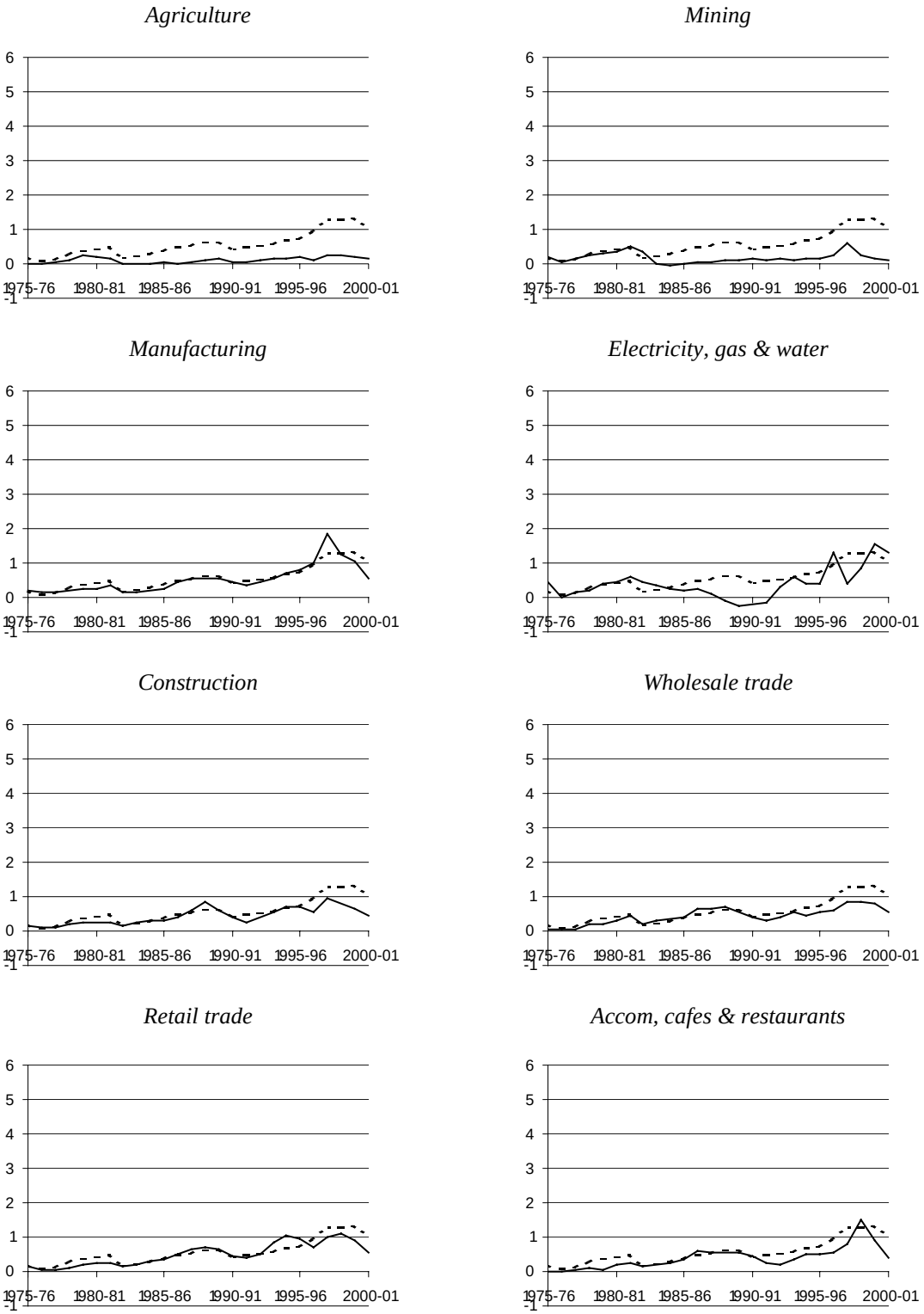


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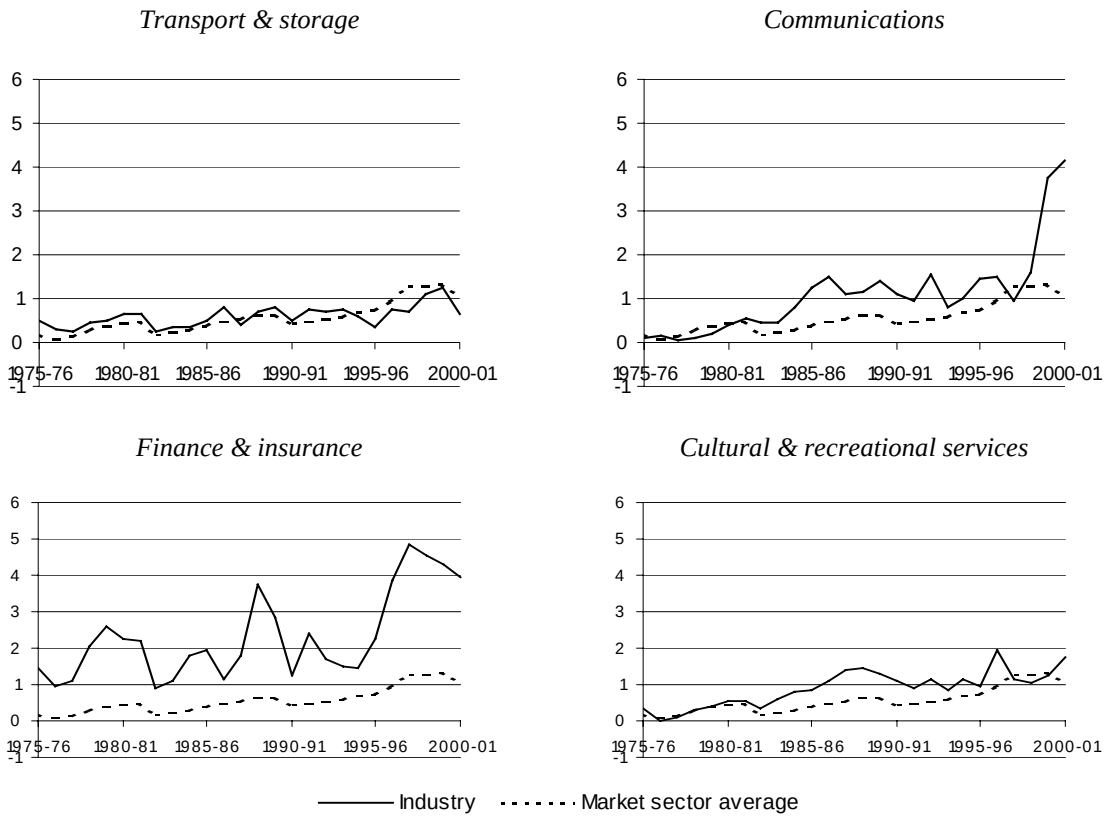
Figure 2.7 **(continued)**



Source: Productivity Commission estimates based on unpublished ABS data.

Contributions to productivity growth

Three forms of evidence are examined for signs of a link between IT use and MFP at the sectoral level:

- Growth in sectoral IT use and MFP in the 1990s;
  - Table 2.6 accounts for contributions to sectoral labour productivity growth. Growth in IT use is indicated by the contribution from IT capital deepening.[16] The time period used is the last aggregate productivity cycle and so no allowance is made for any industry-specific cyclical effects.
- Acceleration in sectoral IT use and MFP in the 1990s:
  - Table 2.7 accounts for the IT capital deepening and MFP contributions to the accelerations in sectoral labour productivity growth between the last two aggregate productivity cycles. It further shows the contribution of each sector to accelerations in market sector IT capital deepening and MFP.
  - Figure 2.8 plots observations of changes in IT use (increases in the IT share in each sector's productive capital stock) and acceleration in *trend* MFP (ie, with cyclical effects removed) between the last two aggregate productivity cycles.

[16] Growth in IT use is most accurately indicated by growth in IT capital services (see table 2.5).

Table 2.6 **Contributions to sectoral labour productivity growth, 1993-94 to 1999-2000**

Per cent per year and percentage points

	Labour productivity growth	*Capital deepening*	*IT capital deepening*	*Other capital deepening*	*MFP growth*
	%pa	pp	pp	pp	pp
Agriculture	2.7	-0.7	0.2	-0.9	3.4
Mining	7.3	5.1	0.3	4.8	2.2
Manufacturing	2.8	1.9	1.2	0.8	0.9
Electricity, gas & water	6.7	5.1	1.1	4.0	1.6
Construction	1.0	-0.2	0.6	-0.8	1.1
Wholesale trade	6.0	0.8	0.7	0.1	5.2
Retail trade	1.9	0.9	0.8	0.0	1.1
Accom., cafes & restaurants	1.2	0.9	0.7	0.2	0.3
Transport & storage	2.4	0.6	0.7	0.0	1.8
Communication services	6.0	1.9	1.3	0.6	4.0
Finance & insurance	3.9	2.9	3.3	-0.4	1.2
Cultural & rec. services	-0.5	3.6	1.1	2.5	-3.7
Market sector	**3.0**	**1.2**	**1.0**	**0.2**	**1.8**

Source: Productivity Commission estimates based on unpublished ABS data.

Table 2.7 **IT capital deepening and MFP contributions over the past two productivity cycles**

Percentage points

	Contributions to sectoral labour productivity acceleration		*Contributions to acceleration in aggregate*[a]	
	IT capital deepening	*MFP growth*	*IT capital deepening*	*MFP growth*
Agriculture	0.1	-0.8	0.0	-0.1
Mining	0.2	-0.1	0.0	-0.0
Manufacturing	0.5	-1.1	0.2	-0.4
Electricity, gas & water	1.0	-2.3	0.1	-0.2
Construction	0.1	1.6	0.0	0.3
Wholesale trade	0.2	7.3	0.0	1.2
Retail trade	0.2	0.4	0.0	0.1
Accom., cafes & restaurants	0.4	2.2	0.0	0.2
Transport & storage	-0.1	0.9	0.0	0.1
Communication services	0.0	-2.2	0.0	-0.2
Finance & insurance	1.1	1.1	0.2	0.2
Cultural & rec. services	0.1	-1.3	0.0	-0.1
Market sector	**0.4**	**1.1**	**0.4**	**1.1**

[a] The entries in the first two columns are multiplied by the sectoral share in market sector value added.

Source: Productivity Commission estimates based on unpublished ABS data.

This evidence suggests the following:

- There is wide variation in IT use and productivity performance across industries. And there is no clear systematic relationship between IT use and productivity growth across industries.
- Finance & insurance features prominently in terms of both IT use and productivity growth in the evidence examined. The associations between IT use and productivity growth within the sector are strong; and the sector made relatively strong contributions to aggregate IT capital deepening and productivity growth.
- Wholesale trade also shows evidence of increased IT use (albeit weaker than in Finance & insurance) and very strong productivity acceleration.
- There is mixed evidence of positive associations between IT use and productivity growth in Retail trade, Accommodation, cafes & restaurants and Communication services.
- Manufacturing is relatively important in terms of IT use, but has shown less productivity response — indeed, a sizeable reduction in MFP growth in the 1990s. The pattern in Electricity, gas & water is similar.

The lack of a strong correlation between IT use and productivity growth across all industries reflects a number of factors. First, IT use is not the only influence on productivity growth. For example, policy reforms could have had greater effects in some industries, quite independent of IT usage.[17] Second, the relationship between IT use and productivity growth is most likely to be more complex than examined here. The scope for ICT-related productivity gains could differ across industries. There could be lags between the uptake of IT and productivity response, whereas only contemporaneous correlations have been examined to this point. And some productivity responses may require factors complementary to IT (restructuring and product and process innovation). Variations in the scope for and application of complementary factors could lead to variations in the strength of association observed between IT and productivity across industries. This could be why Manufacturing has not shown a strong productivity response, despite its uptake of IT. (Complementary factors are examined in chapter 4.)

It also needs to be said that correlation between IT and productivity growth does not necessarily imply causation — that is, that an uptake of IT has led to a productivity boost. However, some evidence of a link between IT use and productivity comes from the fact that similar industries have emerged at least in the USA and Australia as being both relatively intensive IT users and displaying relatively strong productivity improvement. These industries include financial intermediation, distribution (wholesale and retail trade) and business services (Nordhaus 2001, CEA 2001 and Pilat and Lee 2001).

The strong productivity gains in Australia's Wholesale trade are consistent with transformation of some activities from storage-based configurations to 'fast flow-through' systems (Johnston et al 2000). ICTs have played a part in this transformation through the increased use of bar-coding and scanning technology, communications and tracking systems and inventory management systems. Less storage and handling has reduced input requirements.

Finance & insurance has also undergone substantial restructuring, with much greater use of electronic transactions and a reduction in face-to-face transactions. New financial and risk-management products, made possible by improved information storage and processing, have been developed and offered. Output has grown with fewer unit requirements for physical offices and staff (Weir 2002, Oster and Antioch 1995).

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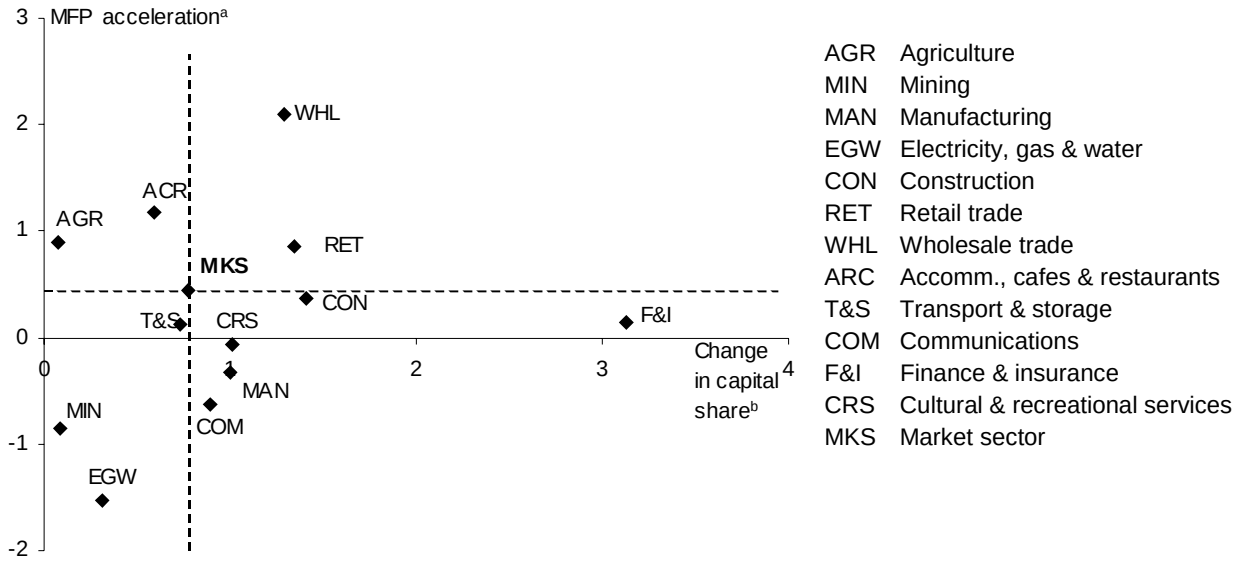
[17] For example, the deceleration in productivity growth in Electricity, gas &water is likely to reflect the influence of policy reforms promoting very strong productivity growth in the 1980s and early 1990s.

Figure 2.8 **Change in sectoral IT use and MFP acceleration in the 1990s**

Per cent and per cent per year



a Change in trend MFP growth between the last two aggregate productivity cycles. **b** Change in the IT share in productive capital stock between the mid-points of the last two aggregate productivity cycles.

Source: Productivity Commission estimates based on unpublished ABS data.

2.4 Main findings

ICT uptake

- IT investment has been growing strongly for decades, but initially from a small base. IT grew in prominence in total investment from the mid-1980s. Real IT investment grew from around 3 per cent of total market sector investment in 1989-90 to around 19 per cent in 2000-01.
- The extent of a post-1995 'boom' may have been overstated somewhat. IT use appears sensitive to the business cycle. Some of the prominence of IT in the second half of the 1990s appears to be due to weaker growth in IT investment and use in the first half of the 1990s, in response to the early-1990s recession. Some of the strong investment late in the decade may also have been associated with uncertainty concerning the Y2K bug. On the other hand, IT prices fell more rapidly and uses for IT (eg Internet) expanded after 1995.
- Services have accounted for at least three quarters of market sector demand for IT, mostly in keeping with their relative size. Finance & insurance has been the major sectoral destination, absorbing at least a quarter of total IT investment in the market sector — more than double its output share. Manufacturing was also a major destination.
- With the strong growth in IT investment, there was strong growth in IT capital services input in the 1990s. However, a strong IT presence had been established by the late 1980s in some industries — Finance & insurance, Communication services and Cultural & recreational services.

Performance effects

- The aggregate and sectoral evidence suggests that the uptake and use of ICTs have contributed to Australia's strong economic performance in the 1990s, including through improved productivity growth.
- IT's contribution to output growth increased from one-fifth of a percentage point in the 1970s to around one and a quarter percentage points in the late 1990s. IT accounted for around a quarter of 1990s output growth of 3.4 per cent a year and made a prominent positive contribution of 0.4 percentage points to the output acceleration of 0.3 of a percentage point (controlling for cyclical effects).
- The IT capital deepening contribution to labour productivity growth showed a similar pattern — climbing from one fifth to just under one and a quarter percentage points. IT capital deepening accounted for around a third of labour productivity growth of 3.0 per cent a year in the 1990s productivity cycle. It was also prominent (0.4 of a percentage point) in the 1990s productivity acceleration of 1.0 percentage point.
- However, the contribution from increase in IT use — even in the 1990s — has been offset by a weaker contribution from use of other capital. Increased IT use has not added to the overall contribution of capital to output growth or to the overall contribution of capital deepening to labour productivity growth.
- Faster MFP growth has provided the major contribution (1.1 percentage points) to the acceleration in output and productivity growth in the 1990s. Comparison with the US experience suggests that one or two tenths of a percentage point — up to 0.3 of a percentage point — of the MFP acceleration could be associated with ICT use.
- There is wide sectoral variation in IT use and performance effects, and no strong correlation across industries. The lack of universal correlation is consistent with there being major influence from other factors unrelated to ICT use, differences in scope for ICT-related productivity gains and differences in factors complementary to ICT use. In addition, there could be lags between ICT uptake and performance effects that have not been examined to this point.
- The Australian sectoral evidence matches the limited evidence from other countries that the ICT uptake and performance effects are concentrated — at least, to date — in financial intermediation and distribution (and also likely in business services, although this sector has not been investigated in this chapter).

3 Firm level evidence: uptake of ICTs

This and the next chapter report on the current joint project work examining firm-level data.

This chapter first outlines the data sources being used. It then describes broad trends in the use of ICTs and investigates factors affecting the uptake of ICTs.[18] The analysis of the take up of ICTs in this chapter should be viewed as preliminary. The principal focus of the project to date has been on analysis of the performance effects of computer use as reported in the next chapter.

3.1 Data sources

The main data base available for empirical analysis is the (Australian) Business Longitudinal Survey (BLS) collected for the years 1994-95 to 1997-98. The BLS provides information about firm performance, innovation, business practices, restructuring and reorganisation for each survey year. Whilst not primarily designed for this purpose, the BLS also provides information on business use of computers and the duration of computer use obtained in the 1996-97 collection and, in less detail, in the 1997-98 collection (box 3.1). The 1996-97 information was sufficiently detailed to impute key computer use indicators for matched firms for the earlier survey years 1994-95 and 1995-96, and for 1997-98. The information about firm performance, computer use and other factors provided a basis for the analysis of the characteristics of firms using ICT and the implications of ICT use for productivity over the four year period 1994-95 to 1997-98.

Overall, this data source and investigation period is particularly suited to the current study since:

- the survey covered a substantial number of firms that used ICT as well as firms that did not report the use of ICT;
- there was a continuation of ICT capital deepening at the national level (chapter 2);
- it corresponded to a period of acceleration in national productivity growth (chapter 2);
- it covers a range of industry sectors which, as demonstrated in chapter 2 have shown significant variation in the uptake of ICTs and productivity growth; and
- it provides information enabling the investigation of the influence of lags and firm characteristics, including some that are considered complementary to ICT.

Another data source is the (Australian) Business Use of Information Technology Survey (BUIT). This survey was first conducted in 1993-94 with 2000-01 being the latest year for which data are available. While this survey does not collect information on business performance or innovational and organisational characteristics of firms, it spans a longer period and thus

[18] This chapter and chapter 4 refer to the broad concept of ICT. In this context, reference is made to computer use, Internet access and Web presence by firms. The growth accounting analysis presented in chapter 2 refers to IT. In that context, reference is made to investments in computers and software as defined in the Australian national accounts. Communications technologies, such as the Internet and the world-wide web and their application, are not within the scope of the IT series.

supports analysis of national trends in the uptake of ICTs to complement data available from the BLS. It also provides topical details on computer use.[19]

Industry sectoring in the BLS and the BUIT is based on the Australian and New Zealand Standard Industry Classification (ANZSIC). A concordance to sectoring and the industry classifications adopted in the BLS and the BIUT is provided in appendix A together with a link to the 'market sector' industry divisions analysed in chapter 2.

Price and quality adjusted information (particularly relevant to the analyses presented in chapter 4) is not available in unit record level data sets.[20] Accordingly, we use current value measures of output and book value measures of capital. In principle, this shorthand approach could result in measurement error in estimates of output, capital and labour inputs and, under certain conditions, may lead to biased results in productivity analyses based on BLS unit record data. Main concerns include:

- the prospect of offsetting pure price and quantity changes leading to the appearance of no change in activity levels where in fact there were changes;
- the decline in ICT (and other capital-good) prices giving the appearance of a decline in capital inputs when in fact there has been an increase; and
- changes in the composition of employment at the firm level leading to a change in 'real' labour inputs when unadjusted employment estimates suggest that there has been no change (a problem shared with a wide range of micro and macro analyses).

Baily, Hulten and Campbell (1992) find that estimates of productivity dispersion and evolution amongst firms were not sensitive to the choice of crude book value and theoretical measures of capital inputs. Also, in periods of low product-price inflation as occurred during the 1990s, the predominant reason for relative price increases (or slower declines, in the case of ICT hardware) amongst firms may well be due to quality improvement and as such would be properly reflected in volumetric measures of inputs and outputs (Brynjolfsson and Hitt 2000 and Hempell 2002).

While, in principle, unit record data sets have limitations for productivity analyses, practical considerations suggest that they should be useful for productivity analyses.

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[19] To complement the analysis based on the BLS, the ABS is linking at a unit record level, business use of ICT information from the BUIT with business performance data from the ABS Economic Activity Survey (EAS) or where necessary a Business Income Tax data set provided to the ABS by the Australian Taxation Office (ATO). The reference year for the linked data set is 1999-00. As mentioned in chapter 1, the intention is to present analyses from this new data set in later reports from this project.

[20] For productivity measurement, outputs and inputs should be measured in volumetric terms. For traditional productivity analyses at the national and sectoral level, such volumetric measures are typically estimated by the application of 'quality adjusted' price indexes to observed current-value estimates of outputs and inputs, that is: $Y_t = \frac{P_{Y,t-1}}{P_{Y,t}} Y_t^{\$}$ and $K_t = \frac{P_{K,t-1}}{P_{K,t}} K_t^{\$}$ for output and capital inputs, respectively (see also chapter 2). Labour inputs are also required in volumetric units. For national and sectoral analyses in Australia, hours worked is preferred to persons employed as a measure of labour inputs.

Box 3.1 Background of Australian Business Longitudinal Survey as it relates to the analysis of ICT, productivity and growth at the firm level

The BLS was conducted by the ABS to establish a data set for the analysis of the growth and performance of small to medium-size enterprises in Australia. A primary aim of the BLS was to gather detailed firm-level information on growing businesses with an innovation and export focus. The BLS was conducted over the financial years 1994-95 to 1997-98. In the 1994-95 phase of the survey, around 9000 live responses were collected. In later phases and after further stratification of firms, between 5000 and 6000 live responses were collected. A panel of over 4000 firms operated for all four years of the survey.

Although not part of the original design, questions on ICT use were introduced in the 1996-97 phase of the survey in recognition of the growing importance of ICT use to firm operation and performance.

The BLS:

- survey period — 1994-95 to 1997-98 — coincides with a period of substantial take-up of ICT and productivity growth in the Australian economy;
- provides information obtained in the 1996-97 collection on the duration of computer usage (in terms of years of use), business use of computers in selected functions (eg electronic stock monitoring, purchasing and selling) and the intensity of use (in terms of the number of employees using computers per week). It also provides information on Internet use for the reference years 1996-97 and 1997-98;
- provides a comprehensive range of information across all survey years on firm performance, involvement in exporting, product innovation, business practices, business restructuring and reorganisation and training;
- provides information on employment in firms, industrial relations and manager qualifications;
- provides information on total business capital (although separate details on the components of capital (including ICT software and hardware) were not collected);
- provides information on firm entry and exit; and
- covers firms in 11 industry sectors. In addition, the manufacturing industry sector is disaggregated into 9 industry subdivisions. Analysis using BLS data in this study has focused on 8 of the 11 industry sectors (appendix A).

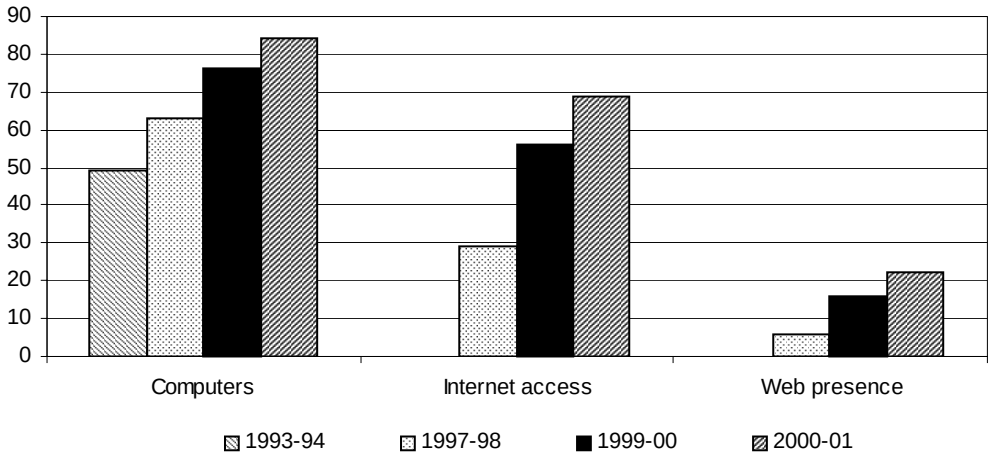
Details of information provided in the BLS are published in ABS, *Business Longitudinal Survey: Confidentialised Unit Record File 1994-95 to 1997-98* (Cat. no. 8141.0.30.001), ABS, Canberra released in June 2000. A detailed description of features of the BLS is provided in Will and Wilson (2001).

3.2 Take up of ICTs

Time series data from the BUIT survey indicate rapid diffusion of the use of ICT technologies among businesses during the 1990s. The uptake of ICTs covered the majority of businesses by the financial year 2000-01 when over 80 per cent of Australian businesses used computers, up from about one half only seven years before (figure 3.1). Whilst computer use to date has been more widespread than Internet access and a Web presence, take-up of these computer-based communications technologies has been rapid and is catching up with computer use.

Figure 3.1 **Australian businesses using ICT[a,b,c]**

Per cent



a All employing businesses in Australia except businesses in Agriculture, forestry & fishing and general government and like activities. **b** Information technology refers to services and technologies which enable information to be accessed, stored, processed, transformed, manipulated and disseminated. **c** Data on Internet access and Web presence were not collected in 1993-94.

Source: ABS (Business Use of Information Technology, Australia, 2000-01, Cat. no. 8129.0).

More than two thirds of firms in all BUIT industry sectors were using computers by 2000-01 (figure 3.2). For a number of sectors, there was a substantial increase in computer use over the four-year period 1993-94 to 1997-98 and further increases to 2000-01. For example, around 30 per cent of firms in Retail trade reported using computers in 1993-94. By 1997-98 this proportion had risen to over 50 per cent of firms and by 2000-01 it had risen again to nearly 80 per cent of retail businesses. For other industries, the majority of firms reported using computers by 1993-94. For example, over 70 per cent of firms in the Property & business services and Finance & insurance sectors reported using computers by 1993-94 with this proportion rising to 90 per cent or more by 2000-01.

Firms reporting that they had Internet access increased dramatically for all sectors over the last few years so that by 2000-01 the majority of businesses in each sector reported having access to the Internet. Between 20 and 30 per cent of firms in most sectors also reported having a Web presence by 2000-01. For most sectors, BUIT data suggest that the incidence of firms with a Web presence is on the increase, particularly if take up follows trends established for the spread of computer use and Internet access. However, BUIT data also suggest that this is not the case for all sectors. For example, in Mining the proportion of firms with a Web presence remained around the same level between 1999-00 and 2000-01 while for the Electricity, gas & water supply sectors the proportion of firms with a Web presence was estimated to have declined.

In summary, use of computers is now widespread in all industries. At this stage, Internet access and the establishment of a Web presence is not as widespread and more variation across industries is evident.

Figure 3.2 **Australian businesses using ICT by industry[a,b,c]**

Per cent

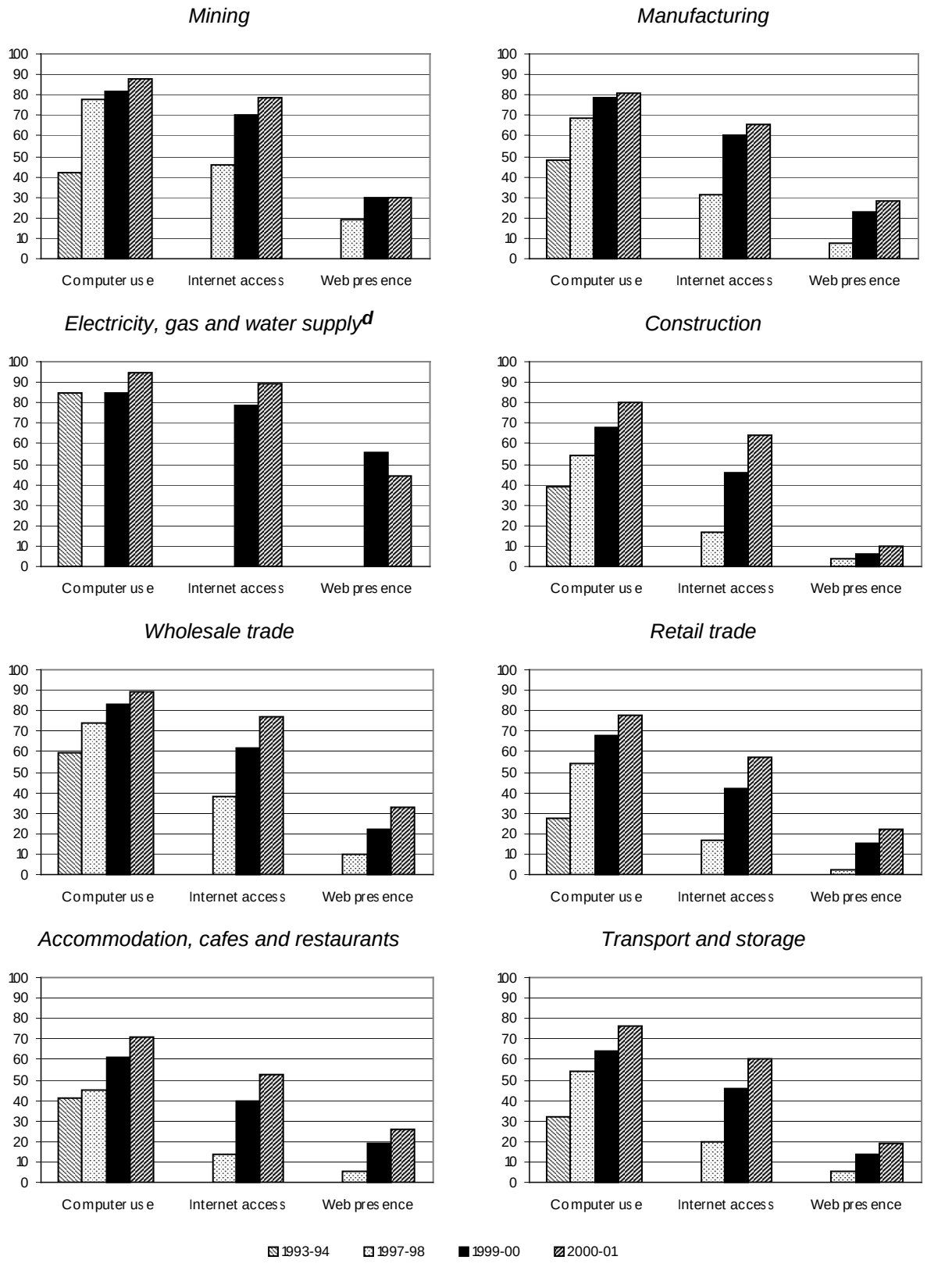


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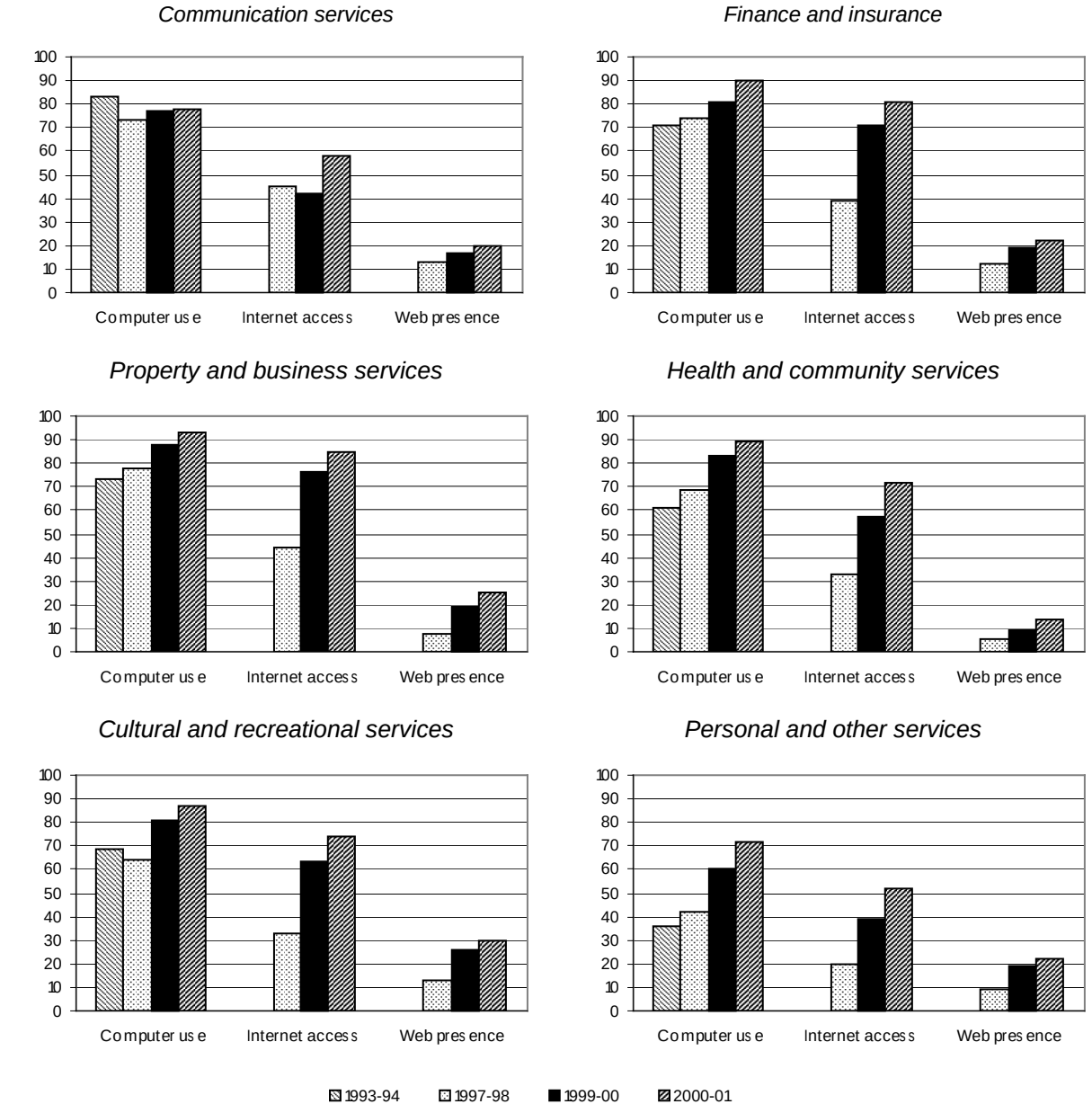
Figure 3.2 **(continued)**



a,b,c For footnotes, see table 3.1. **d** Data not published for 1997-98.

Source: ABS (Business Use of Information Technology, Australia, 2000-01, Cat. no. 8129.0).

3.3 General characteristics of firms using ICTs

Cross sectional information from the 1996-97 BLS collection is used in this section to outline key characteristics of firms using ICTs in 10 industry sectors (appendix A). The year 1996-97, when around 60 per cent of firms used computers, lies in the middle of the take-up period considered above.

Studies from a number of countries suggest that the take up of advanced technologies such as ICTs increases with firm size. While there is an issue concerning the direction of causality, that is, whether large firms have more to gain from advanced technologies or whether adoption of advanced technologies enable firms to grow in size, Australian data appear to confirm the broad

relation that advanced technologies in the form of ICT are more prevalent and were adopted earlier amongst large firms (figures 3.3 and 3.4).

BLS data suggest that by 1996-97 nearly all medium to large firms (ie firms employing 50 persons or more) used computers (figure 3.3). However, the use of computers by 'smaller' firms in terms of employment (ie with employment of up to 50 persons) varied substantially across sectors. For example, over 70 per cent of small firms in the Wholesale trade, Finance & insurance, Property & business services and Cultural & recreational services were computer users by this time. On the other hand, only around 40 per cent of small firms in the Retail, Accommodation etc and Transport & storage sectors were computer users.

There was substantial variation across firms of different sizes in terms of Internet access and a Web presence. While the average rate of connection was around one third for Internet access and less than 10 per cent for a Web presence in the mid-1990s, BLS data suggest that more than half of the larger firms had Internet access with a somewhat lower proportion with a Web presence. There was a marked tailing off in the take up of these facilities with decline in firm size.

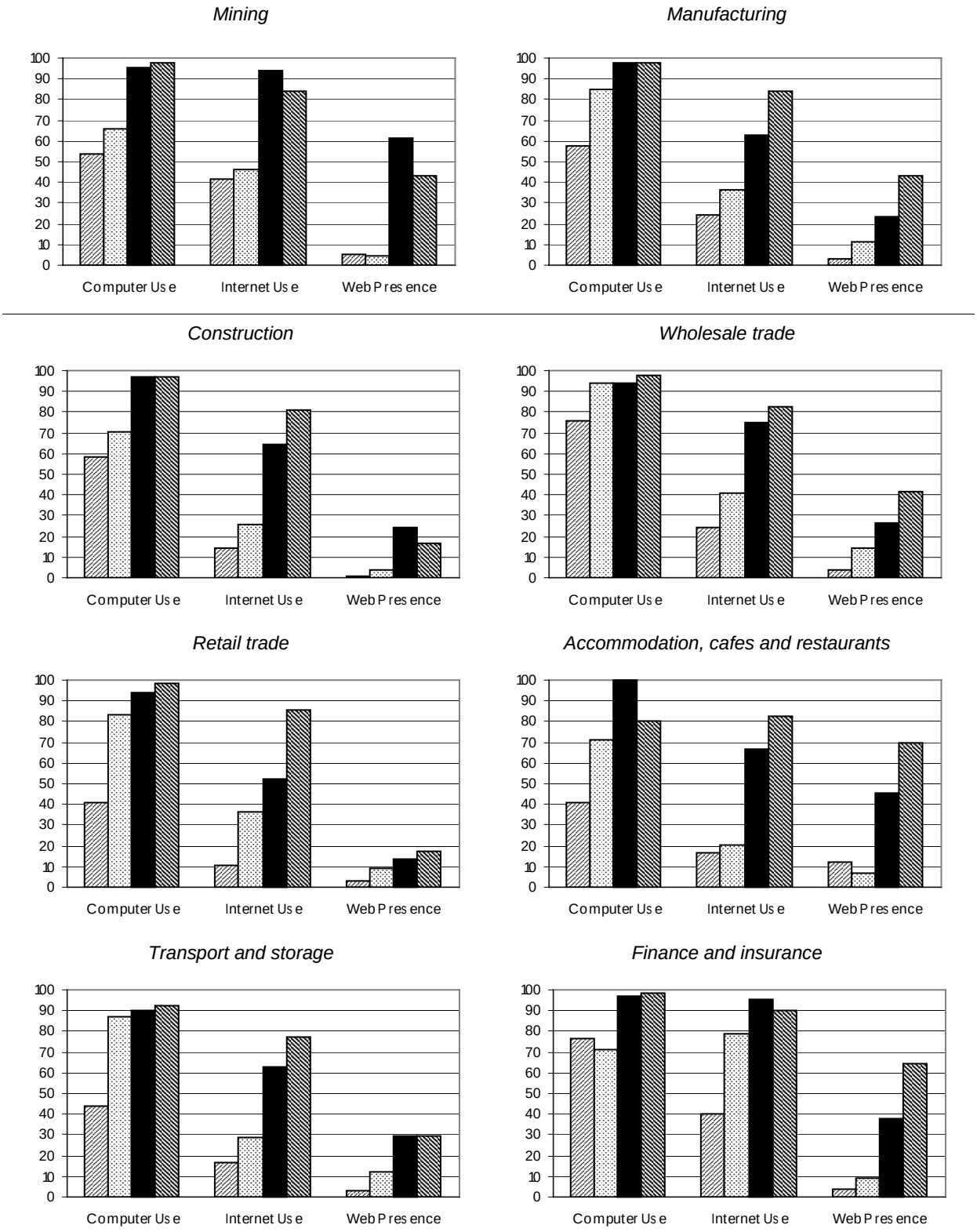
When the data about computer use are cross classified by firm size and duration of use of computers, it is also evident that larger firms tended to adopt computers earlier than smaller firms (figure 3.4).

Another basic firm characteristic is firm age. On the one hand, it may be suggested that more experienced older firms are more able to recognise and take up new technological opportunities while younger firms may face credit and other constraints that inhibit adoption of new business practices. On the other hand, new firms may bring new and more technologically advanced ways of working to an industry which would have favoured the early and more intensive adoption of ICT.

Information for 1996-97 has been used to divide firms into three age groups — less than 5 years old, 5 to 20 years and 20 or more years. This information suggests that at a broad level there was not a lot of difference in computer use between firms of different ages (figure 3.5). That said, there is a tendency for computer use to have been more widespread amongst 'younger' firms in the Mining, Construction, Retail trade and Property & business service sectors but to have been more widespread amongst older firms in Manufacturing, Transport & storage, Finance & insurance and Cultural & recreational services sectors. Also, younger firms appear to have moved towards Internet access and establishing a web presence in the Construction, Retail and Property & business services ahead of other firms.

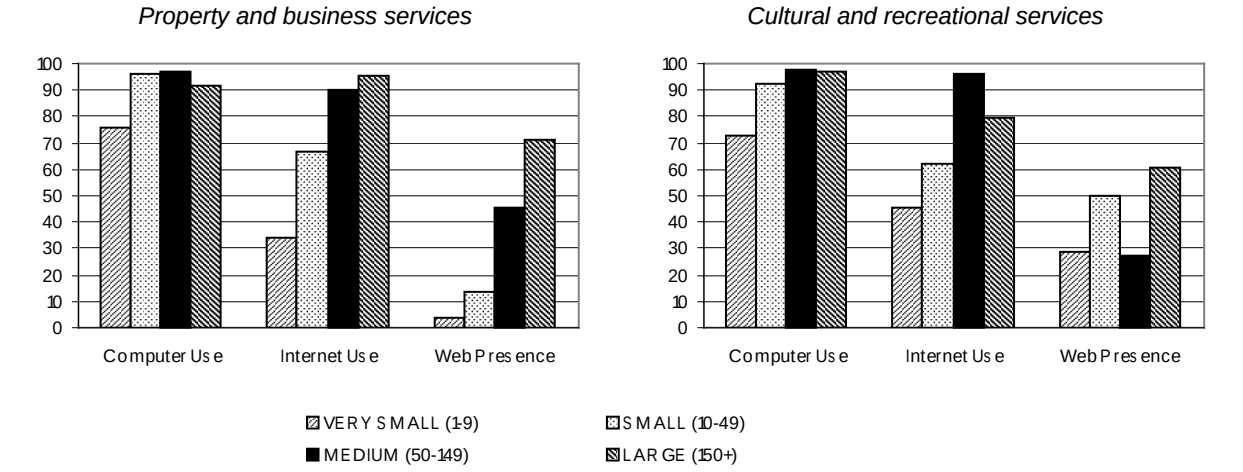
Figure 3.3 **Take up of ICT by firm employment size, 1996-97**

Per cent



(continued on next page)

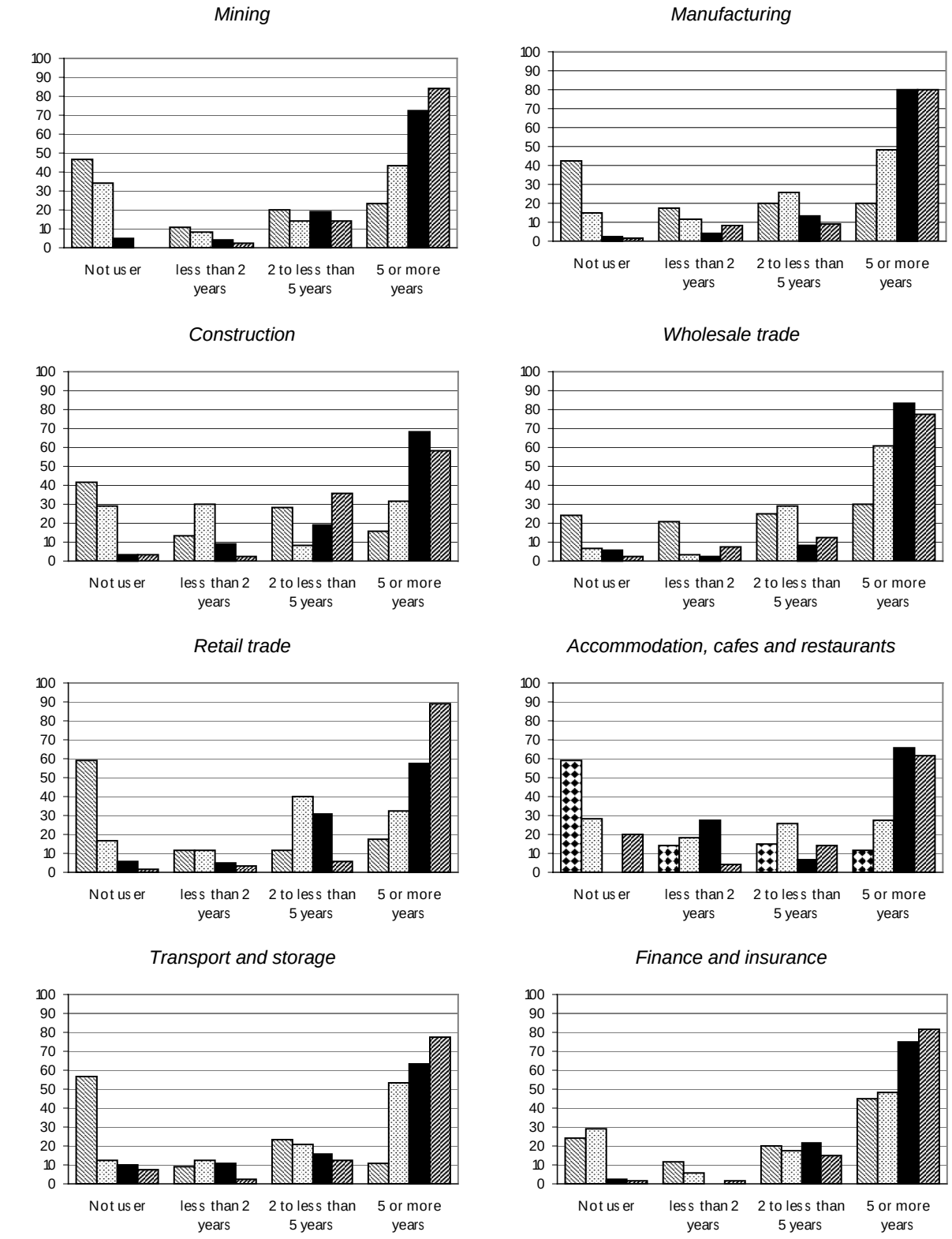
Figure 3.3 **(continued)**



Source: ABS (*Business Longitudinal Survey, 1994-95 to 1997-98* Cat. no. 8141.0.30.001; special tabulations by the ABS based on the Main Unit Record File (MURF)).

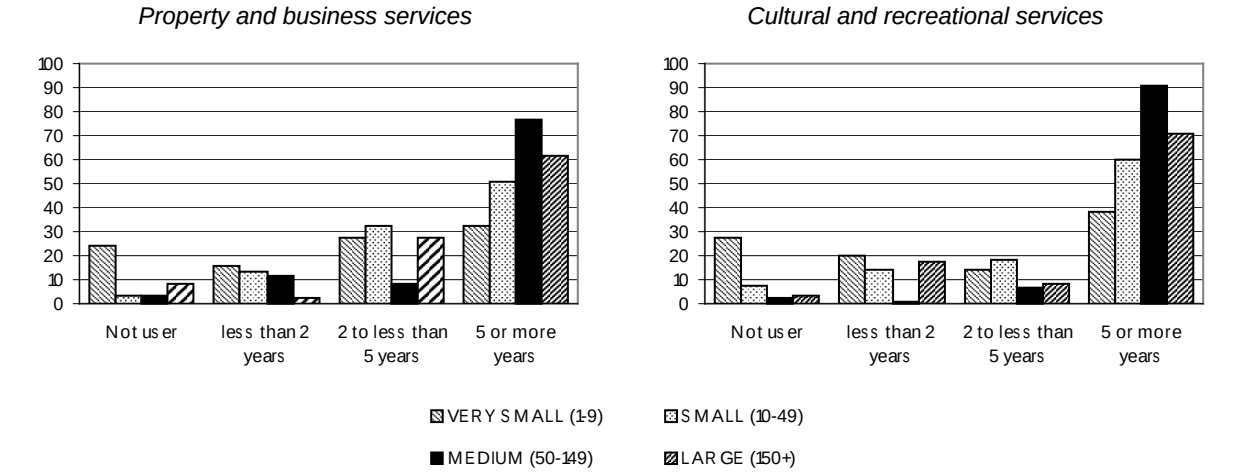
Figure 3.4 **Duration of computer use by firm employment size, 1996-97**

Per cent



(continued on next page)

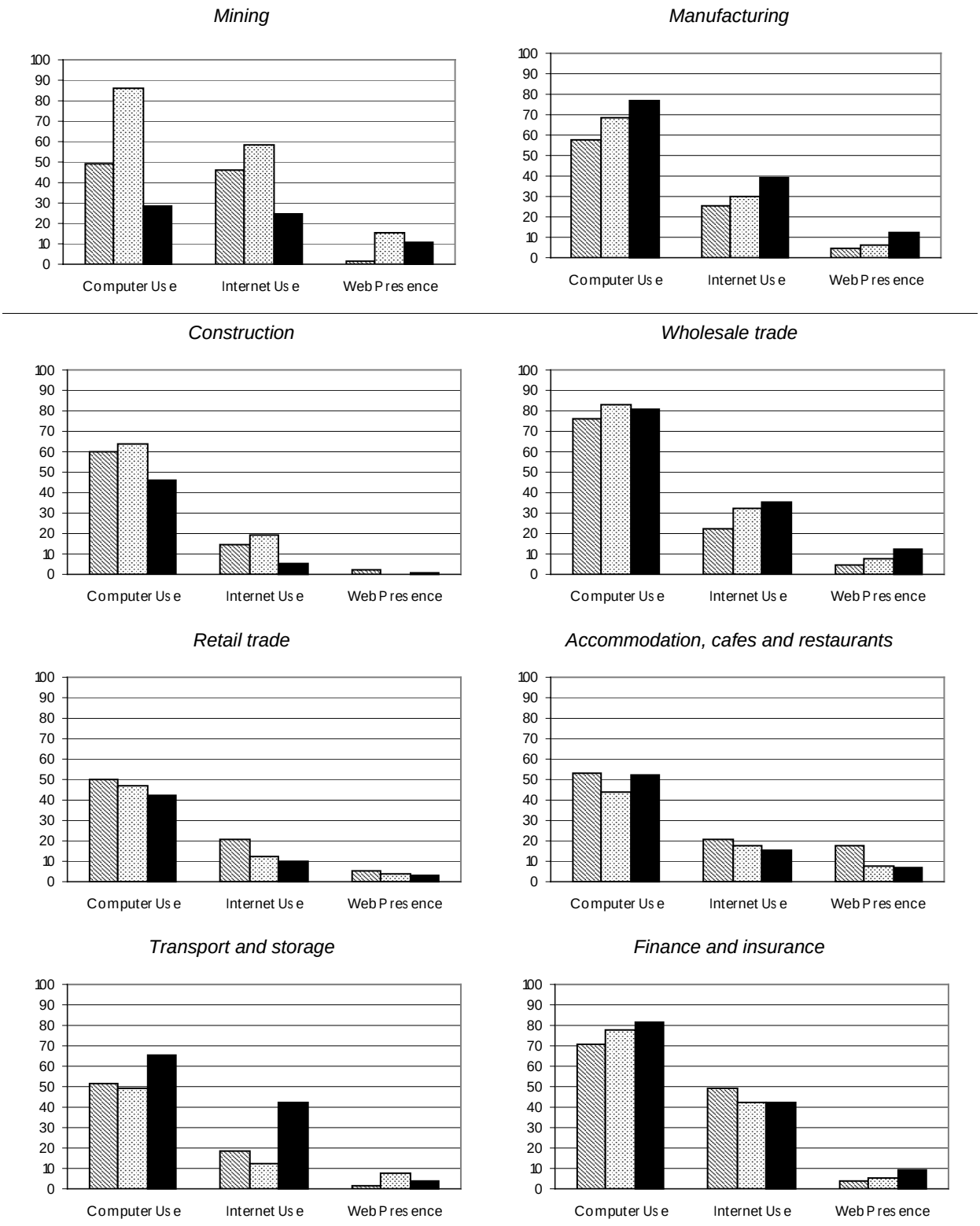
Figure 3.4 **(continued)**



Source: ABS (*Business Longitudinal Survey, 1994-95 to 1997-98* Cat. no. 8141.0.30.001; special tabulations by the ABS based on the Main Unit Record File (MURF)).

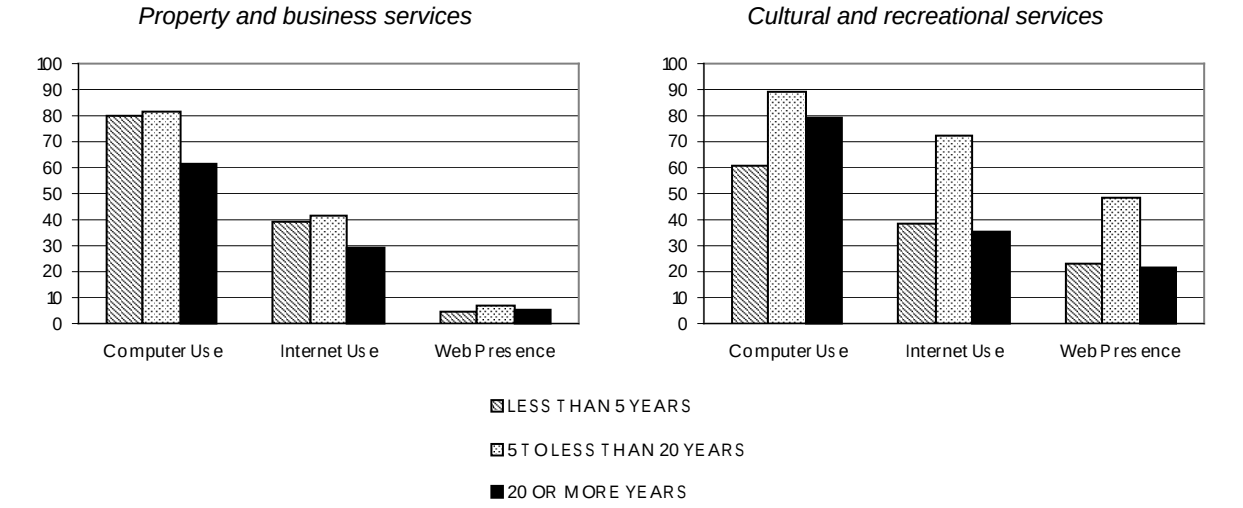
Figure 3.5 **Take up of ICT by firm age, 1996-97**

Per cent



(continued on next page)

Figure 3.5 **(continued)**



Source: ABS (*Business Longitudinal Survey, 1994-95 to 1997-98* Cat. no. 8141.0.30.001; special tabulations by the ABS based on the Main Unit Record File (MURF)).

3.4 Analysis of factors influencing the use of ICTs

Overview of methodology

This section formally examines the characteristics of firms:

- using computers against firms not using computers; and
- with Internet access against firms without Internet access.

To do this, binary choice (ie logit and probit) models were used in which the dependent variable is an index indicating whether a firm used ICT or not. The data for the analysis of computer use were drawn from all of the four BLS years in pooled regressions. Data for the analysis of Internet access were drawn from pooled data for the two BLS years 1996-97 and 1997-98. The pooled regressions enabled the inclusion of time-related effects on the spread of ICT technologies across firms in addition to cross section information on firm-specific factors drawn from the BLS.[21,22]

21 The pooled regression analysis is based on two important assumptions. First, it was assumed that the use of ICTs in each year was an independent decision unrelated to their behaviour in other years. Second, it was assumed that any unobserved firm-specific effects were uncorrelated with the error of estimates.

22 Consideration was given to the use of logit and probit panel data techniques. However, they were not taken up for this study as they appeared to provide unlikely results (in the case of probit random effects models) or did not reliably reach a solution (in the case of logit fixed effect models). A possible reason for such outcomes was attributed to the likely high level of correlation between observed firm-specific characteristics across time. By assuming that variability is primarily between firms and that errors are independent of unobserved firm-specific effects the pooled cross-sectional estimator did not encounter such problems.

The independent, or explanatory variables, upon which ICT use was considered to be conditional include firm size and firm age examined above, and a range of other firm-specific characteristics. The approach adopted has been to include, as far as practicable, characteristics suggested by the literature as increasing the likelihood of firms adopting and using ICTs early and using them more intensively than other firms.[23] Groupings of characteristics and a rationale for their inclusion in the analysis are outlined in table 3.1 while a detailed list of BLS variables under each category is provided in appendix B.

The regression analysis on the characteristics of firms using ICTs in this chapter and on the productivity implications of ICTs on chapter 4 cover BLS eight industry sectors: Manufacturing; Construction; Wholesale trade; Retail trade; Accommodation, cafes & restaurants; Transport & storage; Property & business services; and Cultural & recreational services. It does not cover the Mining sector of the Finance & insurance sector because of the lumpiness of changes in a small number of large firms comprising Mining and the lack of information to define firm value added in Finance & insurance.

[23] The approach adopted allows computer use to be reversible. Another approach would be to treat the uptake of ICTs as a one way process in which take up is seldom reversed. For example, Hollenstein (2002) based his analysis of the adoption of ICT on the assumption that "… potential users of new technology differ from each other in important dimensions so that some firms obtain a greater return from new technology than others do. The larger the net advantage resulting from the technology adoption, the stronger the tendency to adopt early and intensively".

Table 3.1 **Firm-characteristic groups**

Group	*Rational*
Balance panel indicator	A flag to identify which firms operated in each year for which the BLS was conducted for inclusion in regression analysis
Time dummies	Allow for the diffusion of ICTs over time on account of declining relative prices, information spillovers and network externalities between firms (Geroski 2000)
Absorptive capacity	Allow for potential economies of scale and scope arising from size, multiple locations and type of legal organisation, and the impact of experience through firm age (Karkenas and Stoneman 1995) vs the lower adjustment costs for young firms (Dunne 1994)
Financial conditions	Allow for the possibility of liquidity constraints to the take up and use of ICTs (Hollenstein 2002)
Human capital	Allow for firms ability to assess technological opportunities and put new technologies into practice (Cohen and Levinthal 1989, Hollenstein 2000), and learning effects from the adoption of new technology (Colombo and Mosconi 1995, McWilliams and Zilberman 1996 and Arvanitis and Hollenstein 2001)
Information and knowledge	Allow for the effects of advanced business practices — formal business planning, budget forecasting, regular reporting, firm comparisons, export marketing — on the propensity to recognise and take up new technologies
Organisational and management conditions	Allow institutional conditions (such as union membership) to be linked to use of new technologies
Organisational change and processing efficiency	Allow for links between the implementation of organisational change and the use of new general purpose/productivity improving technologies (Ichniowski et al. 1997and Black and Lynch 2001)
Product innovation	Allow for the possibility that innovative firms are more successful and are likely to use new technologies as inputs to the innovation process, ahead of general market supply functions (Loundes 2002)
Openness	Allow for the possibility that openness, as measured by export intensity, increases market competition and motivates firms to rapid technological adoption (eg Majumdar and Venkataraman 1993)
Sample bias	Allow for the possibility that the BLS sample design unintentionally was biased either toward or away from firms using ICT, after controlling for other factors

Computer use

The first regression analysis investigated the characteristics of firms using computers using pooled-cross section data for the years 1994-95 to 1997-98. Results are presented in table 3.2 for eight market sector industries.

A key finding is that for each sector, the time dummy variables were positive and significant reflecting the influence of the declining relative prices of ICTs (chapter 2) and spillovers between firms. In addition, the analysis indicates that there were a number of firm-specific factors positively and significantly associated with the use of computers.

- Firm size (*_totfte*) indicated by employment levels (measured as a full time equivalent) is positively related to the use of computers for all sectors. This finding reinforces the descriptive analysis above centred on figure 3.3 and suggests that significant economies arise from the use of computer technologies by large firms, once account has been taken of firm-specific financial and skill characteristics included separately.
- The level of educational qualification of the major decision maker (*educatn*) is positively and significantly related to computer use for six of the eight sectors, the exceptions being Wholesale trade and Property & business services. This suggests that higher levels of human capital of lead managers is individually important to the adoption of technologies.
- The average wage of employees (*wagerate*), a measure of the human capital across all workers in a sector is also positively and significantly related to computer use in six sectors. Notably, it is relevant for the Wholesale and Property & business services sectors, suggesting that human capital within the workforce of these sectors may, on balance, be a more important variable than the skill level of management alone. By contrast, variability in the skill levels of managers appears more important for the Retail and Construction sectors. For Manufacturing and Cultural & recreational services (the remaining two sectors) human capital of the managers and workforce are both identified as important.
- The intensity with which advanced business practices (*_buspract*) such as business planning, budget forecasting and inter-firm comparisons (see appendix B) are used by firms is positively and significantly related to the use of computers in each sector. This result can be interpreted in different ways. On one hand, it could point to the importance of how businesses are managed as a factor determining the uptake and use of new technologies. It could also point to the possibility that ICTs introduce to firms information handling capabilities that enable them to use a wider range of advanced business practices than otherwise.
- Being an incorporated company is positively and significantly related to the use of computers for 5 sectors. This suggests that the additional complexity and statutory reporting requirements associated with incorporation is individually important in decisions to use computers. The sectors in which variability of other factors is dominant are Construction, Accommodation etc and Cultural & recreational services.
- At least one of the variables representing firm reorganisation (*_busrest* and *restd1*) is positively and significantly related to computer use in all sectors, except Cultural & recreational services. Of the two variables, the strength of restructuring (*_busrest*) based on an index of 11 within period possibilities (such as changes in range of products and services, advertising, technical and on the job training, and business structure, see appendix B) is significant in seven industries. The flag (*restd1*) indicating whether firms restructured in any one of the four survey years is significant in four cases. These results provide support for the view that the take up of new technologies is led by firms with a capacity for restructuring — with the greater the capacity for change increasing the probability of computer use. Two

directions of causality in relation to ICT use may be considered. First, a propensity to restructure leads to computer use to support change or alternatively the adoption of ICT involves other organisational changes.

For some other variables noted in the literature, a mixed relation with computer use was indicated by the regression analysis.

- After controlling for firm age and size, the number of business locations (*_buslocs*) is positively related to computer use for a number of sectors but negatively related for Transport & storage. A possible explanation for this result is that transport networks adopting computer technology as a means of coordination are recognised in statistics as 'single locations' even though their operations may span a wide geographic area.
- After controlling for other factors, whether firms undertook product innovation (involving new or substantially changed goods and services) in any year (*innod1*) and the frequency of innovation during the four-year period (*innofreq*) has a mixed relation with computer use. This result is somewhat at odds with the view that there is an important and widespread positive link between the use of ICT and the ability of a firm to 'innovate'. It may signify the possibility: that the takeup and use of advanced technologies may be more directly associated with 'input' (or process) innovation such as adoption of new business strategies, business processes and organisational structures (covered by other explanatory variables); or that the link between ICT use and product innovation specified in the current model is only part of the story. It may also indicate lagged relationships between computer use or product innovation, or data considerations, that are not fully reflected in the model specification.

It should also be noted that the sample weight is significant and negative in five of the eight cases. These results suggest that firms with a low probability of sample selection (ie firms with the highest sample weights) were biased towards non-computer users and this bias was stronger in some sectors than others. For Cultural & recreational services the bias appears to have gone in the opposite direction. Noting that firm employment was a BLS stratification variable, the results may indicate a non-linear relationship between firm size and computer use not picked up in the linear form of firm size (*_totfte*).

Overall, large firms with more skilled managers and workforce, a greater propensity to use advanced business practices and implement organisational change were the firms most likely to have been early computer users during the uptake period of the mid-1990s. As time progressed, computer use spread fairly quickly so that by the early 2000s it was uncommon to encounter firms not using computers (figures 3.1 and 3.2).

Internet access

The second regression analysis investigated the characteristics of firms with Internet access using pooled-cross section data for firms with computers for the years 1996-97 to 1997-98. There was not sufficient information on Internet access in the BLS to include data for 1994-95 and 1995-96 in the analysis. Results are presented in table 3.3 for eight industry sectors.[24]

[24] In contrast to computer use, there was a substantial mix of firms with and without Internet access during the survey period (figures 3.1 and 3.2). This additional variability provides some basis for testing the accuracy of the statistical models in distinguishing between firms that have Internet access and those that do not. The diagnostics at the foot of table 3.6 indicate that on average, the model correctly predicted the Internet access status of organisations with computers in around 3 out of every 4 observations. This level of accuracy is well above the chance of randomly selecting an Internet user which ranged from 14 per cent for Accommodation etc services to around 60 per cent for Property &

Restricting the analysis to firms already using computers presupposes that establishing Internet access was conditional on a firm already having taken up computer technologies and can be modelled as being independent of the decision to use computers in the business. It therefore does not address possible simultaneous relationships whereby a firm acquires computers to establish Internet access. However, the specification of the analysis would be consistent with the view that the use of computers leads to 'input innovation' which in this case is the communication services provided by Internet access.

Again a key finding is that for each sector (except Accommodation etc.), the progression of time, after controlling for other influences, was important for the spread of business communication via the Internet. This is indicated by the positive and significant coefficient on the time dummy (*tdum98*). Spillovers occurring between firms are likely to be a contributing factor to the take-up of Internet communications, in this context.

Concerning other factors considered, Internet access is positively and significantly related to:

- human capital of firms represented by the education of the main decision maker (*educatn*) and average wages (*wagerate*);
- information and knowledge of the firm as represented by use of advance business practices (*_busprac*);
- measures to improve firm organisation and processing efficiency represented by the intensity of restructuring (*_busrest*) and the presence of restructuring in a survey year (*restd1*); and
- the degree of openness indicated by the intensity of exporting (*_expint*). This result would indicate that the Internet has significant advantages over traditional media for communications, searches and perhaps transactions over long distances and between countries. The result contrasts with mixed results concerning the relation between computer use and export intensity which suggest that computer use alone is not important to exporting.

Overall, as with computer usage, BLS data suggest that larger firms with more skilled managers and workforce, a greater propensity to used advanced business practices and implement organisational change were the firms most likely to have been found to adopt Internet communications earlier than other firms. Openness to international trade was also important.

These results taken from experience in the mid to late 1990s have some commonality with other research findings that have recently come to light. For example, Loundes (2002) reported evidence from a *Melbourne Institute Business Survey* of 281 top Australian enterprises (in terms of revenue) from a range of industries including Manufacturing, Electricity, gas & water supply, Wholesale and Retail trade, and Transport & storage. The survey showed that:

- there was little benefit to firms from the Internet unless its use was incorporated into an overall strategy;
- manufacturing firms were more likely to use the Internet for coordination of delivery arrangements whereas firms in services were more likely to use the Internet to forge closer links with customers;
- organisations that were strong in at least one nominated competitive strategy (ie 'operational excellence', 'customer intimacy' and 'product leadership') were more likely to use the Internet than other firms;
- management style made a difference with 'bold' organisations (eg firms that favoured higher risk projects and taking a more aggressive attitude towards change by new products or

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business services. The models, although not based on an integrated theory relating to the take up of new technologies, appear to be a relevant method for identifying the characteristics of firms using ICTs.

research and development) were more likely to make extensive use of Internet features than other firms; and

- process and product innovative organisations were more likely to extensively use Internet features than others.

These results reinforce the findings of this study which emphasise adoption of advanced business practices and organisational change as important factors influencing the likelihood of firms having access to the Internet. They also reinforce the link between openness and Internet access for some sectors. The emphasis in Loundes on the link between process and product innovation and Internet access is also evident in the current study. Although as noted above, the link between product innovation and Internet access is evident for some sectors but not others in the current study.

Table 3.2 **Characteristics of firms using computers, 1994-95 to 1997-98**[a]

Pooled cross-section regression, unweighted estimates

											Sector summary	
Characteristic	*Mnemonic*	*Exp-ected sign*	*Manu-factur-ing*	*Cons-truction*	*Whole-sale trade*	*Retail trade*	*Accom., cafes & rest's*	*Trans-port & storage*	*Property & bus. services*	*Cultural & rec. services*	*No. of postives*	*No. of neg-atives*
Dummy 1996	TDUM96	+	+***	+***	+***	+***	+**	+**	+**	+*	8	
Dummy 1997	TDUM97	+	+***	+***	+***	+***	+***	+**	+#	+*	8	
Dummy 1998	TDUM98	+	+***	+***	+***	+***	+***	+***	+**	+***	8	
Absorptive capacity												
Employment	_TOTFTE	+	+***	+***	+***	+***	+***	+***	+***	+**	8	
Business locations	_BUSLOCS	+				+*	+#	-***	+#		3	1
Older firm flag	DAGE2	+		-***	+**		-***	+**	-***	+#	3	3
Financial conditions												
Low profitability flag	DEBIT1	-		-#	+#		+***	+***	-*	+#	4	2
Human capital												
Education of decision maker	EDUCATN	+	+#	+*		+**	+#	+**		+#	6	
Tertiary qual. of decision maker	TERTQUA	+			+#	-#		-**		-#	1	3
Average wage	WAGERATE	+	+***		+**		+***	+***	+#	+#	6	
Information and knowledge												
Use of advanced bus. practices	_BUSPRAC	+	+***	+#	+***	+***	+***	+***	+***	+*	8	
Organizational and management conditions												
Union membership	_UNIONME	-/+					+#	-#	-#		1	2
Type of legal organization	TOLO	+	+***		+**	+***		+**	+#		5	
Organizational and processing efficiency												
Intensity of restructuring	_BUSREST	+	+***	+***	+***	+***	+**	+**	+**		7	
Restructuring flag	RESTD1	+	+***	+***				+**	+**		4	

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Table 3.2 **(continued)**

Characteristic	*Mnemonic*	*Exp-ected sign*	*Manu-factur-ing*	*Cons-truction*	*Whole-sale trade*	*Retail trade*	*Accom., cafes & rest's*	*Trans-port & storage*	*Property & bus. services*	*Cultural & rec. services*	*Sector summary: No. of postives*	*Sector summary: No. of neg-atives*
Product innovation												
Innovation flag	INNOD1	+		-#	+#	+#	+#	+**	+**		5	1
Frequency of innovation	INNOFREQ	+	+**	+**	-#		-**	-***		+#	3	3
Openness												
Export intensity	_EXPINT	+			+#	-#	-#	+#	+#		3	2
Sample bias												
Sample weight	_WGHT_F	-			-***	-***	-***	-***	-#	+#	1	5
Diagnostics												
Period	1994-95 to 1997-98											
Model	Unweighted, Logit										*Average*	
Observations	No.		5340	936	2419	1164	595	596	2388	384		
Firms using computers	%		89%	71%	95%	78%	56%	75%	88%	86%	79%	
Correct predictions	%		90%	75%	95%	83%	80%	79%	89%	87%	84%	

*** coefficient significant at the 1 per cent level, ** at the 5 per cent level or * at the 10 per cent level. # coefficient relevant as indicated by a t-statistic > 1. **a** Firms in the BLS only in 1994-95 and firm-records with incomplete data are not included in the regression. Typically each firm is observed four times.

Source: Regression analysis based on the BLS Confidentialised Unit Record File (CURF). See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98*, Cat. no. 8141.0.30.001).

Table 3.3 **Characteristics of firms with Internet access, 1996-97 and 1997-98**[a]

Pooled regression, unweighted estimates

Characteristic	*Mnemonic*	*Expected sign*	*Manufacturing*	*Construction*	*Wholesale trade*	*Retail trade*	*Accom., cafes & rest's*	*Transport & storage*	*Property & bus. services*	*Cultural & rec. services*	*Sector summary*	
											No. of postives	*No. of negatives*
Time												
Dummy 1998	TDUM98	+	+***	+#	+**	+#		+#	+**	+#	7	
Absorptive capacity												
Employment	_TOTFTE	+	+***	+**	+***	+***			+***	+***	6	
Business locations	_BUSLOCS	+	+**		-#			+#			2	1
Older firm flag	DAGE2	+	+#			+#	+#				3	
Financial conditions												
Low profitability flag	DEBIT1	-	+**		+#					+**	3	
Human capital												
Education of decision maker	EDUCATN	+	+***	+#	+**		+**	+#		+#	6	
Tertiary qual. of decision maker	TERTQUA	+	-#									1
Average wage	WAGERATE	+			+#	+***			+***	+**	4	
Information and knowledge												
Use of advanced bus. practices	_BUSPRAC	+	+***	+***	+***	+***	+**	+***	+***		7	
Organizational and management conditions												
Union membership	_UNIONME	-/+	-**		-#			+#	-***	-**	4	1
Type of legal organization	TOLO	+				+#	-#				1	1
Organizational and processing efficiency												
Intensity of restructuring	_BUSREST	+	+***		+#	+#	+**				4	
Restructuring flag	RESTD1	+	+#								1	

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Table 3.3 **(continued)**

Characteristic			*Manu-facturing*	*Cons-truction*	*Whole-sale trade*	*Retail trade*	*Accom., cafes & rest's*	*Trans-port & storage*	*Property & bus. services*	*Cultural & rec. services*	*Sector summary: No. of postives*	*Sector summary: No. of neg-atives*
Product innovation												
Innovation flag	INNOD1	+						+**		+**	2	
Frequency of innovation	INNOFREQ	+	+*						+*	-*	2	1
Openness												
Export intensity	_EXPINT	+	+***		+***	+**		+**	+**	+#	6	
Sample bias												
Sample weight	_WGHT_F	-		-**	-**	+#	-**	-*	-*	+#	2	5
Diagnostics												
Period	1996-97 & 1997-98											
Model	Logit										Average	
Observations	No.		2481	349	1188	668	178	233	1058	170		
Firms with internet access	%		49%	31%	56%	32%	24%	35%	66%	58%	44%	
Correct predictions	%		68%	77%	67%	75%	81%	75%	73%	79%	74%	

*** coefficient significant at the 1 per cent level, ** at the 5 per cent level or * at the 10 per cent level. # coefficient relevant as indicated by a t-statistic > 1. [a] Firms in the BLS with incomplete data are not included in the regression. Typically each firm is observed twice.

Source: Regression analysis based on the BLS Confidentialised Unit Record File (CURF). See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98,* Cat. no. 8141.0.30.001).

Other issues

A number of other issues have been raised in the context of the ICT and firm performance study. Particular interest has been given to factors that effect higher intensity of computer use, the early adoption of ICT technologies and reasons advanced by firms for not using ICTs. Where practicable, it is intended to extend our investigations into these areas of interest in later work by reference to BLS and BUIT unit record data.

3.5 Main findings

- There was rapid diffusion of computers during the 1990s. By 2000-01 over 80 per cent of firms used computers in some way while 70 per cent had Internet access.
- In the mid-1990s, the pattern of uptake was broadly similar between sectors, with larger firms tending to have computers for the longest and non-users being concentrated amongst the smaller firms.
- The substantial growth in computer use since the mid-1990s suggests that the use of computers by smaller firms has deepened while larger firms have continued to extend their application of ICTs including through gaining Internet access and establishing a Web presence.

Information from the key mid-1990s period indicates:

- Firms that took up ICT earliest and made most intensive use of ICT tended to be the larger firms with skilled managers and workforce, a greater propensity to use advanced business practices and a record for implementing organisational change.
- There was also an important link between openness to international trade and use of technological innovations that improve communication (such as the Internet).

Lower prices, spillovers between firms and learning by doing are likely to have been important in the deepening of computer use and computer-based applications (including Internet access).

4 Firm level evidence: effects of ICTs on performance

This chapter uses firm-level data from the BLS (described in chapter 3) to examine two key issues concerning the influence of computer use on firm performance:

- Has computer use raised the productivity of Australian firms and contributed to economic growth?
- Was computer use complemented by other factors in attaining productivity improvements?

To address these issues this chapter first outlines the association between computer use and labour productivity of firms. Section 4.2 then overviews the analytical framework and methodology used to analyse the impact of computer use on multifactor productivity (MFP) growth. This is followed by sections 4.3 and 4.4 which report first, results concerning the relationship between computer use and MFP growth and, second, the likely interaction between computer use and other factors. This chapter focuses on the eight industry sectors analysed in detail in chapter 3 (section 3.4, appendix A).

4.1 Characteristics of better performing firms

Using labour productivity as a measure of firm performance, data drawn from the BLS for 1996-97 indicate that firms using computers are on average more likely to have had higher labour productivity than those that did not (indicated by vertical productivity bars in figure 4.1). There was also a tendency for firms that had used computers longer to also have had higher labour productivity on average.

Figure 4.1 also reports information on the variability of labour productivity between firms within each sector (measured as the standard deviation from the mean and shown by the vertical lines. This information shows that variability is large in all sectors relative to the mean and it also shows significant differences between sectors. For example, variation in labour productivity between firms in the Construction, Transport & storage and Property & business services sectors appears to have been greater than for firms in other sectors.

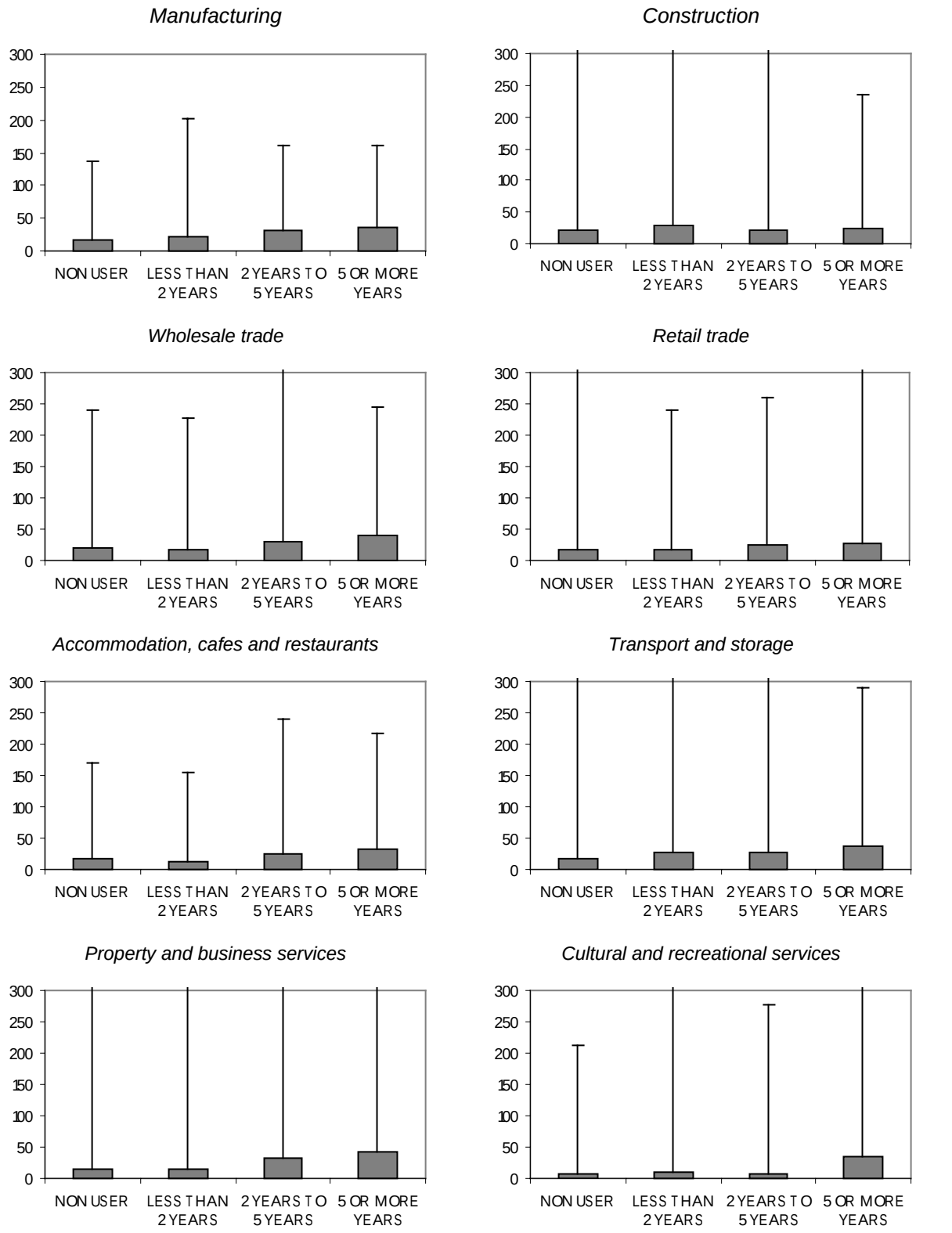
The BLS also provides information on whether or not firms made use of a number of computer-based functions. Figure 4.2 reports the relative productivity of users and non-users of computers plus three functional categories — Internet access, Web presence and online marketing. In four of these sectors — Manufacturing, Wholesale trade, Transport & storage and Property & business services — users of each category had higher labour productivity than the non-users in 1996-97. For remaining sectors, the relationship between use and non-use was mixed with BLS data suggesting the labour productivity was higher for users in some categories but lower for others (eg Construction and Retail trade). Again, there was very high variability (not reported in figure 4.2) between firms in each ICT use category.

When firms are ranked according to their labour productivity to form ‘productivity quartiles’, proportionately more firms in the highest quartile were computer users or had Internet access and/or a Web presence than in other quartiles (figure 4.3). However, because of the substantial variability in the level of labour productivity between users and non-users, there is no simple progressive relation across quartiles that can be applied to each sector. For example, for Manufacturing, the relationship between the incidence of firms using computers and productivity appears strongly positive. On the other hand, for Retail trade, the proportion of firms using computers in the first and second productivity quartiles is similar. And for Accommodation etc. more firms in the lowest productivity quartile were found to use computers than in some higher productivity quartiles.

Because of the high variation in labour productivity for both computer users and non-users, it is difficult to use sectoral averages and simple comparisons of performance to draw inferences about the influence of computer use on productivity. Also, firms that adopt ICT may already have been the more productive firms. Thus, there may be either no relationship between the length and intensity of use and productivity, or a more complex analysis is necessary to disentangle the relationship if one exists. Regression analysis has therefore been used to examine in more depth the complex relationship between computer use, MFP and labour productivity growth, after controlling for other factors that may also influence labour productivity growth.

Figure 4.1 **Labour productivity by duration of computer use, 1996-97**

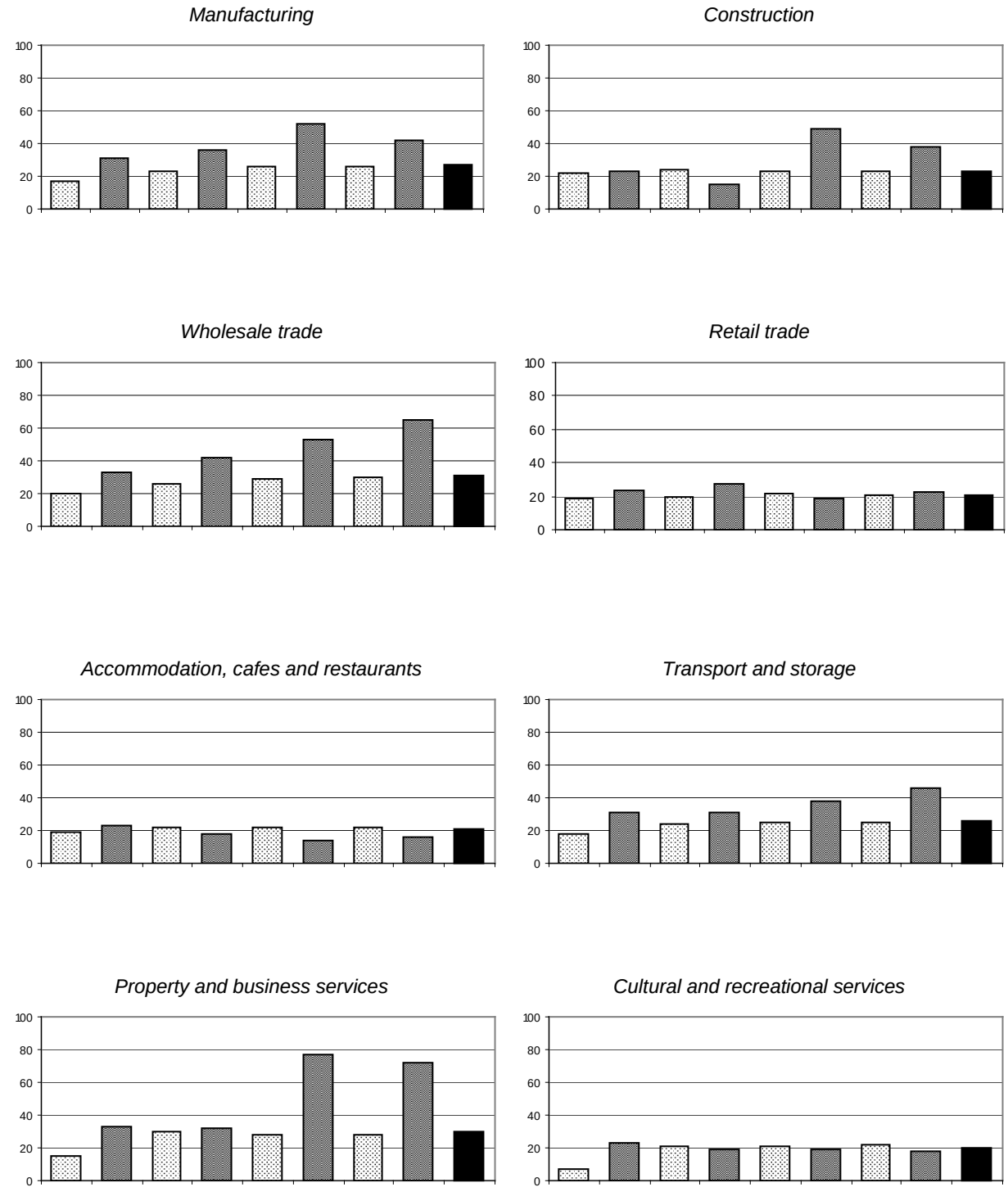
Average (bars), Standard deviation (lines), $000 value added per person



Source: ABS (*Business Longitudinal Survey, 1994-95 to 1997-98* Cat. no. 8141.0.30.001; special tabulations by the ABS based on the Main Unit Record File (MURF)).

Figure 4.2 **Labour productivity by functional use of ICT, 1996-97**

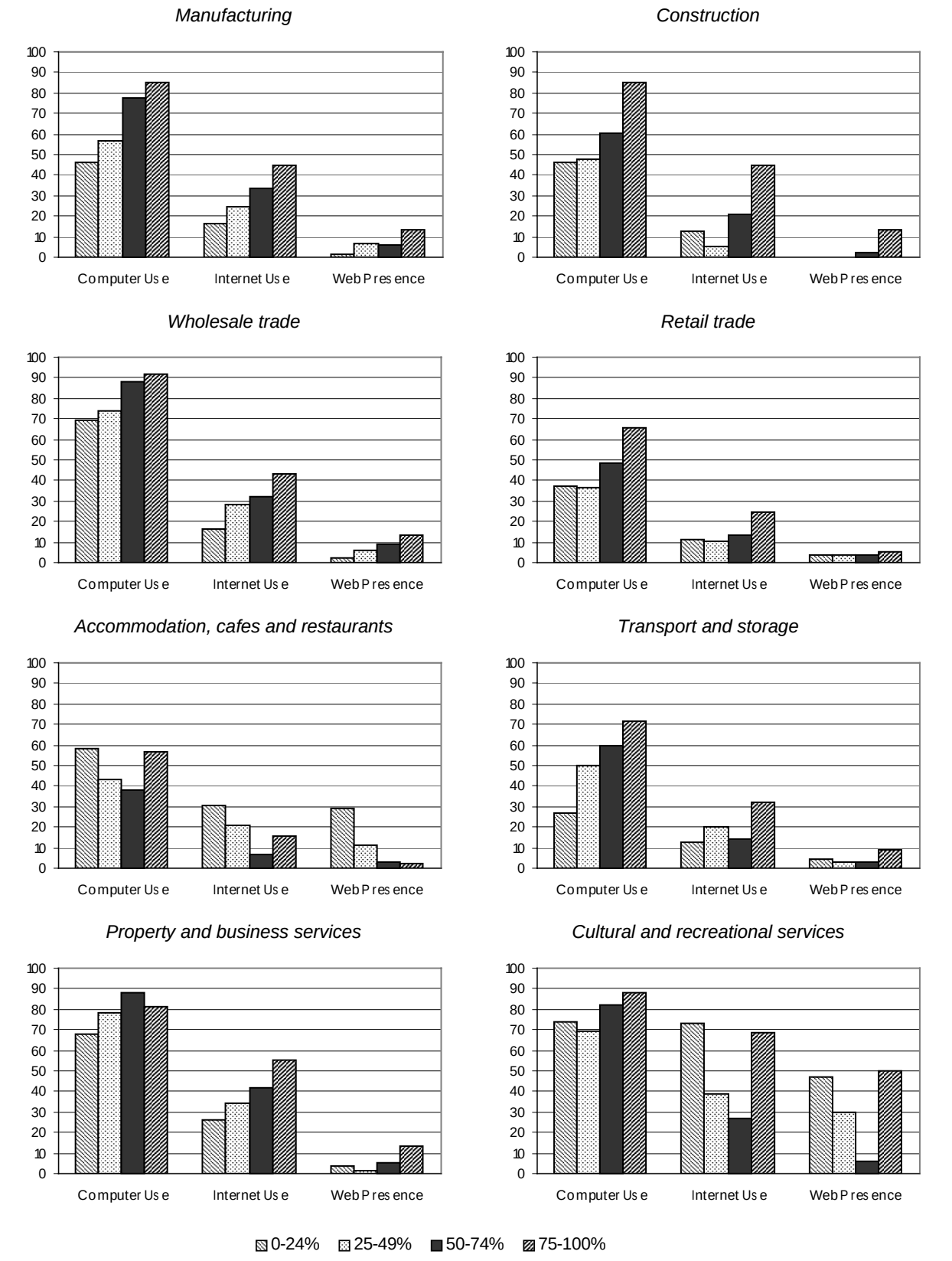
Average (bars), $000 value added per person



Source: ABS (*Business Longitudinal Survey, 1994-95 to 1997-98* Cat. no. 8141.0.30.001; special tabulations by the ABS based on the Main Unit Record File (MURF)).

Figure 4.3 **ICT use by labour productivity quartiles, 1996-97**

Per cent



Source: ABS (*Business Longitudinal Survey, 1994-95 to 1997-98* Cat. no. 8141.0.30.001; special tabulations by the ABS based on the Main Unit Record File (MURF)).

4.2 Framework for analysis of the influences of ICTs on firm productivity

Overview of methodology

The regression model adopted in this study is based on a production function approach derived from a growth framework in which technological progress shows up as a new basic innovation or general purpose technology (box 4.1). Viewing ICT as a new general purpose technology provides a rationale for ICT contributions to MFP growth to be analysed in this general framework. It also enables the introduction of ICT to be considered as part of a continuum of change contributing to growth rather than as an ad hoc technological disturbance.

For empirical analysis, the underlying estimation model is expressed in its labour intensive form. Formally, labour productivity is defined as $y = \frac{Y}{L}$ where Y is the level of value added output[25] and L is the level of labour inputs. Similarly, capital inputs per unit of labour input are defined as $k = \frac{K}{L}$ where K is the level of capital inputs. Secondly, the model is specified in changes to provide a basis for the inclusion of growth dynamics in the analysis. The basic labour productivity growth equation including ICT is:

$$\dot{y} = \beta_0 + \beta_1 \dot{k} + \beta_2 ICT + \varepsilon \tag{4.1}$$

where the dot over y and k indicates the logarithmic change between years in labour productivity and capital intensity, respectively.[26] The coefficient β_1 is the elasticity of labour productivity with respect to a change in capital intensity. It is the empirical equivalent to the technological parameter $1-\alpha$ in the theoretical model (box 4.1). $\beta_1 = 1-\alpha$ would also be equal to the capital income share in output for firms characterised by constant returns to scale (CRS) with competitive pricing of inputs. Where there is a prior understanding that these conditions generally hold, the magnitude of the estimated β_1 provides a useful qualitative test on the specification of the estimated model.

β_2 represents the impact of ICT take-up on labour productivity growth and is a component of the measure 'multifactor productivity' growth which is the subject of traditional productivity analyses (and the focus of chapter 2 of this paper). A positive and statistically significant value would indicate that the take-up of ICT has contributed to MFP growth. β_0 represents the growth in labour productivity not accounted for by other factors. In traditional growth studies, β_0 would also provide an estimate of the MFP arising from all technological and organisational changes. However, as the contribution of ICTs to MFP growth is being separately estimated in this study, the definition of β_0 is differs from that of traditional growth accounting studies.

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[25] This practice conforms to many other studies, for example Rogers and Tseng (2000), Atrostic and Nguyen (2001), Baldwin and Sabourin (2001), and Hempell (2002).

[26] That is, $\dot{y} = \log\left(\frac{y_t}{y_{t-1}}\right)$ and $\dot{k} = \log\left(\frac{k_t}{k_{t-1}}\right)$.

Box 4.1 Outline of a model of technological change with an expanding variety of products

One aspect of technological advance comes from basic innovations or new general purpose technologies that can be regarded as being embodied in conventional physical and human capital. A tractable way of considering this kind of technical advance is though models with an expanding variety of products introduced by Romer (1986, 1990) and outlined and discussed in Barro and Sala-i-Martin (1995, chapter 6). The basic product supply function aligned with these theoretical contributions and adopted for this study is:

$$Y_i = A_i L_i^{\alpha} \left(K_i\right)^{1-\alpha} N^{\alpha}$$

where $0 < \alpha < 1$, Y_I is output, L_i and K_i are labour and capital inputs, respectively, and A_I is technological progress and improvements in organisation other than that attributable to increased product variety. *N* represents technical progress through increased input variety and takes the form of an increase in the number of specialised inputs 'available' to firms.

As information on the number of varieties (*N*) and changes in this number (*n*) that underpin the expression of the theoretical model with an expanding variety of products is not directly observable, it is necessary to adopt simplifying assumptions and approximations to complete empirical models. In our study, we have replaced these theoretical variables with dummy variables which take a positive value when a firm is an ICT user and zero otherwise. This focuses the empirical model on the impact of ICT without reducing the generality of the framework.

This augmented Cobb-Douglas production function exhibits diminishing returns to individual inputs and constant returns for all inputs together. This specification provides a tractable way to emphasise that long-run growth arises from technological advance and to model one kind of endogenous technical change. The assumption of constant returns to scale also provides a useful benchmark against which empirical results can be evaluated.

The model of expanding product variety is appropriate for analysing the impact of breakthrough innovations, such as ICT, that provide a material increase in the number of input varieties. The model also suggests that if the diffusion of ideas from one country to another is rapid, then technologies in all countries would improve. This feature is particularly pertinent to Australia which has been predominantly a user of ICT hardware technologies rather than a developer and manufacturer.

The specification of the model was refined in a number of ways to complete two estimation models. First, a basic estimation model was specified in which:

- the ICT variable was decomposed into five components with four indicating the duration of ICT use to allow for non-linearities between the duration of use and MFP growth, and one indicating whether a firm has Internet access or not; and
- two variables were added to the model, one to account for conditional convergence in labour productivity towards a 'best practice' and a second to allow for a possible underlying relation between firm size and growth.

The basic model is specified more formally in box 4.2. Results from the implementation of the basic model are reported in section 4.3 below.

Box 4.2 **Specification of the basic regression model**

Formally, the basic estimation model can be written as:

$$\dot{y} = \beta_1 \log(y_{t-1}) + \beta_2 Size + \beta_3 \dot{k} + \beta_{4,1} ICT\_d1 + \beta_{4,2} ICT\_d2 + \beta_{4,3} ICT\_d3 + \beta_{4,4} ICT\_d4 + \beta_{5\_} netacc$$

Where the variables $\dot{y}$ and $\dot{k}$ are defined in the text. The variable *size* is defined as full time equivalent employment (the BLS variable *_totfte*). The four duration of computer 'dummy' variables are: ICT_d1 (the BLS variable *COMDUM1*) that has a value of one if a firm used computers for less than two years and zero otherwise; ICT_d2 (the BLS variable *COMDUM2*) that has a value of one if a firm used computers for a 'shorter' period of time and zero otherwise (imputed for the years 1994-95 and 1995-96 on the basis of duration of use data collected in 1996-97 returns); ICT_d3 (the BLS variable *COMDUM3*) that has a value of one if a firm used computers for between two and five years and zero otherwise; and ICT_d4 (the BLS variable *COMDUM4*) that has a value of one if a firm used computers for five or more years and zero otherwise.

Because of data limitations, it was not possible to extend this methodology to Internet use or Web presence variables. In our analysis, therefore, account has been taken of the extension of the use of ICT, through these media with a single binary variable *_netacc* with a value of one for firms with Internet access and zero otherwise.

While the basic model explores the central relation between ICT use and growth, it does not elaborate on possible complementary relations between ICT use by firms and their level of skill (or human capital), innovation, business practices and organisational changes. It also does not take account of all information available from the BLS that may influence productivity growth in its widest sense. To take account of these influences the basic model was augmented in two ways:

- first, the ICT variables, in addition to being entered individually, were interacted with organisational and technical factors to take account of the proposition that for firms to achieve improvements through the use of ICT they must possess skill advantages, have business practices that enable the assimilation of knowledge about new technologies and undertake organisational change; and
- second, additional growth variables suggested by the literature were added as independent explanatory variables to control, as far as practicable, for firm specific productivity influence not accounted for other factors.

The specification of the augmented model is outlined in box 4.3. Results from the augmented model are reported in section 4.4.

Box 4.3 **Outline of augmented model with ICT complements**

Formally, the empirical model is augmented with other variables and computer use interaction variables as shown below. The dependent variable is the same as in the basic growth model — logarithmic change in labour productivity. The explanatory variables in the augmented model include:

A regression constant

$$\beta_0$$

The basic growth and ICT variables

$$\beta_1 \log(y_{t-1}) + \beta_2 Size + \beta_3 \dot{k} + \beta_{4,1} ICT\_d1 + \beta_{4,2} ICT\_d2 + \beta_{4,3} ICT\_d3 + \beta_{4,4} ICT\_d4 + \beta_5 \_netacc$$

Computer use interaction variables

$$+\beta_{6,1}(ICT\_d1 * wagerate\text{^}2) + ,...,$$
$$+\beta_{7,1}(ICT\_d1 * \_innova) + ,...,+\beta_{8,1}(ICT\_d1 * l1inovat) + ,...,$$
$$+\beta_{9,1}(ICT\_d1 * \_busprac) + ,...,+\beta_{10,1}(ICT\_d1 * l1buspra) + ,...,$$
$$+\beta_{11,1}(ICT\_d1 * \_busrebi) + ,...,+\beta_{12,1}(ICT\_d1 * l1busre) + ,...,$$

where the variables interacted multiplicatively with each computer use dummy *(ICT_d)* are: the wage rate (squared) (*wagerate^2*) to represent human capital; innovation experience and the lag of innovation experience (*_innovat* & *l1inovat)*; an index reflecting the intensity of adoption of 6 advanced business practices and the lag of those business practices (*_busprac & l1buspra*) and an index of the propensity of current and past year implementation of 11 major firm-specific organisational changes (*_busrebi & l1busre*).

Other control variables

$$+\beta_{13} \_buslocs + \beta_{14} \_age + \beta_{15} l1newbus + \beta_{16} tolo + \beta_{17} \_randd + \beta_{18} \_expbi$$
$$+\beta_{19} \_unionme + \beta_{20} \_conout + \beta_{21} \_arrawar + \beta_{22} \_arrcont + \beta_{23} \_arrunre + \beta_{24} \_arrreg$$
$$+\varepsilon_{it}$$

The variables included in this group are: the incidence of multiple locations (*_buslocs*), firm age (*_age*); new business status (*l1newbus*); type of legal operation *(tolo);*); research and development (*_randd*); export status of the firm (*_expbi*); extent of union membership (*_unionme*); incidence of contracting out activities previously done by own employees (*_conout*); type of employment arrangements — awards (*_arrawar*); individual contracts (*_arrcont*); and unregistered & registered agreements (*_arrunre* &*_arrreg).*

Details about the definition of model variables are provided in appendix B while an outline of the rationale for including each item is set out in appendix C. Panel regression methods were used to estimate of the basic and augmented models. Appendix D outlines the econometric method used and choice of estimator and also canvases some key econometric issues relevant to the current study.

4.3 Growth effects of ICT use

Results for the basic model are presented in table 4.2. The results describing the impact of computer use on productivity growth are summarised in figure 4.4. This figure shows that:

- coefficients on computer use are generally positive and statistically relevant for all the eight sectors analysed; and
- the impact of computer use on firm productivity growth shows a clear dynamic pattern common between sectors. Under this pattern, the initial impact of computer take-up tends to be negligible (or a small negative/positive). As the duration of computer use increases, so do the positive effects on firm performance. Finally, after a period of adjustment of around five years, the productivity stimulus of computer take-up appears to have been largely completed with growth returning to 'normal'.

While the results show a clear dynamic pattern which conforms with the predictions of growth theory, they should be interpreted cautiously as they do not incorporate changes in the intensity of computer use and the variables for the earlier years in the survey period were imputed using information collected towards the end of the period (see above).

The regression results in figure 4.4 also indicate that Internet access typically had a positive and significant influence on productivity growth. (As mentioned above, available information did not support the analysis of time profiles for this aspect of computer use.)

The more detailed results reported in table 4.2 indicate that the:

- coefficients on lagged labour productivity ($\log(y_{t-1})$) are negative and significant, indicating that conditional convergence is implied by the firm-level data. The coefficient on that factor provides an indication of the adjustment period required to reach a new equilibrium following a change in capital intensity. The results suggest that adjustment halfway towards a new equilibrium would be: around three years for Construction;[27] four years for Wholesale and Retail trade; five years for Manufacturing, Transport & storage and Property & business services; six years for Accommodation, cafes & restaurants; and twelve years for Cultural & recreational services; and
- coefficients on growth in capital per unit of labour inputs (ie capital deepening, *kdot*) are generally of a similar magnitude to the capital share in value added, suggesting, in broad terms, the data are not inconsistent with the benchmark technology with constant returns to scale and competitively priced inputs. Nevertheless, the results for the Wholesale trade, Retail trade, Accommodation etc sectors appear to be upwardly biased (according to the CRS criterion) and Cultural & recreational services downwardly biased. Possible sources of bias include: sampling differences between the BLS and national accounts and aggregation bias; and firm restructuring and demand changes that occur simultaneously with investment decisions;[28]
- coefficients on firm (employment) size (*size*) are negative and significant for four of the eight sectors analysed indicating that on balance, coordination costs may increase with size. Positive coefficients for the Manufacturing and Construction sectors, on the other hand, suggest that size provides some productivity advantage for these sectors.

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[27] Calculated as $\left[-\ln(0.5)/-\ln(-0.638+1)/4\right]$ (Barro and Sal-i-Martin 1995, p. 37).

[28] In technical terms, the error term in the regression would be positively correlated with the change in capital intensity (*kdot*) for the Wholesale trade, Retail trade and Accommodation etc. and negatively correlated for Cultural & recreational services.

4.4 How other factors interacted with ICT use

This section extends the basic growth analysis to report results from the model augmented to take account of the impact of interactions between computer use and key firm characteristics, and to control for the influence of an extended range of other factors potentially influencing growth and outlined in section 4.2.

The results for the impact of computer use are summarised in table 4.3. Results for the general growth variables are repeated in this table as they were generally not sensitive to the changes in model specification considered. However, in the case of Wholesale trade, the coefficient on capital (*kdot*) aligned more closely with the national accounts capital-income share.

Table 4.3 shows that the impact of computer use taken alone tended to be of lower significance than in the basic model (table 4.2). This can be attributed to a tendency for the combined effect of computer use with firm characteristics (ie the interaction terms of the model) outweighing the effect of computer use alone. Nevertheless, the results also suggest that computer use alone still had a positive and significant impact on productivity growth particularly in the medium term (represented by *ICT_d2, d3*). Generally speaking, the inclusion of interaction effects in the analysis has indicated that the relation between the uptake of a new technology and productivity growth is more complicated than portrayed by the basic model.

Figure 4.5 explores this issue by comparing the contribution of computer use to productivity growth in the basic and augmented models. It repeats the contribution of computer use estimated from the basic growth model (dark line) (from figure 4.4). It also shows the estimated impact of computer use in combination with other selected factors (light line).

The main finding from this comparison is that the impact of computers inclusive of interaction effects generally lies *above* the impact of computer use alone. In addition, the combined analysis also indicates that the impact of other factors differs with the duration of computer use:

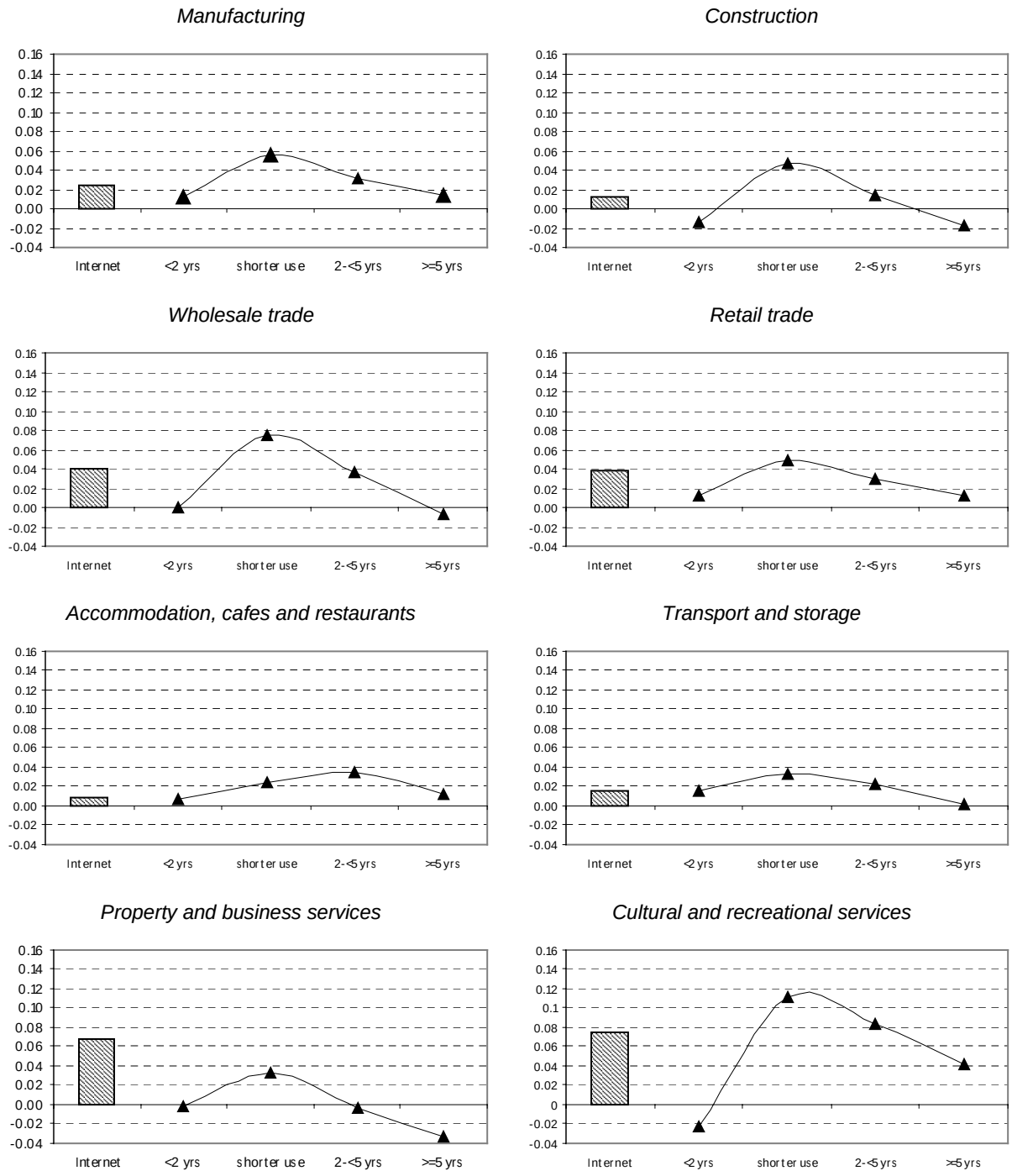
- firms using computers for less than two years appear to have little complementary association with innovation, skill and organisational changes for most sectors;
- the impact of computer use and complementary changes tends to generally taper off with the length of computer use;
- for the Manufacturing, Accommodation etc and Property & business services sectors, the dynamic pattern based on duration of computer use was maintained from the basic model.
- however, for some sectors the estimated dynamic pattern was modified, in particular:
  - for Construction and Cultural & recreation services the complementary changes appear to have had a substantial additional positive impact on productivity in the early stages of computer use;
  - for the Wholesale trade, Retail trade, Transport & storage sectors and Cultural & recreational services transition (or adjustment) costs appear to have been significant in periods following the commencement of computer use. These adjustment costs were identified with the reorganisation of firms as indicated by the total impact point (on light line) lying below the partial point (on dark line). For example, the Wholesale sector was subject to significant restructuring during the period, and it is possible that adjustment costs estimated in this simulation are reflective of widespread reorganisation of the sector (eg see Johnston et al. 2000).

Table 4.3 elaborates the relationship between computer use interactions and productivity growth. Some important findings reflected in this table include:

- a positive relation between the interaction of computer use and skill (*wagerate^2*) on productivity growth was found in all sectors. This relationship was generally maintained regardless of the duration of computer use;
- the interaction of computer use and the intensity of advanced business practices adopted by firms in the current and previous year, respectively (ie *_busprac and l1buspra*) typically had a positive and relevant impact on productivity growth in all but two sectors. Nevertheless, some evidence that interaction of advanced business practices also induced adjustment costs in certain circumstances is indicated by some negative coefficients. A similar picture emerged with the interaction of computer use with organisational change variables (*busrebi* and *l1busre*);
- while the link between computer use and 'innovation' (ie *innovat* and *l1inovat*) is frequently mentioned in the literature, this relation is not widely evident in the current analysis. For example, the interaction of computer use and product innovative activity of firms was estimated to have had a positive relation with productivity growth for the Manufacturing sector but mixed relations elsewhere. This may suggest that the key forms of innovation relate to 'input innovation' in the form of organisational change and re-skilling. Input innovation in these forms would be covered by other factors in the model. It may also suggest that the relation between computer use, product innovation and productivity is more complicated than modelled.

Figure 4.4 **Contribution of ICT to productivity growth[a] — basic model**

Percentage points



a Contribution of each ICT_d variable to average labour productivity growth evaluated at the BLS regression sample means.

Source: Regression analysis based on the BLS Confidentialised Unit Record File (CURF). See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98,* Cat. no. 8141.0.30.001).

Table 4.2 **Estimated impact of ICT on productivity growth — basic model**

Regression coefficients, Dependent variable is change in labour productivity, unweighted estimates

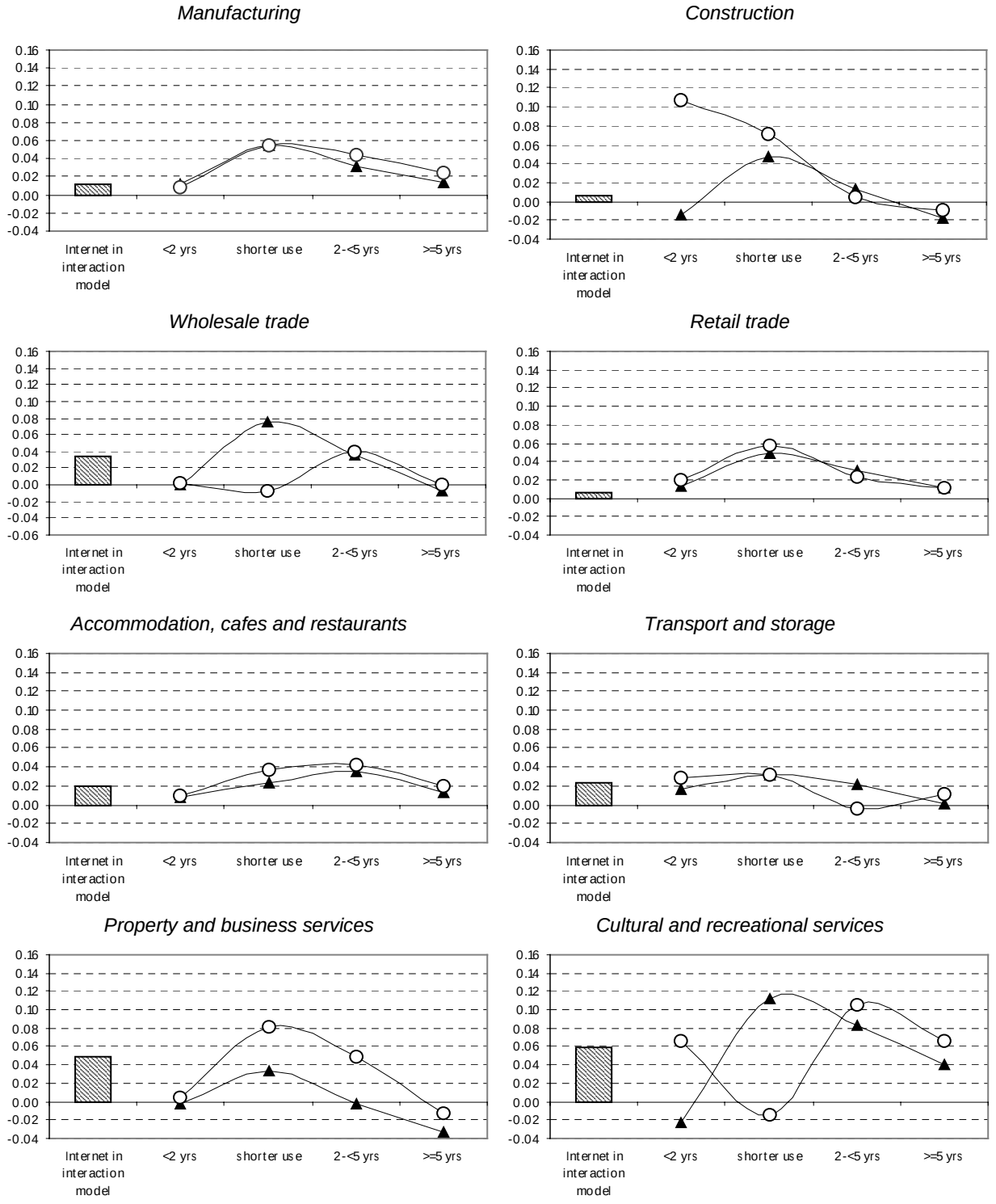
	Manufacturing	*Construction*	*Wholesale trade*	*Retail trade*	*Accommodation, cafes & restaurants*	*Transport and storage*	*Property and business services*	*Cultural and recreational services*
Intercept	1.498***	2.409***	1.815***	1.683***	1.333***	1.525***	1.756***	0.518**
Log(y_{t-1})	-0.423***	-0.638***	-0.478***	-0.48***	-0.391***	-0.415***	-0.45***	-0.224***
k dot	0.397***	0.272***	0.422***	0.385***	0.334***	0.390***	0.333***	0.297***
Size ('00)[b]	0.047*	0.210*	0.022	-0.228***	-0.199#	0.087	-0.004	-0.232#
ICT_d1(<2yrs)	0.124***	-0.095#	-0.005	0.124**	0.071	0.131#	-0.025	-0.148
ICT_d2 (short)	0.223***	0.319***	0.283***	0.202***	0.178#	0.169#	0.139#	0.539**
ICT_d3 (2-5yr)	0.130***	0.061	0.136**	0.124***	0.187***	0.097#	-0.011	0.318*
ICT_d4 (5+ yrs)	0.054*	-0.132#	-0.025	0.052#	0.110#	0.007	-0.152	0.210#
Netacc	0.064***	0.059	0.082***	0.072*	0.051	0.065	0.132***	0.163#
Capital share								
Australian national accounts[a]	0.40	0.26	0.30	0.20	0.24	0.36	0.37	0.41
Model summary								
Panel model	One way RE	One way RE	One way RE	One way RE	One way RE	One way RE	One way RE	One way RE
BLS observations	8077	1398	3375	2570	952	942	3615	565
Model observations	4503	623	1858	1299	477	432	1473	187
Number of firms[b]	1790	289	738	549	207	192	652	92
R^2	0.40	0.46	0.40	0.44	0.40	0.43	0.41	0.30
BP LM test	15.31	0.63	0.36	3.23	6.09	2.18	9.36	3.17
Hausman χ^2 test	3809.84	120.91	1196.7	352.64	318.25	122.1	970.07	179.24
Wald χ^2 test	1783.71	656.35	1738.84	1242.7	326.05	415.74	1329.71	91.67

*** significant at 1% level, ** 5% level, * 10% level, # relevant with the t-statistic is at least one. [a] National accounts capital income exclusive of an allowance for labour income of owner operators included in the national accounts aggregate gross operating surplus and mixed income. (Data were not available to complete the adjustment for Property & business services). [b] Firms in the BLS only in 1994-95 and firms with incomplete data not included in the regression. Typically, each firm is observed three times.

Source: Regression analysis based on the BLS Confidentialised Unit Record File (CURF). See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98,* Cat. no. 8141.0.30.001).

Figure 4.5 **Contribution of ICT and ICT with complementary factors to productivity growth[a] — basic and augmented models**

Percentage points



a Contribution of each computer use variable and its interaction effects to average labour productivity growth evaluated at the BLS regression sample means.

Source: Regression analysis based on the BLS Confidentialised Unit Record File (CURF). See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98,* Cat. no. 8141.0.30.001).

Table 4.3 **Estimated impact of ICT and complementary factors on productivity growth — augmented model**

Regression coefficients, Dependent variable is change in labour productivity, unweighted panel estimates

ICT interactions	*Manufacturing*	*Construction*	*Wholesale trade*	*Retail trade*	*Accom., cafes & restaurants*	*Transport & storage*	*Property & business services*	*Cultural & recreational services*	*Incidence[a] of*	
									Positives	*Negatives*
Intercept	1.614***	2.395***	2.082***	1.742***	1.655***	1.701***	1.998***	0.392#	8	
Log(y_{t-1})	-0.467***	-0.664***	-0.553***	-0.536***	-0.501***	-0.500***	-0.539***	-0.281***		8
k dot	0.358***	0.223***	0.342***	0.331***	0.265***	0.351***	0.246***	0.204***	8	
Size ('00)[b]	-0.076**	0.037	0.021	-0.368***	-0.478***	-0.052	-0.070#	-0.096		4
ICT_d1 (< 2yrs)	0.120**	-0.420**	-0.317**	0.107	-0.019	-0.111	-0.174#	0.599#	2	3
ICT_d2 (short)	0.130**	0.304#	0.241**	0.087	0.308#	-0.194	0.179#	-0.049	5	0
ICT_d31 (2-5yrs)	0.025	0.046	0.066	0.099#	0.120#	-0.043	-0.070	-0.012	2	0
ICT_d4 (> 5yrs)	-0.063*	-0.159#	-0.227***	-0.085#	-0.072	0.013	-0.327***	0.313#	1	5
Netacc	0.029*	0.030	0.070***	0.031	0.126#	0.099#	0.096**	0.129	5	
ICT and skill										
ICT_d1 X wagerate^2	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***		7	
ICT_d2 X wagerate^2	+ ***	+ ***	+ ***	+ ***		+ ***	+ ***	+ ***	7	
ICT_d3 X wagerate^2	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ ***	+ *	8	
ICT_d4 X wagerate^2	+ ***	+ ***	+ ***	+ ***	+ ***	+ *	+ ***	+ *	8	
ICT and product innovation										
ICT_d1*_INNOVAT					- ***					1
ICT_d2*_INNOVAT				- *	+ *				1	1
ICT_d3*_INNOVAT	+ **	- *		- #					1	2
ICT_d4*_INNOVAT		+ #	+ #		- *		- #		2	2
ICT_d1*L1INOVAT					+ #				1	
ICT_d2*L1INOVAT			- *			- #				2
ICT_d3*L1INOVAT					- #		- #			2
ICT_d4*L1INOVAT	+ ***	- #							1	1

(Continued on next page)

Table 4.3 **(continued)**

	Manufacturing	*Construction*	*Wholesale trade*	*Retail trade*	*Accom., cafes & restaurants*	*Transport & storage*	*Property & business services*	*Cultural & recreational services*	*Incidence of positives*	*negatives*
ICT and organisational changes										
ICT_d1*_BUSPRAC	- #			+ #					1	1
ICT_d2*_BUSPRAC	- **		- ***					-#		3
ICT_d3*_BUSPRAC			+***		- *	+ **	+ #		3	1
ICT_d4*_BUSPRAC								- #		1
ICT_d1*L1BUSPRA			+#	- #					1	1
ICT_d2*L1BUSPRA	+ ***		+ **					+ #	3	
ICT_d3*L1BUSPRA	+ *					- **		+ #	2	1
ICT_d4*L1BUSPRA	+ ***	+ #	+ #			+ #		+ #	5	
ICT_d1*BUSREBI	- #		+ #		+ #	+ *			3	1
ICT_d2*BUSREBI	- #		+ #	+**	+ #		+ **		4	1
ICT_d3*BUSREBI			- #							1
ICT_d4*BUSREBI	+ ***	- #			+ #		+ **		3	1
ICT_d1*L1BUSRE	+ #		- #		+ **		+ #		3	1
ICT_d2*L1BUSRE		- #								1
ICT_d3*L1BUSRE	+ ***	+ **			+ #				3	
ICT_d4*L1BUSRE					+ #				1	

*** significant at 1% level, ** 5% level, * 10% level, # relevant the t-statistic is at least one. a Only coefficients with t-statistic of one or more counted. **b** Firms in the BLS only in 1994-95 and firms with incomplete data not included in the regression. Typically, each firm is observed three times.

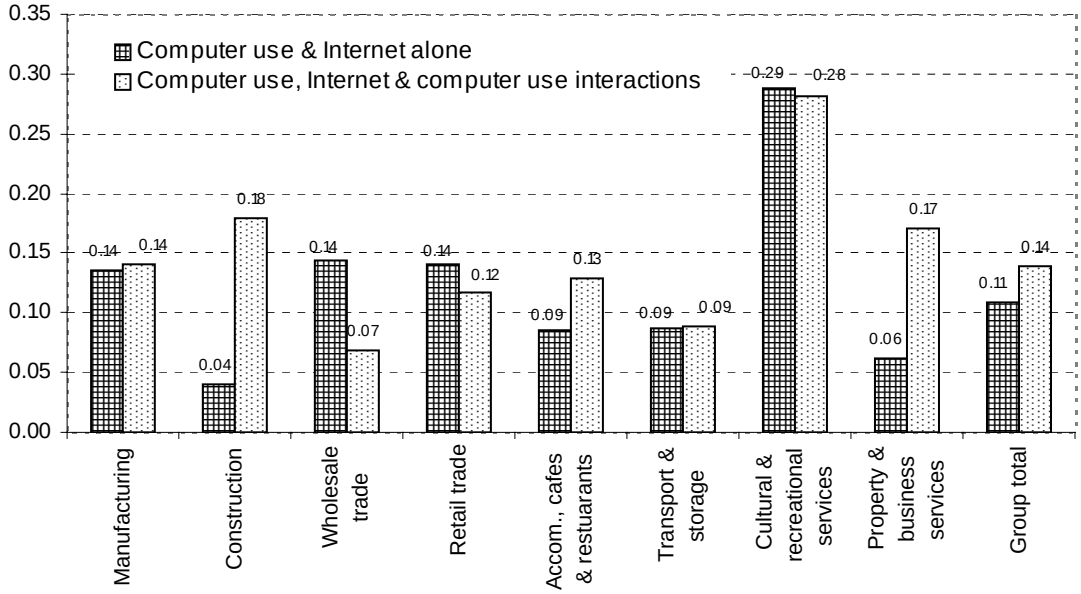
Source: Regression analysis based on BLS unit record data. See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98,* Cat. no. 8141.0.30.001).

4.5 A re-aggregated view

Overall, the current analysis suggests that the use of computers had a positive impact on firms productivity growth during a key mid-1990s period (figure 4.6). Computer use and Internet access alone is estimated to have raised MFP growth for the eight industry sectors (as a group) by over 0.11 percentage points per year over the period 1994-95 to 1997-98. Once the influence of associated skill, restructuring and organisational characteristics of firms is explicitly taken into account, MFP growth is estimated to have been raised by a further 0.03 points to 0.14 percentage points per year.

Noting the dynamic structure of the impact of computer uptake on MFP growth, as computer use becomes established, the incremental growth in MFP would decline (although the level effects would not decline). Growth theory would predict that future MFP growth would be contributed by other technological and organisational changes.

Figure 4.6 **Estimated contribution of ICTs to multifactor productivity growth[ab]**
Percentage points



a Contribution of Internet access and computer use alone (hatched bars), and the contribution of Internet access and computer use alone plus computer use interactions (spotted bars) evaluated at the mean of the sample of BLS firms included in the regression analysis. **b** The contributions of the Manufacturing, Construction, Wholesale trade, Retail trade, Accommodation etc, Transport & storage, Property & business services and Cultural & recreational services are weighted by their Australian national accounts valued added share to form the group total reported. These BLS sector activities cover around 52 per cent of GDP. Market sector activities (appendix A) not included in this analysis are Agriculture etc, Mining, Communications services and Finance & insurance. Property and business services is not included in the market sector in traditional productivity analyses (chapter 2).

Source: Estimates based on BLS data; EconData (2002).

4.6 Main findings

Firm-level data for the mid-1990s suggests that businesses using computers had, on average, higher labour productivity than non-uses. There was also a tendency for firms that had used computers longer to also have had higher labour productivity, on average. That said, the firm-level data did not indicate the underlying reasons for the productivity differences (eg differences in capital intensity versus efficiency differences) or explain the substantial variability in the level of labour productivity across firms. These considerations suggest that it would be difficult to use sectoral averages and simple comparisons of performance to draw inferences about the influence of computer use on productivity.

In order to link firm performance, as measured by MFP, with use of computers, an empirical model of economic growth was adopted. Simulations based on this model across eight industry sectors suggest that:

- the use of computers had a positive effect on MFP growth in the mid-1990s;
- the MFP effects varied across industries;
- the positive effect was largest in the earlier years of uptake but appears to taper off as firms return to 'normal' growth after the productivity boost of the new technology; and
- the level of human capital or skill base within firms, firms' innovation experience, application of advanced business practices and intensity of organisational restructuring interacted with the uptake of ICTs in boosting MFP growth, while the nature of the complementary relations appeared to vary significantly between sectors.

Overall, the analysis suggests that the uptake of computers was associated with a substantial reorganisation of industry and ways of working and that these developments raised the level of productivity amongst firms. The estimated contribution of these changes to growth over the period 1994-95 to 1997-98 was 0.14 percentage points per year.

The analysis also provides empirical support for the proposition that adoption and spread of a new general purpose technology, such as ICTs, can contribute to economic growth, although the intensity and duration of any individual contribution may vary between technologies and the implications of each technology in different sectors.

5 Conclusions

This paper has brought together aggregate and sectoral growth accounting and econometric analysis of a firm-level longitudinal dataset. The main objectives have been to explore the factors affecting the uptake of ICTs in Australia and to assess the effects of ICTs on output and productivity performance at the aggregate, sectoral and firm levels. The focus has been on ICT products — chiefly, computer hardware and software. ICT services have not been included.

5.1 Main findings

The aggregate, sectoral and firm level evidence examined in this paper presents a picture of strong ICT uptake in Australia in the 1990s which, in concert with restructuring of firms and production, has brought performance gains.

Uptake of ICTs

ICT investment has been growing strongly for decades, but initially from a low base. Real IT investment grew from around 3 per cent of total market sector investment in 1989-90 to around 19 per cent in 2000-01.

Services industries featured very prominently in the uptake of ICTs, absorbing at least three-quarters of total market sector IT investment (about 10 percentage points more than their share of market sector output). The Finance & insurance sector stands out as the main area of uptake, with a 25 per cent share of investment — more than double its output share. Manufacturing has also been a major user. These two sectors were major contributors to the acceleration in market sector IT use in the 1990s (table 5.1).

The uplift in ICT use has not just been a post-1995 phenomenon. Some sectors (Finance & insurance, Communication services and Cultural & recreational services) raised their use of ICTs strongly from the second half of the 1980s. Some cyclical and one-off factors may have also contributed to the perception of a post-1995 ‘boom’. Nevertheless, there were some genuine post-1995 developments, including more rapid technological advances and price declines.

There was rapid diffusion of ICTs among firms in the 1990s to match the rapid growth in investment and use. In 1993-94, around 50 per cent of firms in a wide range of sectors used computers and around 30 per cent had Internet access. By 2000-01, these proportions had grown to nearly 85 and 70 per cent respectively. But the penetration still varies across industries (table 5.1).

The firm-level analysis in this paper has pointed to the ‘march of time’ as a significant explanator of ICT uptake and Internet access. This covers time-related factors and could include the continual decline in ICT prices, lower adjustment costs (learning) and network effects (advantages from more users joining computer networks).

The influence of other factors on ICT and Internet use varied across industry sectors. But positive relationships with firm size and skill were commonly found. The earliest and most intensive users of ICTs and the Internet tended to be large firms with skilled managers and workers. Computer use was also commonly associated with use of advanced business practices, company incorporation and firm reorganisation. There also appears to have been a link between openness to trade and the use of the Internet.

Table 5.1 **Summary statistics of ICT use, MFP growth and effects of ICT use on productivity growth**

	National accounts (1993-94 to 1990-00)				*Business Use of IT (2000-01)*			*Effect of ICT use[c] (1994-95 to 1997-98)*			
	IT growth[a]		*MFP growth*		*Proportion of firms using*			*ICT alone*		*With complements*	
	Sector	*Contrib to Mkt sect acceler[b]*	*Sector*	*Contrib to Mkt sect acceler[b]*	*Computers*	*Internet*	*Web*	*Sector*	*Contribution to total*	*Sector*	*Contribution to total*
	%pa	pp	%pa	pp	%	%	%	pp	pp	pp	pp
Agriculture	27.4	0.1	3.4	-0.1	-	-	-				
Mining	25.0	0.1	2.2	0.0	88	79	30				
Manufacturing	29.0	1.2	0.9	-0.4	81	66	28	0.14	0.04	0.14	0.04
Electricity, gas & water	28.8	0.8	1.6	-0.2	95	89	44				
Construction	23.1	0.1	1.1	0.3	80	64	10	0.04	0.00	0.18	0.02
Wholesale trade	22.2	0.0	5.2	1.2	89	77	33	0.14	0.02	0.07	0.01
Retail trade	26.2	0.2	0.4	0.1	78	57	22	0.14	0.02	0.12	0.01
Accom., etc	28.6	0.1	0.3	0.2	71	53	26	0.09	0.00	0.13	0.01
Transport & storage	19.5	-0.3	1.8	0.1	76	60	19	0.09	0.01	0.09	0.01
Communications	22.5	0.0	4.0	-0.2	78	58	20				
Finance & insurance	26.8	1.7	1.2	0.2	90	81	22				
Cult. & rec. services.	26.2	0.1	-3.7	-0.1	87	74	30	0.29	0.01	0.28	0.01
MARKET SECTOR	**25.6**	**4.1**	**1.8**	**1.1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Prop. & bus. services					93	85	25	0.06	0.01	0.17	0.03
Health & comm.					89	72	14				
Personal services					72	52	22				
TOTAL					**84**	**69**	**22**		**0.11**		**0.14**

a Annual average rates of growth in IT capital services. **b** Sector contribution to acceleration in market sector growth between the last two productivity cycles. **c** Effect on annual MFP growth from ICT use and complementary factors, evaluated at mean values.

Performance effects

The use of ICTs has contributed to Australia's growth in output and labour productivity. Growth in inputs of IT accounted for a quarter of 1990s output growth of 3.4 per cent a year and made a reasonably strong contribution of 0.4 of a percentage point to output acceleration in the 1990s. IT capital deepening accounted for a third of labour productivity growth of 3.0 per cent a year in the 1990s productivity cycle and contributed 0.4 of a percentage point to labour productivity acceleration.

However, controlling for cyclical effects, increased ICT use has not affected the overall contribution from capital inputs. Rather, the contribution of increased ICT use has been offset by slower growth in the use of other forms of capital. (This finding is a departure from other Australian and overseas studies, which have not taken account of cyclical effects and the offsetting effect of lower growth in other capital.) This also means that the rate of substitution of capital for labour has remained unchanged.

With no net effect on capital deepening, the net effect of ICT on labour productivity growth hinges on whether and to what extent it influences MFP growth. With little ICT production in Australia, there are no nationally-significant MFP gains from ICT production. Comparison with the USA suggests that the contribution to Australia's aggregate MFP growth from ICT use has been of importance, but not major — one or two tenths of a percentage point of annual average growth, up to a maximum of 0.3 of a percentage point. The firm-level analysis provides strong supporting evidence of a link between ICT use and MFP growth. Aggregation of firm-level effects across industry sectors also suggests that the aggregate MFP growth effect is around one or two tenths of a percentage point (table 5.1).

There is no simple correlation between ICT use and MFP growth across industries (table 5.1). To a large extent, this reflects the fact that non-ICT factors, including policy reform, have had independent effects on productivity performance. But it also reflects the fact that the links between ICT use and performance are complex, involving lags and the joint influence of ICTs interacting with changes in the organisation of production. Even allowing for these factors, the scope for ICT-related productivity gains may also vary across industries.

At the sectoral level, the association between ICT use and productivity growth is clearest in Finance & insurance. A somewhat weaker association appears in Wholesale trade. These findings accord with overseas evidence of links between ICT use and productivity growth in financial intermediation and distribution (and business services).

The firm-level econometric analysis in this paper has found positive links between ICT use and productivity growth in all industry sectors examined. Significant interactions between ICT use and complementary organisational variables were also found in nearly all sectors. In this study, the complementary factors for which there are data and which were found to have significant influence were: human capital, history of innovation, use of advanced business practices and intensity of organisational restructuring.

However, the strength of the links to ICTs, and the importance of complementary factors, varies across industries (table 5.1). Controlling for a range of other factors, ICTs were found to have the greatest influence on productivity growth in Cultural & recreational services. (Finance & insurance was not included in the analysis due to data limitations.) Manufacturing, Wholesale trade (without complements), Retail trade (without complements), Construction (with complements), and Property & business services (with complements) formed a middle group.

Taking relative sector size into account, ICT use in Manufacturing, Property & business services and Construction had the most effect on aggregate productivity performance (table 5.1).

The micro analysis has also highlighted dynamics and the importance of lags. Productivity growth effects in industry sectors taper over time, meaning that the ultimate productivity effect from adoption of (a type or vintage of) of ICT is a step up in levels, rather than a permanent increase in the rate of growth. Naturally, further technical developments over time can set further productivity-enhancing processes in train.

Whilst further research is needed, the finding of negative effects of complements in some industries appears consistent with there being adjustment costs in the short to medium run. In Wholesale trade, for example, there were negative interactions between ICTs and complements in the short to medium term, compared with the effects of ICTs alone. But, importantly, the interactions added to productivity growth in the longer term.

Although the aggregate evidence suggests that ICTs do not affect aggregate employment growth, the firm-level evidence suggests that the structure of employment is affected. The micro analysis has confirmed earlier research that ICT use is biased toward higher levels of skill.

5.2 Further interpretation of results

The micro analysis in this paper supports the view reached in earlier research that Australia has derived productivity gains associated with the use of ICTs. Production of ICT equipment is not necessary to access ICT-related productivity gains.

The paper also supports the general purpose technology view of ICTs — that is, that ICTs generate productivity gains by enabling restructuring, new products and new ways of producing, distributing and transacting. The firm-level analysis has found that ICTs have significant effects in their own right, but that they also have influence through their interaction with skills, restructuring and so on.

The aggregate, sectoral and firm-level perspectives give somewhat different views on the importance of ICT-related productivity effects. The aggregate view is that the effects have been reasonably modest. The sectoral view provides a plausible explanation — that ICT use and performance effects have been concentrated in a few sectors, especially Finance & insurance and Wholesale trade. The firm-level view confirms that performance effects are larger in some sectors, but also suggests that, controlling for other influences, the performance effects at the firm level are significant across the range of industry sectors.

These differences suggest that the weaker relationship at the broad level comes from aggregation — the strong positive effects in some firms and industries are counterbalanced in a given period by weaker effects in other firms and industries. The aggregate performance effects over time depend on the rate of development of ICTs, their diffusion, lags, complementary changes, adjustment costs and the productivity-enhancing potential of ICTs in different industries. In principle, the aggregate productivity effects of ICTs could increase above that found in the time periods analysed here.

There are differences in measurement and approach between the aggregate, sectoral and firm-level analyses presented in this paper. The aggregate and sectoral analysis simply accounts for growth in output and labour productivity in terms of growth in ICT use. ICT use is measured in volume terms that take account of improvements in the quality of equipment. The firm-level analysis, on the other hand, is an econometric approach that controls for the influence of many other factors on productivity growth and, in principle, can identify more precise ICT-

performance relationships. ICT use, in this case, is measured in terms of whether ICTs are used or not and the duration of use, rather than in volume terms. Even with the difference in approach, there is remarkable similarity in the aggregate productivity effects derived from both the econometric and growth accounting methods.

The firm-level analysis also helps to resolve the puzzle about the apparent lack of productivity response to ICT use in Manufacturing. Controlling for other factors, a relatively large and significant relationship between ICT use and productivity is found. In other words, the analysis suggests that the drop in Manufacturing productivity performance in the 1990s is due to factors unrelated to ICT use and associated restructuring, etc.

Whilst the analysis has supported the importance of ICTs and associated organisation and innovation variables, it has not spelt out the mechanisms through which ICTs generate productivity improvements. (The case studies undertaken for this project are intended to identify such mechanisms.) But the evidence is consistent with there being major restructuring in the economy, particularly through financial transactions and management and the distribution of goods. It is also consistent with ICTs assisting performance improvement through better coordination of production and distribution, lower transactions costs, development of new products, improved management and changes in work arrangements.

The analysis in this paper supports the view that aggregate productivity growth can be promoted by fostering the 'smart' use of ICTs — not just the use of ICTs but their use as part of a process of economic restructuring, organisational change and innovation in products and processes.

Use of ICTs can be fostered through ensuring access to the latest technological advances and with the full flow-through benefit of price reductions. (Australia has also enjoyed real income gains through the terms of trade effects associated with importing most of its ICT equipment requirements.) Appropriate access to reliable communications infrastructure is also likely to be important.

This paper has also pointed to the significance of management and employee skills to the uptake and use of ICTs. This has implications for education and training. The analysis suggests that decision makers require not only ICT-related skills (seeing the opportunities that ICTs provide) but the management skills to implement the necessary structural changes.

The links between ICTs and restructuring also points to the importance of flexibility. This can have wide policy implications including the reduction in unnecessary 'process' regulation, ensuring that product and factor markets operate as freely as possible, consistent with social and environmental objectives, and tailoring the education and training systems to meet the need for flexibility.

The main tenets of policy reforms in Australia over the past two decades are likely to have done a lot to foster the smart use of ICTs. Reforms have provided competitive incentives to take up ICTs in order to improve performance; have opened the economy to trade, investment and the transfer of technology, including access to ICTs; and have increased the flexibility of the economy to adjust. Some of these reforms will have continuing effect as they provide ongoing incentives and greater ability for businesses to review and change what they do and how they do it.

A Industry sector classification

The Australian study draws on data from the Australian National Accounts, the (Australian) Business Longitudinal Survey (BLS) and the (Australian) Business Use of Information Technology Survey (BUIT). The sectoral coverage adopted in each collection is based on the Australian and New Zealand Standard Industry Classification (ANZSIC, ABS Cat. no. 1292.0). This appendix outline the details of industry classification.

A.1 Industry sectoring

The industry divisions of the ANZSIC are listed in the table below together with the industry coverage of the key survey-based data sources referred to in this study.

Table A.1 **Industry divisions**

				Business Longitudinal Survey	
	ANZSIC divisions	*National Accounts market sector*	*Business Use of Information Technology Survey*	*Covered*	*Included in regression analyses*
A	Agriculture, forestry & fishing	√			
B	Mining	√	√	√	
C	Manufacturing	√	√	√	√
D	Electricity, gas & water supply	√	√		
E	Construction	√	√	√	√
F	Wholesale trade	√	√	√	√
G	Retail trade	√	√	√	√
H	Accommodation, cafes & restaurants	√	√	√	√
I	Transport & storage	√	√	√	√
J	Communications services	√	√		
K	Finance & insurance	√	√	√	
L	Property & business services		√	√	√
M	Government administration & defence				
N	Education				
O	Health & community services		√		
P	Cultural & recreational services	√	√	(partial)	√
Q	Personal & other services		√	(partial)	

Sources: ABS (ANZSIC 1993, Cat. no. 1292.0); ABS (Australian National Accounts, Concepts Sources and Methods, Cat. no. 5216.0); ABS (Business Use of Information Technology 2000-01, Cat. no. 8129.0); ABS (Business Longitudinal Survey, Confidentialised Unit Record File, 1994-95 to 1997-98, Cat. no. 8141.0.30.001).

The statistical unit for which data are collected and made available is termed the *management unit*. The ABS defines the management unit as the highest level accounting unit within a business, having regard to homogeneity of activities, for which detailed accounts are maintained. In most cases, it coincides with the legal entity owning the business (that is, company, partnership etc). In the case of larger diversified businesses, there may be more than one management unit, each coinciding with a division or 'line of business'. For larger businesses, a management unit may coincide with one legal entity, a part of a legal entity, or combination of legal entities (or parts thereof) under common ownership or control.

As indicated in the table, the coverage of activities varies between series.

In particular, the national accounts 'market sector' is defined to include those industry divisions for which independent measures of outputs and inputs are available. The lack of an independent measure of output makes it impractical to disaggregate output growth of non-market sector activities into capital, labour and productivity components.

The Business Longitudinal Survey (BLS) covers all businesses except:

- 'non-employing' businesses;
- units classified to the general government institutional sector (although Public Trading Enterprises were included); and
- units classified to the ANZSIC industries:
  - Agriculture, forestry & fishing (division A);
  - Electricity, gas & water supply (division D);
  - Communications services (division J);
  - Government administration & defence (division M);
  - Education (division N)
  - Health & community services (division O);
  - Libraries, museums and parks and gardens (groups 921, 922 and 923 from division P); and
  - Other services and Private households employing staff (subdivisions 96, 97 from division Q).

The Business Use of Information Technology Survey (BUIT) covers all businesses in Australia, except:

- 'non-employing' businesses.
- units classified to the general government institutional sector (although Public Trading Enterprises are included); and
- units classified to ANZSIC industries:
  - Agriculture, forestry & fishing (division A); and
  - Education (division N).

While the industry coverage of analyses in this study in generally conform to the coverage of basic data series, the regression analyses based on BLS data and presented in chapter 3 and 4 do not include results for the mining or Finance & insurance sectors because of the 'lumpiness' of changes in a small number of large firms that comprise the Mining sector and the lack of information to define firm value added in the Finance & insurance sector. The coverage of firms in BLS is provided in next section.

A.2 Details of BLS sectors

The activity coverage of BLS sectors is detailed in table A.2.

Table A.2 **Industry details of BLS sectors**

ANZSIC divisions		*Details of sub sectors*
C Manufacturing	21	Food, Beverage and Tobacco Manufacturing
	22	Textile, Clothing, Footwear and Leather Manufacturing
	23	Wood and Paper Product Manufacturing
	24	Printing, Publishing and Recorded Media
	25	Petroleum, Coal, Chemical and Associated Product Manufacturing
	26	Non-Metallic Mineral Product Manufacturing
	27	Metal Product Manufacturing
	28	Machinery and Equipment Manufacturing
	29	Other Manufacturing
E Construction	41	General Construction
	42	Construction Trade Services
F Wholesale Trade	45	Basic Material Wholesaling
	46	Machinery and Motor Vehicle Wholesaling
	47	Personal and Household Good Wholesaling
G Retail Trade	51	Food Retailing
	52	Personal and Household Good Retailing
	52	Motor Vehicle Retailing and Services
H Accom., Cafes & Restaurants	571	Accommodation
	572	Pubs, Taverns and Bars
	573	Cafes and Restaurants
	574	Clubs (Hospitality)
I Transport and Storage	61	Road Transport
	62	Rail Transport
	63	Water Transport
	64	Air and Space Transport
	65	Other Transport
	66	Services to Transport
	67	Storage
L Property and Business Services	*77*	*Property Services*
	771	Property Operators and Developers
	772	Real Estate Agents
	773	Non-Financial Asset Investors
	774	Machinery and Equipment Hiring and Leasing
	78	*Business Services*
	781	Scientific Research
	782	Technical Services
	783	Computer Services
	784	Legal and Accounting Services
	785	Marketing and Business Management Services
	786	Other Business Services

(continued on next page)

Table A.2 **(continued)**

ANZSIC divisions		*Details of sub sectors*
P Cultural and Recreational Services	*91*	*Motion Picture, Radio and Television Services*
	911	Film and Video Services
	912	Radio and Television Services
	92	*Libraries, Museums and the Arts* [a]
	924	Arts
	925	Services to the Arts
	93	*Sport and Recreation*
	931	Sport
	932	Gambling Services
	933	Other Recreation Services

[a] Libraries, museums and parks and gardens were not covered in BLS. See text.

Sources: ABS (ANZSIC 1993, Cat. no. 1292.0); ABS (Business Longitudinal Survey, Confidentialised Unit Record File, 1994-95 to 1997-98, Cat. no. 8141.0.30.001).

B ICT and other variables from Business Longitudinal Survey

Table B.1 of this appendix lists ICT use variables measured in the BLS-based data base used in this study.

Table B.1 **ICT variables**

Mnemonic	*Name*	*Range*	*Definition*
COMBUS	ICT use	[0,1]	1 if firm uses computers, zero otherwise (imputed using 1996-97, 1997-98 data)
COMDUM1	Recent take up of computers	[0,1]	1 if firm used computers < 2 years, zero otherwise (imputed using 1996-97, 1997-98 data)
COMDUM2	Recent/Medium-term user	[0,1]	1 if firm used computers 2 to <5 years, zero otherwise (imputed using 1996-97 data)
COMDUM3	Medium-term computer user	[0,1]	1 if firm used computers 2 to <5 years, zero otherwise (imputed using 1996-97, 1997-98 data)
COMDUM4	Longer-term computer user	[0,1]	1 if firm used computers 5 or more years, zero otherwise (imputed using 1996-97, 1997-98 data)
_ELSM	Used electronic stock management	[0,1]	1 if firm used computers & used this facility in 1996-97, zero otherwise
_ELEOP	Used electronic ordering/purchasing	[0,1]	as above
_ELEFT	Used electronic financial transfers	[0,1]	as above
ELEOTH	Other computer facilities	[0,1]	1 if firm uses computers and reports zero against preceding items, zero other wise
CINTORD	Intensity of computer use	[0-3]	0 not computer user 1 firm used single facility in 1996-97 2 firm used 2 facilities in 1996-97 3 firm used 3 facilities in 1996-97
_COMLON	Length of computer use	[0-3]	0 not computer user in 1996-97 1 used computers < 2 years in 1996-97 2 used computers 2 to <5 years in 1996-97 3 used computers 5 or more years in 1996-97
_NETACC	Internet access	[0,1]	1 if firm has Internet access, zero otherwise (imputed using 1996-97, 1997-98 data)

Source: Analysis of BLS data in ABS (*Business Longitudinal Survey, Confidentialised Unit Record File, 1994-95 to 1997-98*, Cat. no. 8141.0.30.001).

Table B.2 lists other variables used in the regression analyses in chapters 3 and 4. The variables are groups according to firm characteristic groups in table 3.1. There are around 50 BLS-based variables referred to in the analyses. To make the analyses tractable and to avoid problems of multicolinearity, the number of items included in the regression analyses was substantially reduced from the possible maximum. The guidelines referred to in specifying the models reported in chapter 3 are set out below. The guidelines for specifying the growth modals reported in chapter 4 our outlined in appendix C.

Choice of explanatory variables in characteristics of firms using ICTs models

Explanatory variables were chosen from the above list using the following guidelines:

- items subject to specific comment in the literature (eg firm employment size, firm age) were included;
- at least one item from each group of variables was included. If items within a group cover different themes, each theme was represented in the model (eg the items relating to union membership and type of legal organisation in the group 'organisational and management conditions' are both included);
- summary indexes were used in place of individual variables (eg the model includes an index of intensity of business restructuring (*_busrest*) formed from 11 component variables). In future work, it may be practicable to decompose such summary indexes to highlight the significance of individual components or groups of components;
- indexes of organisational characteristics were included to reflected firm responses in a particular year (eg whether a firm restructured in a particular year as reflected by *_busrest*) and to reflect a 'typical' characteristic (whether they restructured in any year of the survey as reflected by *restd1*)
- possible summary items from a group were selected on the basis of statistical significance and impact of the variables inclusion/exclusion on the predictive power of the model; and
- period dummies were including according to the coverage of the model (eg the model on computer use included data pooled across the years 1994-95 to 1997-98 and hence included time dummies representing the last 3 years (with 1994-95 being the reference case).

This selection process resulted in the inclusion of nearly 20 variables in each model, with some variation due to the inclusion of time dummies depending on the time coverage of the model.

While reflecting the characteristics of firms using ICTs, the models applied in chapter 3 are not predictive in the sense that they do not suggest conditions that may lead a firm to take up ICT. This feature reflects the use of historical data from the BLS for the analysis that observes the condition of firms with ICTs in particular reference years rather than the conditions of a planning process leading to the adoption of the new technology.[29] Secondly, because data screening processes undertaken to create the model-estimation data bases from the full BLS data sets (unintentionally) tended to favour the inclusion of firms using computers by 1994-95 (the first year of the BLS), the scope for testing the explanatory power of the binary choice models was limited. Nevertheless, where model testing was possible (particularly in the regression on Internet access), the explanatory power of the models proved to be quite good.

[29] In this sense, the current study differs from the study by Hollenstein: Determinants of the Adoption of Information and Communication Technologies, an Empirical Analysis Based on Firm-level Data for the Swiss Business Sector (2002), which investigates the decision of firms to adopt ICTs.

Table B.2 **Other variables**

Mnemonic	*Name*	*Range*	*Definition*
Time dummies			
TDUM96	Year dummy 1996	[0,1]	1 for year 1996
TDUM97	Year dummy 1997	[0,1]	1 for year 1997
TDUM98	Year dummy 1998	[0,1]	1 for year 1998
Basic growth analysis variables			
_VADDED	Value added	Value	Total sales minus total expenses, plus opening stocks minus closing stocks
CAPSH	Capital share	Percent	Gross operating surplus divided by value added
LABSH	Labour share	Percent	Wages divided by value added
LABPROD (y)	Labour productivity	Value	Value added divided by total full time equivalent employment (_TOTFTE)
DLABPROD ($\dot{y}$ *or ydot*)	Logarithmic change or growth rate of labour productivity	Value	Current period labour productivity divided by last years' labour productivity and expressed in logarithms
KINTENS (k)	Capital intensity	Value	Total assets divided by full time equivalent employment
DKINTENS ($\dot{k}$ *or kdot*)	Logarithmic change or growth rate of capital intensity	Value	Current period capital intensity divided by last years' capital intensity and expressed in logarithms
Absorptive capacity			
_TOTFTE	Total full time equivalent employment	Persons	Full time employment plus part time adjusted to a full tome equivalent using a constant ratio of 0.43 derived from Australian labour force surveys
_BUSLOCS	Business locations	Number	
_AGE_A	Age of firm	[1-5]	<2 years old
			2 to < 5 years old
			5 to < 10 years old
			10 to < 20 years old
			20 or more years old
DAGE1	Firms less than 5 years old in 1995	[0,1]	1 for firms less than 5 years old in 1995, zero otherwise
DAGE2	Firms 5 or more years old in 1995	[0,1]	1 for firms 5 or more years old in 1995, zero otherwise
L1NEWBUS	New business	[0,1]	1 for new firm; zero otherwise
Financial conditions			
EBITFTE	Earnings before interest and tax to value of fixed tangible assets	Ratio	Earnings measured as value added less labour income
DEBIT1	Dummy - low profitability firms	[0,1]	1 for firms with EBITFTE < 0.05, zero otherwise
DEBIT2	Dummy – medium profitability firms	[0,1]	1 for firms with EBITFTE < 0.05, zero otherwise
DEBIT3	Dummy – higher profitability firms	[0,1]	1 for firms with EBITFTE > 0.1, zero otherwise

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Table B.2 **(continued)**

Mnemonic	*Name*	*Range*	*Definition*
Human capital			
EDUCATN	Highest educational attainment achieved by major decision maker	[0-3]	0 not applicable 1 school 2 trade 3 tertiary
TERTQUA	Tertiary qualifications of major decision maker in management, commerce or admin.	[0,1]	1 for firms with major decision maker with specified tertiary qualifications, zero otherwise
WAGERATE	Average wage	Value	Wages divided by full time equivalent of persons employed and not adjusted for owner operator
Information and knowledge			
_BUSPRAC & L1BUSPRA	Index of intensity of use of six advanced business practices (ABP, see below)[a] and their one year lag	[0-1]	0 no use of ABP to 1 use of six ABP
_BUSPBIN	Firm uses ABP	[0,1]	1 if firm used any of the six items of ABP, zero otherwise
Index (ABP) components (not separately included)			
_BPFOR	Formal business planning	[0,1]	1 if firm undertook formal planning, zero otherwise
_BPBUD	Budget forecasting	[0,1]	1 if firm undertook budget forecasting, zero otherwise
_BPREG	Regular income and expenditure reports	[0,1]	1 if firm undertook regular reporting, zero otherwise
_BPNET	Formal networking with other firms	[0,1]	1 if firm undertook networking, zero otherwise
_BPCOM	Comparison of firm performance with other firms during financial year	[0,1]	1 if firm made comparisons, zero otherwise
_BPEXP	Export marketing	[0,1]	1 if firm undertook export marketing, zero otherwise
Organization and management conditions			
Corporate structure			
TOLO	Type of legal organisation	[0,1]	1 for incorporated firms, zero otherwise
Labour market & industrial relations			
_UNIONME	Percentage of persons employed that were union members at 30 June	[1-6]	1. no union role; 2. up to 10 percent coverage; 3. 11 to 25 percent coverage; 4. 26 to 50 percent coverage; 5. 51 to 75 percent coverage and 6. 76 to 100 percent coverage
_CONOUT	Contract out activities previously done by employees of the firm	[0,1]	1 for firm who contract out activities, zero otherwise

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Table B.2 **(continued)**

Mnemonic	*Name*	*Range*	*Definition*
_ARRAWAR	Firm has an award form of employment arrangement during the last pay period in June	[0,1]	1 for firm who has this type of arrangement, zero otherwise
_ARRCONT	Firm has an individual contract form of employment arrangement during the last pay period in June	[0,1]	1 for firm who has this type of arrangement, zero otherwise
_ARRUNRE	Firm has an unregistered enterprise employment arrangement during the last pay period in June	[0,1]	1 for firm who has this type of arrangement, zero otherwise
_ARRREG	Firm has a registered enterprise agreement during the last pay period in June	[0,1]	1 for firm who has this type of arrangement, zero otherwise
Organizational and processing efficiency			
_BUSREST	Index of intensity of major change against eleven types of change (MJCS, see below).[b]	[0-1]	0 no major change to 1 all 11 forms of major change
_BUSREBI & L1BUSRE	Firm made major changes in current and past years	[0,1]	1 if firm made major change in any of the eleven items of _BUSREST, zero otherwise
RESTFREQ	Frequency of major change	[0-4]	0 if no major change over 4 years 1 major change(s) in 1 year 2 major change(s) in 2 years 3 major change(s) in 3 years 4 major change(s) in each year
RESTD1	Firms with major change in any year	[0,1]	1 if major change in any year, zero otherwise
RESTD2	Firms with major changes in any 2 years	[0,1]	1 if major change in any 2 years, zero otherwise
RESTD3	Firms with major changes in any 3 years	[0,1]	1 if major change in any 3 years, zero otherwise
RESTD4	Firms with major changes in each year	[0,1]	1 if major change in each year, zero otherwise
Index (MJCS) components (not separately included)			
_MJCRANG	Range of products or services	[0,1]	1 if major change occurred, zero otherwise
_MJCADVE	Advertising	[0,1]	Ditto
_MJCDIST	Distribution	[0,1]	Ditto
_MJCDOM	Domestic markets targeted	[0,1]	Ditto
_MJCEXP	Export markets targeted	[0,1]	Ditto
_MJCSOFT	Accounting software	[0,1]	Ditto
_MJCPROD	Production technology	[0,1]	Ditto
_MJCMGTT	Management training	[0,1]	Ditto

(Continued on next page)

Table B.2 **(continued)**

Mnemonic	*Name*	*Range*	*Definition*
_MJCTRN	Technical and on the job training	[0,1]	Ditto
_OMCBUST	Business structure	[0,1]	Ditto
_OMCOTHE	'Other' business changes	[0,1]	Ditto
Product innovation			
_INNOVAT & L1INOVA	Firm developed new or substantially changed products or services during current year or past year	[0,1]	1 if firm made change, zero otherwise
INNOFREQ	Frequency of product change	[0,4]	0 no product change 1 product change(s) in 1 year 2 product change(s) in 2 years 3 product change(s) in 3 years 4 product change(s) in each year
INNOD1	Firms with new or substantially changed product in any year	[0,1]	1 if major change in any year, zero otherwise
INNOD2	Firms with changes in any 2 years	[0,1]	1 if major change in any 2 years, zero otherwise
INNOD3	Firms with changes in any 3 years	[0,1]	1 if major change in any 3 years, zero otherwise
INNOD4	Firms with changes in each year	[0,1]	1 if major change in each year, zero otherwise
_RANDD	Performed or paid others to perform research & development	[0,1]	1 if firm performed or paid to others, zero otherwise
Openness			
_EXPINT	Export intensity	Ratio	Ratio of value export sales to total value of sales
_EXPBI	Export status	[0,1]	1 if firm exported, zero otherwise
Sample bias			
_WGHT_F	Cross sectional flow weight assigned by ABS reflecting sample design	Value	Probability of inverse selection of a firm in the sample

a Defined as: $\sum_{n=1}^{6}\left(\frac{ABP_{nj}}{6}\right)$ for each firm *j*. **b** Defined as: $\sum_{m=1}^{11}\left(\frac{MJCS_{mj}}{11}\right)$ for each firm *j*.

Source: Analysis of BLS data in ABS (Business Longitudinal Survey, Confidentialised Unit Record File, 1994-95 to 1997-98, Cat. no. 8141.0.30.001).

C Explanatory variables included in the growth model

The explanatory variables included in the basic and augmented empirical models reported in chapter 4 are outlined in table C.1 together with a rational for the inclusion of each.

Table C.1 **Explanatory variables included in the growth models**

Explanatory variable[a]	*Study*	*Rationale*	*Expected sign*
Basic model variables			
Log lag labour productivity ($\log(y_{t-1})$ defined as log($LABPROD_{t-1}$))	Barro and Sala-i-Martin (1995) and Mankiw, Romer and Weil (1992), Baldwin and Sabourin (2001)	Allow for transitional dynamics of firm's growth path. Firms with low levels of capital stock will have a higher marginal product of capital and hence for similar rate of capital accumulation, grow faster than those which already have higher levels of capital. A coefficient value of around -0.3 would indicate most of the gap between low and high productivity firms is eliminated after ten years (Bartlesman and Doms 2000)	negative
Logarithmic change in capital intensity ($\dot{k}$ defined as *DKINTENS*)	Broersma, McGuckin and Timmer (2002), Baldwin and Sabourin (2001)	Allow for the growth in the total value of capital employed per person in the production process. It is measured as the total book value of assets per person	positive
Size (represented by full time equivalent employment defined as *_TOTFTE*)	Atrostic and Nguyen (2001), Broersma, McGuckin and Timmer (2002), Baldwin and Sabourin (2001)	Allow for networking externalities within firms. Firm size is proxied through the number of full time equivalent (FTE) employees. A negative coefficient would suggest that size creates coordination problems for firms in the introduction of productivity improving innovations. A positive coefficient would suggest that the absolute size gives firms a productivity advantage, such as could occur when a firm can spread the benefits of a fixed cost innovation over a larger base	positive/ negative
ICT variables ICT_d1 (COMDUM1) ICT_d2 (COMDUM2) ICT_d3 (COMDUM3) ICT_d4 (COMDUM4) _netacc	Atrostic and Nguyen (2001), Broersma, McGuckin and Timmer (2002), McGuckin *et al* (1998), Greenan and Mairesse (1996), Brynjolfsson and Hitt (2000)	Allow for multifactor productivity effects arising from the adoption of the new general purpose technology (see chapter 3 for definition of variables).	positive

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Table C.1 **(continued)**

Explanatory variable	*Study*	*Rationale*	*Expected sign*
Augmented model variables			
Variables interacted with each computer use dummy variable			
ICT & human capital			
ICT_d1*WAGERATE^2 ICT_d2*WAGERATE^2 ICT_d3*WAGERATE^2 ICT_d4*WAGERATE^2	Bartlesman and Doms (2000)	Allow for skill and experience related labour productivity.	positive
ICT & product innovation			
ICT_d1*_INNOVAT ICT_d2*_INNOVAT ICT_d3*_INNOVAT ICT_d4*_INNOVAT ICT_d1*L1INOVAT ICT_d2*L1INOVAT ICT_d3*L1INOVAT ICT_d4*L1INOVAT	Hempell (2002)	Allow for innovation that has a long lag effect on productivity. Since the panel is relatively short, in order to avoid losing observations, only a one year lag is included.	positive/ negative
ICT & organisation			
Information and knowledge			
ICT_d1*_BUSPRAC ICT_d2*_BUSPRAC ICT_d3*_BUSPRAC ICT_d4*_BUSPRAC ICT_d1*L1BUSPRA ICT_d2*L1BUSPRA ICT_d3*L1BUSPRA ICT_d4*L1BUSPRA	Milgrom and Roberts (1990), Ichniowski, Shaw & Prennushi (1997), Falk (2001), Baldwin and Sabourin (2001)	Control for firm's business restructuring and improved business practices.	positive/ negative
Organisational change and process efficiency			
ICT_d1*BUSREBI ICT_d2*BUSREBI ICT_d3*BUSREBI ICT_d4*BUSREBI ICT_d1*L1BUSRE ICT_d2*L1BUSRE ICT_d3*L1BUSRE ICT_d4*L1BUSRE			
Other firm-specific variables			
Absorptive capacity			
Multilocations (_BUSLOCS)	Atrostic and Nguyen (2002), Bosworth and Loundes (2002)	Allow for firm's geographical diversity and hub-spoke effects	positive/ negative

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Table C.1 **(continued)**

Explanatory variable	*Study*	*Rationale*	*Expected sign*
Firm age (_AGE) and / or New business (L1NEWBUS)	Doms, Dunne and Roberts (1995), Harris, Tang and Tseng (2002)	Allow for underestimation of assets. Using book value of assets will in general lead to the under estimation of the true value of capital due to the treatment of depreciation. As firms get older, the book value of capital is generally depreciated at a rate greater than the diminution in the true value of the services provided by the capital stock. This can be controlled for at least partly thorough including the age of the firm. Age also controls for industry specific knowledge.	positive/ negative
Corporate structure			
Type of legal operation (TOLO)	Harris, Tang and Tseng (2002)	Allows for greater complexity in accounting requirements of legally incorporated firms compared to unincorporated firms.	positive
Labour market and industrial relations			
Union membership (_UNIONME)	Tseng and Wooden (2001),	Allows for easier dissemination of information about the productivity enhancing workplace changes that have been implemented. In other words, controlling for high unionised firms to 'catch-up' to their less unionised counterparts.	positive/ negative
Contracting out (_CONOUT)	Motohashi (2001), Brynjolfsson and Hitt (2000), Girma and Gorg (2002), Bosworth and Loundes (2002)	Controlling for effect of out sourcing on labour productivity	positive/ negative
Employee coverage of agreements - Awards (_ARRAWAR) - Individual contracts (_ARRCONT) - Unregistered (_ARRUNRE) - Registered (_ARRREG)	Tseng and Wooden (2001)	Control for employee coverage effect of labour productivity	positive
Openness			
Export status (_EXPBI)	Bernard and Jensen (1995), Roberts and Tybout (1996), Bosworth and Loundes (2002)	Control for high productive export firms as these firms are more likely to survive in highly competitive international markets or trade may prompt faster absorption of new foreign technology.	positive

a The mnemonics listed refer to the variable mnemonic listed in appendix B where each variable is defined.

D Econometric issues and sensitivity testing

Available BLS data for the four-year period 1994-95 to 1997-98 provides a basis for controlling for firm-specific and dynamic factors using panel regression methods in the basic and augmented modes reported in chapter 4. This appendix outlines the choice of panel regression estimator adopted in work to date and some contemporary panel data estimation techniques.

D.1 Panel estimation and choice of estimator

There has been an increasing use of sophisticated panel methods by empirical researchers to account for various biases and other disturbances in the regression analysis. A panel model can be represented as:

$$\dot{y} = \beta_0 + \beta x_{it} + \mu_i + \lambda_t + m_{it} + \upsilon_{it} \quad i = 1,..., N \qquad t = 1,..., T$$

where β_0 is unidentified technical change, x_{it} are independent variables. The latter four terms are related to the components of the error term in the regression. The assumptions of correlation between the errors and the independent variables determine the appropriate estimator for panel regressions. The first term (μ_i) represents firm-specific effects. For example, efficiency or comparative advantage known to the firm but not otherwise specified that affect the input choices of the firm. The second term (λ_t) represents time-specific effects such as business cycles and trend growth that affect all firms in the sample. The third term (m_{it}) represents net errors in measurement of variables (eg, quality of labour, utilization of capital and decline of ICT prices not accounted for in the data). The final term (υ_{it}) represents pure random error and does not affect input choices.

The means of controlling for unobservable omitted variables depends upon whether a fixed effects or random effects model is used. A fixed effects (within-firm) estimator is typically chosen when unobservable firm-specific effects are assumed to be *correlated* with the observed explanatory variable(s). In this set up, the within transformation of the fixed effects estimator eliminates firm-specific effects and thereby lessens possible simultaneity bias. A random effects estimator is typically chosen when unobservable firm-specific effects are assumed to be *uncorrelated* with the observed explanatory variables.

A choice was made between fixed or random effects panel estimators in the current study on the basis of formal statistical tests (ie the Hausman specification test and Breusch Pagan LM test) and the sign and magnitude of parameters that could be independently validated. In particular, the coefficient on capital intensity was compared to the capital share in value added as reported in the Australian national accounts adjusted for owner operator. A parameter value similar to independent estimates of the sectoral capital share reported in Australian national accounts indicated that constant returns to scale was not rejected by the data, and it has provided some overall confidence in model specification and estimates.

Another reason for preferring the random effects over fixed effects estimators is that the explanatory power of variables, particularly ICT variables, is less likely to be diminished by the presence of a relatively large set of dummy variables included in the fixed effects. In addition, random effects models by taking into account within and between firm variability, provide estimates with greater precision than the fixed effect models.

D.2 Sources of bias and recent development

Productivity estimates obtained using regression analysis may be subject to a number of biases. Key sources of bias include, endogeneity, which leads to simultaneous equation bias; and omitted variable bias. In addition, input and output measures are subject to measurement error and leads and lags can exist among variables (including concerns relating to the valuation of flows).

There have also been a number of recent developments in panel data estimation techniques which are discussed in section D.1. To give a flavour of these developments and an indication of the sensitivity of our results to different estimators, some key econometric issues and sensitivity tests for basic growth model are applied for eight sectors.

However, biases can also be pertinent to models estimated in growth rates, where current year productivity *growth* is influenced by the initial level of productivity (or other state variables). In our growth regressions, we have attempted to incorporate some dynamics and correct for bias by the adoption of the partial adjustment model mentioned above. However, there could remain residual specification problems due to simultaneity and mis-specified dynamics, and measurement error.

To correct for any outstanding specification problems, we are investigating dynamic panel analysis. The method we have used so far is referred to as 'first differenced Generalised Method of Moments (GMM)' estimation (Arellano and Bond 1991) and is applied using algorithms in STATA 7. Box D.1 provides an outline of dynamic panel analysis and methods currently suggested in the literature on growth regressions. The first differenced GMM technique was applied to eight sectors of the basic growth model and results are reported in table D.1.

The relation between duration of computer use and labour productivity growth is sensitive to model specification, although the differing levels of statistical significance on the items has implications for interpretation of model results.

Box D.1 **An outline of dynamic panel data models**

Traditional panel techniques provide a means of including firm-specific factors. However, they do not correct the bias introduced by the presence of correlation between lagged dependent variables and firm specific-effects.

There have been a number of developments to address this source of bias, for example:

- a first difference transformation which imposes independence between the lag dependent variable and unobserved firm-specific effects (Anderson and Hsiao 1981). The instrumental variable method used leads to consistent but not necessarily efficient estimates of parameters. The method is a restricted form of the 'growth model' adopted in this study (see equation in box 4.2). It was applied to the data with very similar results to the unrestricted model.
- the first differenced Generalised Method of Moments (GMM) uses a different instrumental variable method to the first difference transformation (dot point 1) and was found to have no singularities and much smaller variances than characterised the earlier method (Arellano and Bond 1991). However, the method is highly sensitive to the persistence of data and initial conditions (the state variables). Application of the method to short panels (such as the ABLS) can result in biased parameter estimates. The method was applied as a sensitivity test in this study (see table D.1).
- the system GMM estimator introduces additional moment conditions to eliminate the identification problem characterising the first differenced GMM estimator (Arellano and Bover 1995, Blundell and Bond 1998). The additional conditions are also supposed to lessen the effect of measurement errors (including those owing to lack of price index data) and endogenous explanatory variables. The method is specifically designed for panel data sets such as the ABLS. We are considering the application of this method for sensitivity testing.

These modelling approaches further the contribution of the error correction model (ECM) which takes into account the fact that a change in labour productivity consists of a change associated with a movement along a long-run path plus part of the deviation of the firm from its 'equilibrium'.

Source: Anderson and Hsiao (1981), Arellano and Bond (1991), Arellano and Bover 1995, Blundell and Bond (1998), Griliches and Mairesse (1998) and Bond (2002).

Table D.1 **Sensitivity test for determinants of labour productivity**

Unweighted panel

	Manufacturing		*Construction*		*Wholesale trade*		*Retail trade*		*Accommodation, cafes & restaurants*		*Transport & storage*		*Property and business services*		*Cultural and recreational services*	
	GLS	1st GMM	GLS	1st GMM	GLS	1st GMM	GLS	1st GMM	GLS	1st GMM	GLS	1st GMM	GLS	1st GMM	GLS	1st GMM
Intercept	1.49***	0.17***	2.41***	0.30***	1.82***	0.11***	1.68***	0.12***	1.33***	0.324***	1.53***	0.14**	1.76***	0.31***	0.52***	0.08
Log(y-1)	-0.42***		-0.64***		-0.48***		-0.48***		-0.39***		-0.42***		-0.45***			
Change log(y_{-1}) **a**		-0.21***		-0.30***		-0.16***		-0.29***		-0.321***		-0.18*		-0.20***	-0.22***	-0.20***
Change log(k) (γ_k)	0.40***	0.38***	0.27***	0.001#	0.42***	0.47***	0.39***	0.48***	0.33***	0.052	0.39***	0.44***	0.33***	0.31***	0.30***	0.011
Size ('00)	0.05*	-0.80***	0.21*	-1.57***	0.02	-0.48**	-0.23***	-0.14***	-0.20#	-0.845***	0.09	-0.02	-0.04	-1.00**	-0.23#	-3.64***
ICT_d1(< 2yrs) **b**	0.12***	0.14*	-0.10#	-0.07	-0.01	-0.12	0.12**	0.03	0.07	0.102	0.13#	-0.13	-0.03	0.05	-0.15	-0.24
ICT_d2(short)	0.22***		0.32***		0.28***		0.20***		0.18#		0.17#		0.14#		0.54**	
ICT_d3 (2-5yrs)	0.13***	0.08	0.06	-0.22	0.14*	0.24	0.12***	-0.08	0.19***	0.490#	0.10#	-0.10	-0.01	0.32	0.32*	1.80***
ICT_d4(> 5yrs)	0.05*		-0.13#		-0.03		0.05#		0.11#		0.01		-0.15		0.21#	
Net Access	0.06***	0.02	0.06	-0.03	0.08***	0.004	0.07*	0.05	0.05	-0.118	0.07	0.11	0.13***	0.02#	0.16#	-0.22
Model summary																
No.of firms **c**	1790	1249	289	151	738	511	549	331	207	116	192	104	652	363	92	40
Wald χ^2 **d**	1783.7	243	656.4	31.68	1738.8	115.2	1242.7	302.6	326.1	92.86	415.7	67.3	1329.7	163.2	91.7	482.1
Sargan test (*p value)* **e**		1.00		1.00		1.00		1.00		1.00		1.00		1.00		1.00

*** significant at 1% level, ** 5% level, * 10% level, # relevant the t-statistic is more than or equal to one. **a** Instead of log level of labour productivity, this estimator takes the lag of the dependent variable without any options left for analysts to use appropriate instruments. In this case the change in labour productivity is the dependent variable. **b** Because of the multicolinearity problem the estimates for all ICT variables are not estimated (STATA 7, the GMM estimator requires stricter orthogonality requirements than the traditional panel estimators). **c** The number of observations in the panel model refers to the number of firms for which complete data were available for the years 1995-96 to 1997-98. As the model is in first differences, data were not available for 1994-95 (the base year). The number of observations in the dynamic models refers to the number of firms operating in 1997-98 for which complete data on lagged and instrumental variables were available for the years 1995-96 and 1996-97. **d** The Wald χ^2 test is applied in dynamic models to test the overall significance of model parameters. The critical value at (6,1249) for these models is 1.64 (5% level). **e** The Sargan test is applied to models that test the appropriateness of instruments applied. A high 'p' value indicates that the instruments are not over identified. However, the Sargan test quite often accepts a misspecified model, particularly in small samples with mismeasured variables.

Source: STATA 7 estimates based on ABS (Business Longitudinal Survey Confidentialised Unit Record File, Cat. No. 8141.0.30.001

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