The effects of ICTs and complementary innovations on Australian productivity growth

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This is a shortened version of the paper by the same authors, 'Uptake and impacts of ICTs in the Australian economy: Evidence from aggregate, sectoral and firm levels' presented to the Workshop on ICT and Business Performance, OECD, Paris on 9 December 2002 (available at http://www.pc.gov.au/research/confproc/uiict/index.html). Econometric estimates based on firm-level data are unchanged but growth accounting estimates have been updated in accordance with a further release of national accounts data. Further econometric work has been undertaken and is documented in forthcoming reports.

The paper was prepared as part of 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 a set of country studies on ICT and Business Performance, 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.

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). Reforms have improved productivity by encouraging and facilitating 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). Since Australia is a very small producer of ICT equipment, it cannot access substantial multifactor productivity (MFP) gains associated with the production of ICTs, as has been found in the major producing countries. On the other hand, OECD comparisons show that Australia became a relatively high user of ICTs in the 1990s (OECD 2002).

Two links between ICT use and Australia's labour 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 ICT 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 provide an indispensable platform upon which further product or process innovations are based (Brynjolfsson and Hitt 2000). The second line of argument looks to spillover effects, such as network economies, as sources of MFP gains. For example, an expansion in connections to the Internet or 'closed' networks could reduce search and transactions costs for businesses.

This paper explores the nature and importance of the links between ICTs and Australian productivity at the aggregate, sectoral and firm levels. A broad indication of the importance of ICTs in Australia's improved economic performance can be obtained from productivity growth accounting at the aggregate and industry-sector levels. 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 productivity growth. Importantly, they do not control for other factors that can influence productivity growth.

Fortunately, an Australian firm-based longitudinal dataset can be used to analyse ICT-productivity links with controls on other influences. This dataset enables comprehensive analysis that is not readily handled elsewhere — analysis of ICTs and complementary changes at the firm level and analysis of ICT-related effects in a range of industry sectors including services as well as manufacturing.

The paper has two main parts. The next section explores the extent of and reasons for the strong uptake of ICTs in Australia. Section 3 investigates the performance effects of ICTs at the aggregate, sectoral and firm levels. Both growth accounting and econometric approaches are used. Conclusions and implications are set out in section 4.

2 Uptake of ICTs

Australia's investment in ICTs has been growing strongly for decades, but initially from a low base. National accounts data[1] (covering information technology equipment, but not communications equipment) show that 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. Growth of 31 per cent a year in the second half of the 1990s was sufficient to double the rate of investment every three years.

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).[2] The Finance & insurance sector stands out as the main area of uptake, with a 25-27 per cent share of investment — more than double its output share. Manufacturing has also been a major user (around 15-17 per cent). These two sectors were major contributors to the acceleration in market sector IT use in the 1990s (table 1). Other prominent sectors were Wholesale trade, Retail trade, Transport & storage and Communication services.

The uplift in ICT use was particularly strong from 1995. Some cyclical and one-off factors — the dampening effect of the early 1990s recession and the accelerating effect of defensive expenditure to forestall the threat of the 'Y2K bug' — may have also contributed to the perception of a post-1995 'boom'. Nevertheless, some genuine post-1995 developments, including more rapid technological advances and price declines, contributed to an uplift in ICT investment trends.

But strong growth in ICT use goes back well before 1995. Some sectors (Finance & insurance, Communication services and Cultural & recreational services) raised their use of ICTs strongly from the second half of the 1980s.

Survey data [3] show that 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 (figure 1). By 2000-01, these proportions had grown to nearly 85 and 70 per cent respectively. But the penetration still varies across industries (table 1).

Large firms were earlier and stronger in the uptake of ICTs. Data from the Business Longitudinal Survey (BLS)[4] suggest that nearly all medium to large firms (ie firms employing 50 persons or more) used computers by 1996-97. However, the uptake of computers by 'smaller' firms (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.

2.1 Analysis of factors influencing the use of ICTs

Formal modelling was used to explore the factors affecting firms' use of computers and the Internet. An overview of the approach is provided in appendix 1. In essence, BLS data from four years (1994-95 to 1997-98) were pooled and firms' use of ICT and the Internet (in logit and probit form) was regressed against a number of explanatory variables including time, firm size and firm age. There were separate regressions for eight industry sectors.

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1 Australian Bureau of Statistics (ABS), *Australian System of National Accounts*, Cat. no. 5204.0.

2 Gretton, Gali and Parham (2002).

3 Australian Bureau of Statistics (ABS), *Business Use of IT*, Cat. no. 8129.0.

4 The BLS is a longitudinal dataset, compiled by the ABS and cast over four years from 1994-95 to 1997-98. It gathered a considerable range of performance, operational and related data from up to 9000 firms. A panel of over 4000 firms were included in all four survey years.

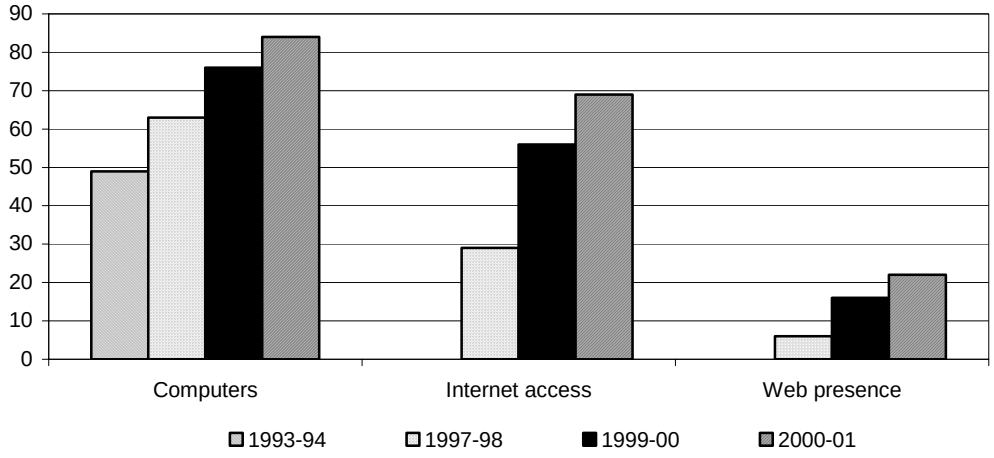
Table 1 **Summary statistics on ICT use and MFP growth by industry sector**

	National accounts (1993-94 to 1998-99)				*Business Use of IT (2000-01)*		
	IT growth[a]		*MFP growth*		*Proportion of firms using*		
	Sector	*Contrib to Mkt sect acceler*[b]	*Sector*	*Contrib to Mkt sect acceler*[b]	*Computers*	*Internet*	*Web*
	%pa	pp	%pa	pp	%	%	%
Agriculture	25.9	0.1	4.3	0.0	-	-	-
Mining	28.5	0.1	0.1	-0.3	88	79	30
Manufacturing	29.0	1.2	0.5	-0.5	81	66	28
Elect., gas & water	28.9	0.9	1.8	-0.2	95	89	44
Construction	22.5	0.1	2.2	0.4	80	64	10
Wholesale trade	21.4	-0.1	5.8	1.1	89	77	33
Retail trade	24.6	0.1	1.4	0.1	78	57	22
Accom., etc	25.2	0.0	0.8	0.1	71	53	26
Transport & storage	16.9	-0.7	1.8	0.1	76	60	19
Communications	17.5	-0.6	5.1	-0.1	78	58	20
Finance & insurance	25.4	1.4	1.7	0.3	90	81	22
Cult. & rec. services.	25.5	0.1	-4.1	-0.1	87	74	30
MARKET SECTOR	**24.2**	**2.6**	**1.8**	**1.1**	**-**	**-**	**-**
Prop. & bus. services					93	85	25
Health & comm.					89	72	14
Personal services					72	52	22
TOTAL					**84**	**69**	**22**

[a] Annual average rates of growth in IT capital services. [b] Sector contribution to acceleration in market sector growth between the last two complete productivity cycles — 1988-89 to 1993-94 and 1993-94 to 1998-99.

Figure 1 **Proportion of 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).

Computer use

Results of the analysis of firms' use of computers are presented in table 2:

- The time dummy variables were positive and significant in each sector regression. Since ICT prices were not included explicitly in the regressions, this result is most likely to reflect the influence of declining prices. It could also reflect declining adjustment costs and spillover effects as more firms became users and gained experience.
- Firm size (measured in terms of employment) was positively related to the use of computers for all sectors during the survey period. This finding suggests that large firms find more scope to use computer technologies.
- The level of educational qualification of the major decision maker was positively and significantly related to computer use for six of the eight sectors. This suggests that higher levels of human capital of lead managers were important to the adoption of technologies.
  - The exceptions were in Wholesale trade and Property & business services.
- The average wage of employees — a measure of the human capital across all workers in a sector — was also positively and significantly related to computer use in six sectors.
  - Workforce skills were found to be more important than management qualifications in the Wholesale and Property & business services sectors, the opposite was found in the Retail and Construction sectors and, in Manufacturing and Cultural & recreational services (the remaining two sectors), qualifications of the managers and skills of the workforce were both identified as important.
- The intensity with which advanced business practices such as business planning, budget forecasting and inter-firm comparisons were used by firms was positively and significantly related to the use of computers in each sector. The direction of causality is not clearcut. Management practices could highlight a need for ICTs, or the presence of ICTs could enable use of advanced business practices.
- Being an incorporated company was positively and significantly related to the use of computers for five sectors. More computer use could stem from the additional reporting requirements associated with incorporation.
- At least one of the variables representing firm reorganisation (listed under the heading 'Organisational and processing efficiency') was positively and significantly related to computer use in all sectors, except Cultural & recreational services.[5]. These results support the view that the take up of ICTs was more prominent among firms undergoing restructuring. Again, the direction of causality is ambiguous. A firm reorganisation could lead to computer use to support change or, alternatively, the adoption of ICT could create a need or opportunity for organisational changes.

[5] The intensity of restructuring variable was 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). The 'flag' variable indicates whether firms restructured in any one of the four survey years.

Table 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 positives*	*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	

(continued on next page)

Table 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 positives*	*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).

- The number of business locations was positively related to computer use for a number of sectors. This suggests that ICTs were useful in coordination of firms' activities between locations, increasing with the number of locations.
  - A negative relation in Transport & storage, however, is difficult to interpret. Even so, it does not rule out the possibility that ICTs have been useful in transport networks that cover a wide geographic area, perhaps coordinated from a single location.
- A positive relationship was generally found between ICT use and the existence of any product innovation (involving new or substantially changed goods and services) at any point over the period. However, the relationship with frequency of product innovation was more mixed.
  - Frequency of innovation was positive in Manufacturing and Construction but negative in Accommodation, cafes & restaurants and, again, in Transport & storage. [6],[7]

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 computer users during the mid-1990s period.

Internet access

Analysis of the characteristics of firms with Internet access was based on pooled cross-section data for firms with computers for the years 1996-97 and 1997-98. There was not sufficient information on Internet access in the BLS to include data for 1994-95 and 1995-96. For reasons of space, the results of this analysis are not specifically reported here (see Gretton, Gali and Parham 2002 for details).

Overall, as with computer usage, the analysis suggested that larger firms with more skilled managers and workforce, a greater propensity to use advanced business practices and implement organisational change were more likely to have been early adopters of Internet communications. The results support the findings of Loundes (2002) on the link between process and product innovation and Internet access, although the link between product innovation and Internet access is evident for some sectors but not others in our work. Openness to international trade was also important in some sectors.

3 Performance effects of ICTs

As noted in the introduction, some indication of any association between ICTs and improved productivity performance can be gained from aggregate and sectoral productivity growth accounting. But firm-based econometric analysis provides the scope for clearer insights. Aggregate and sectoral growth accounting and firm-based modelling are reported here. The growth accounting estimates have been updated since Gretton, Gali and Parham (2002), but the modelling results are the same.

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[6] It should also be noted that the sample weight was 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.

[7] The instances of negative results on product innovation are at odds with the view that the use of ICT enhances the ability of a firm to 'innovate'. They 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); the scope for frequent product innovations may be more limited in particular industries; or the significance of innovation is not reflected in the number of innovations in some cases. It may also indicate lagged relationships between computer use or product innovation, or data considerations, that are not fully reflected in the model specification.

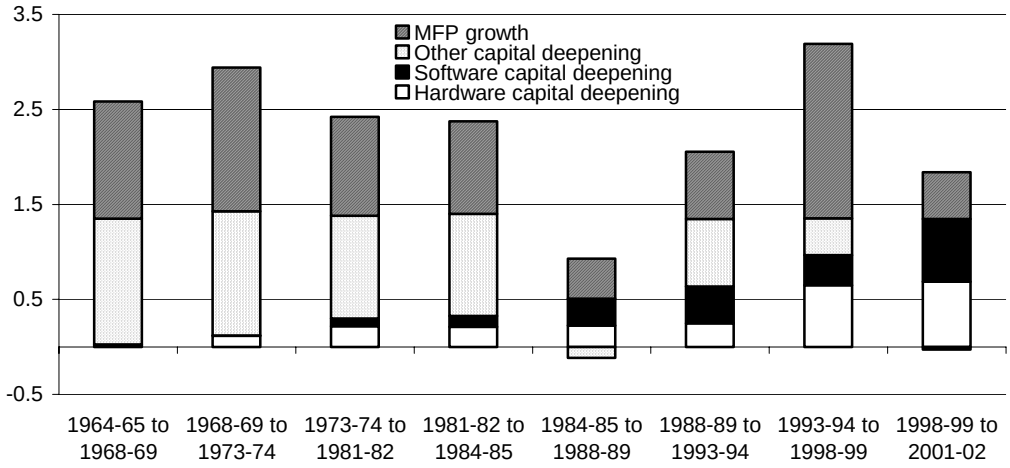
3.1 Contributions to aggregate productivity growth

Growth accounting involves a statistical decomposition of growth in labour productivity into contributions from capital deepening — increases in the capital-labour ratio — and MFP growth.

With the very strong growth in ICT investment, it is not surprising that the IT capital deepening contribution to labour productivity growth climbed to a very substantial proportion in the 1990s (figure 2). Between 1993-94 and 1998-99[8], IT capital deepening accounted for a third of the very strong labour productivity growth of 3.2 per cent a year (table 3). IT capital deepening also made a strong contribution of 0.3 of a percentage point to the labour productivity acceleration of 1.2 percentage points between the last two productivity cycles (table 3).

Figure 2 **Contributions to average annual labour productivity growth over productivity cycles, 1964-65 to 2001-02[a]**

Percentage points



a The final period, 1998-99 to 2001-02 is not a complete productivity cycle.

Source: Productivity Commission estimates based on unpublished ABS data.

Table 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 1998-99*		*Acceleration*
Labour productivity growth	2.0	(100)	3.2	(100)	1.2
Capital deepening	1.3	(66)	1.4	(42)	0.0
- Information technology	0.6	(31)	1.0	(30)	0.3
… Hardware	0.2	(12)	0.6	(20)	0.4
… Software	0.4	(19)	0.3	(10)	-0.1
- Other capital	0.7	(35)	0.4	(12)	-0.3
MFP growth	0.7	(34)	1.8	(58)	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.

8 These two years are productivity peaks and define a complete productivity cycle.

However, in an accounting sense, the larger IT capital deepening contribution has come at the expense of the other-capital deepening contribution, which meant that there was no change in the overall rate of capital deepening. 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 shows very little change in the overall rate of capital deepening across all productivity cycles (apart from the 1984-85 to 1988-89 cycle, during which there was particularly strong employment growth). Table 3 confirms this offsetting effect over the last two (complete) productivity cycles.

The strong surge in MFP growth in the 1990s therefore fully accounted for the labour productivity acceleration (table 3.1). But 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. Parallels with the US experience suggest 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 (Parham 2002b).

It has been common in other growth accounting studies to assess the contribution of IT and other factors to productivity growth in the first and second halves of the 1990s, without controlling for effects of the business cycle. Unsurprisingly, this approach gives rise to more prominent IT-capital deepening and this is not entirely offset by slower other-capital deepening.[9]

3.2 Performance effects at the sectoral level

The seemingly small productivity impact of ICTs at the aggregate level masks more prominent associations at the sectoral level. The strength of IT capital deepening varied across industries in the late 1990s (table 4). It was particularly strong in Finance & insurance and was above average in Manufacturing and Electricity, gas & water. But only in Finance & insurance did IT-capital deepening either make the strongest contribution or raise labour productivity growth above the average.

The ICT-productivity associations appear even weaker across industries when the contribution to labour productivity *acceleration* over the last two productivity cycles are examined (table 5).

None of the three industries with the strongest uplift in ICT-capital deepening (Finance & insurance, Electricity, gas & water and Manufacturing) had above average acceleration in labour productivity growth. In fact, MFP growth slowed in Manufacturing and Electricity, gas & water.

The strongest case for any association between uplift in ICT use and MFP acceleration is in Finance & insurance. There is some possibility also in Wholesale trade, Accommodation, cafes & restaurants and Construction. But an association in the second biggest investor in ICTs — Manufacturing — is not apparent.

The partial overlap of industries showing high uptake of ICTs and productivity in both Australia and the USA strengthens the possibility that ICTs are having some causal effect on productivity. US industries that are high ICT users and have strong productivity improvements include financial intermediation, distribution (wholesale and retail trade) and business services (Nordhaus 2001, CEA 2001 and Pilat and Lee 2001).

The productivity gains in Finance & insurance are consistent with substantial restructuring, 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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9 This finding, as presented in Gretton, Gali and Parham (2002), is not undermined by revisions to national accounts data.

Table 4 **Contributions to sectoral labour productivity growth, 1993-94 to 1998-99**

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	3.7	-0.5	0.2	-0.7	4.3
Mining	5.2	5.1	0.3	4.8	0.1
Manufacturing	2.4	1.9	1.2	0.7	0.5
Electricity, gas & water	7.2	5.5	1.2	4.3	1.8
Construction	2.4	0.1	0.6	-0.5	2.2
Wholesale trade	6.8	0.9	0.7	0.2	5.8
Retail trade	2.3	0.9	0.9	0.1	1.4
Accom., cafes & restaurants	1.8	0.9	0.6	0.3	0.8
Transport & storage	2.3	0.5	0.6	-0.1	1.8
Communication services	7.4	2.1	1.0	1.0	5.1
Finance & insurance	4.4	2.8	3.2	-0.4	1.7
Cultural & rec. services	-0.7	3.8	1.0	2.8	-4.1
Market sector	**3.2**	**1.4**	**1.0**	**0.4**	**1.8**

Source: Productivity Commission estimates based on unpublished ABS data.

Table 5 **Contributions to accelerations in sectoral productivity growth, over the last two productivity cycles [a]**

Percentage points

		Contributions to sectoral labour productivity acceleration			
	Labour productivity acceleration	*Capital deepening*	*IT capital deepening*	*Other capital deepening*	*MFP growth*
Agriculture	-1.1	-1.0	0.1	-1.1	0.0
Mining	-0.1	2.2	0.2	2.0	-2.2
Manufacturing	-1.7	-0.3	0.5	-0.8	-1.5
Electricity, gas & water	-0.1	2.3	0.9	1.4	-2.2
Construction	2.0	-0.8	0.1	-0.9	2.7
Wholesale trade	8.2	0.1	0.2	-0.1	8.0
Retail trade	0.7	0.0	0.2	-0.2	0.7
Accom., cafes & restaurants	3.4	0.6	0.3	0.3	2.8
Transport & storage	0.4	-0.6	-0.2	-0.5	1.0
Communication services	-2.2	-1.3	-0.4	-0.9	-1.0
Finance & insurance	0.8	-0.9	0.9	-1.7	1.7
Cultural & rec. services	-0.2	1.7	0.0	1.7	-1.7
Market sector	**1.2**	**0.0**	**0.3**	**-0.3**	**1.1**

a The last two productivity cycles are 1988-89 to 1993-94 and 1993-94 and 1998-99

Source: Productivity Commission estimates based on ABS data.

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). The sector has not become much more ICT-intensive. But ICTs have played a part in the 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. Part of the very strong productivity acceleration in Wholesale trade can be attributed to ICTs and part to 'catch-up' gains.

The weak correlation between ICT use and MFP growth across industries reflects the fact that non-ICT factors, including policy reform, have had independent effects on productivity performance. More formal analysis is needed to control for other influences.

3.3 Performance effects at the firm level

BLS data for 1996-97 indicate that firms using computers were on average more likely to have had higher labour productivity than those that did not (Gretton, Gali and Parham 2002). There was also a tendency for firms that had used computers longer to have had higher labour productivity on average, although there were significant differences across sectors.

An overview of the methodology used to formally analyse the effect of ICTs on firm productivity is presented in appendix 1. The essential features of the methodology are:

- growth in labour productivity was analysed in a framework consistent with formal growth theory;
- explanatory variables included duration of computer use and whether or not firms used the Internet; and
- growth in fixed capital, lagged level of labour productivity (to allow for the possibility of conditional convergence) and firm size were also included.

Computer use was generally found to have had a positive and statistically significant influence on labour productivity growth in all eight sectors (table 6). For example, firms in Manufacturing, Construction, Wholesale and Retail trade that had used computers for a short period (around two years) were estimated to have raised labour productivity growth by between 0.2 and just over 0.3 of a percentage point.

A particular dynamic effect on firm productivity growth was found, with the productivity response forming an inverted 'U' pattern as the duration of ICT use increased (figure 3). 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. But, after a period of adjustment of around five years, the productivity growth stimulus of computer take-up appears to have been largely completed.

However, the results 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.

Figure 3 also indicates that Internet access typically had a positive and significant influence on productivity growth. (Available information did not support the analysis of time profiles for this aspect of ICT use.)

Table 6 **Estimated impact of ICT on productivity growth — basic model**

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

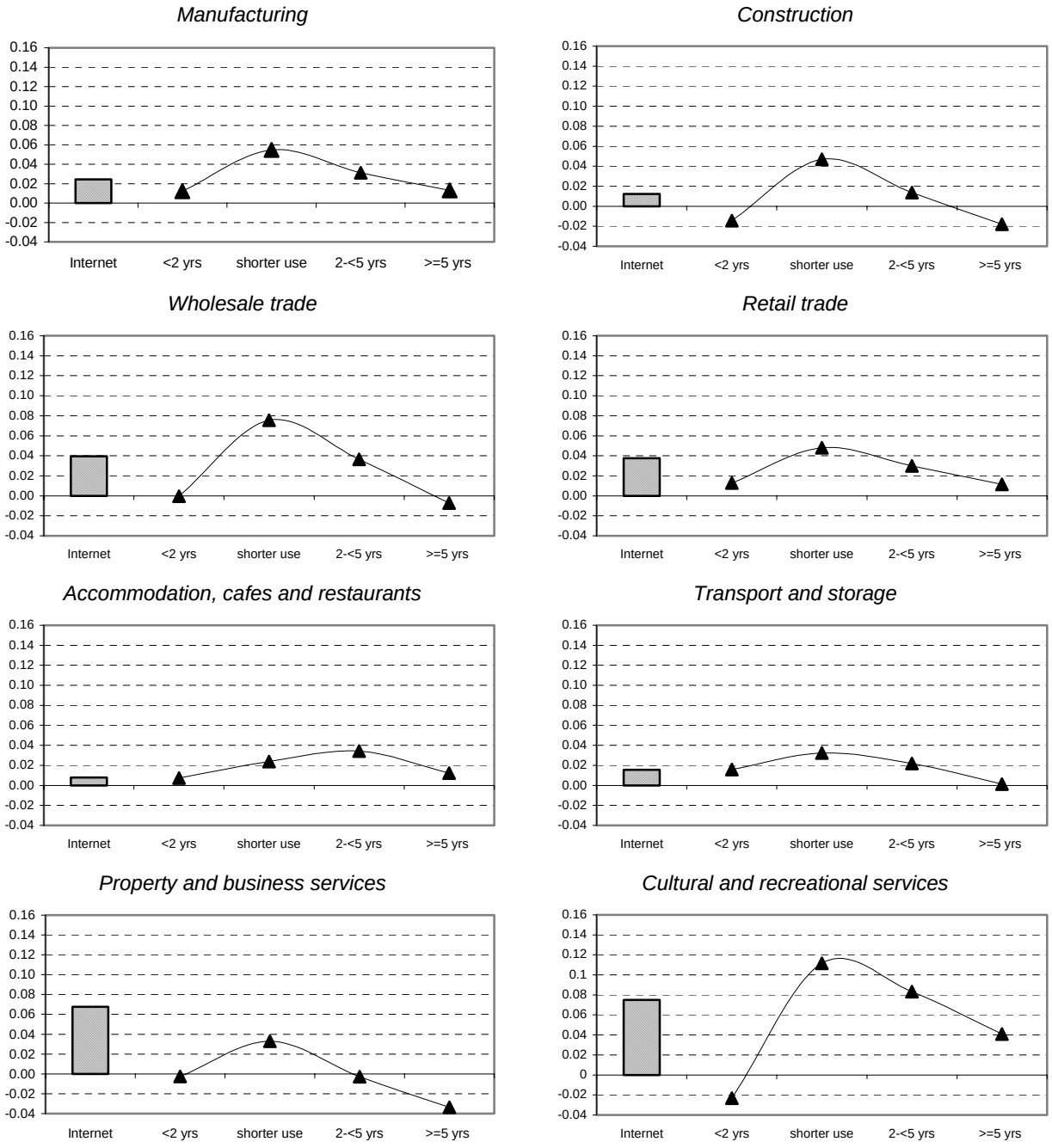
	Manufacturing	*Construction*	*Wholesale trade*	*Retail trade*	*Accommodation, cafes & restaurants*	*Transport and storage*	*Property and business services*	*Cultural and recreational services*
Intercept	1.498***	2.409***	1.815***	1.683***	1.333***	1.525***	1.756***	0.518**
Log(y_{t-1})	-0.423***	-0.638***	-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 3 **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).

More detailed results are reported in table 6:

- The coefficients on lagged labour productivity ($\log(y_{t-1})$) were negative and significant, implying conditional convergence was present — that is, labour productivity growth was more rapid when coming off a lower base.
  - The coefficients provide an indication of the adjustment period required to reach a new equilibrium following a change in capital intensity. They suggest that adjustment halfway towards a new equilibrium was: around three years for Construction;[10] 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.
- The coefficients on growth in capital per unit of labour input (ie capital deepening, *kdot*) were positive and significant.
  - The coefficients were generally of a similar magnitude to the capital share in value added, which is often taken to be the case under assumptions of constant returns to scale and inputs paid according to marginal products.
- The coefficients on firm size (*size*), measured in terms of employment, were positive for the Manufacturing and Construction sectors, suggesting that size provides some productivity advantage in these areas.
  - They were negative in four sectors, and significantly so in Retail trade. This suggests, perhaps counterintuitively, that larger retailers did not have the same scope for productivity gains.

Interactions between other factors and ICT use

The above analysis 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:

- 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.
- Additional growth variables suggested by the literature were added as independent explanatory variables to control, as far as practicable, for firm-specific productivity influences not accounted for by other factors.

Broadly, estimates of coefficients on the general growth variables were not sensitive to the changes in model specification considered. Nevertheless, impact of computer use taken on its own tended to be of lower significance than in the basic model. 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. Generally speaking, the inclusion of interaction effects in the analysis indicated that the relation between the uptake of a new technology and productivity growth is more complicated than portrayed in the basic model.

Negative effects of complements were found in some industries. 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. Whilst further research is needed, this appears consistent

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

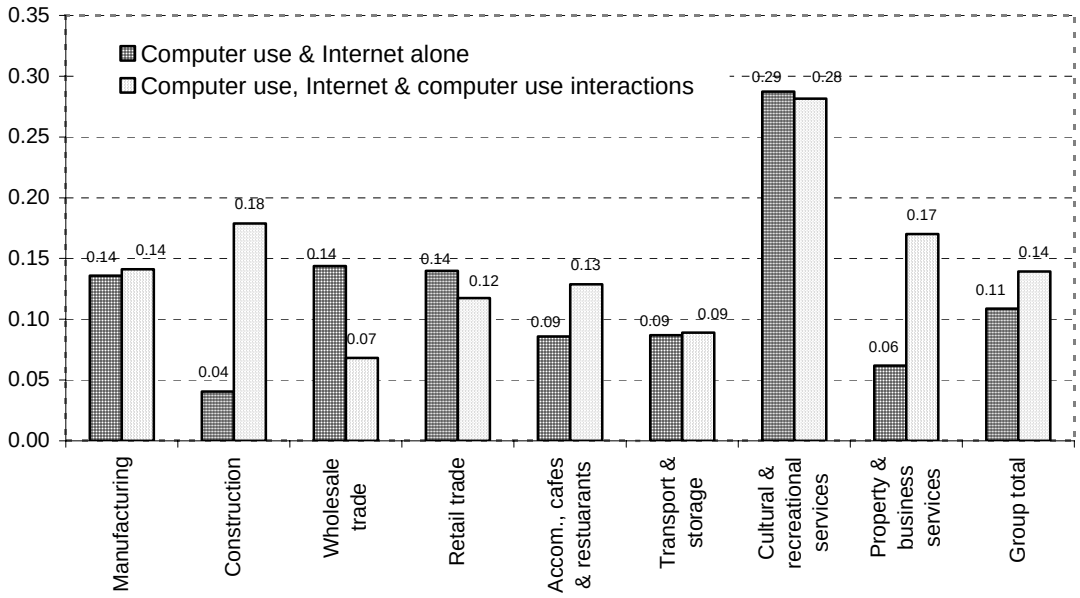
with there being adjustment costs in the short to medium run. Importantly, the interactions added to productivity growth in the longer term.

A re-aggregated view

Overall, the analysis suggests that the use of computers had a positive impact on firms' productivity growth during a key period of uptake in the 1990s. Figure 4 shows effects on annual MFP growth, calculated from the regression coefficients and evaluated at the mean value of variables.

Figure 4 **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 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.

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

The strength of the links to ICTs, and the importance of complementary factors, varies across industries. 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.

Computer use and Internet access alone is estimated to have raised MFP growth across the eight industry sectors (as a group) by 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 to 0.14 percentage points per year.

4 Conclusions

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

4.1 Main findings

Australia experienced very strong growth in ICT investment in the 1990s, especially after 1995 (at over 30 per cent a year). Finance & insurance and Manufacturing were particularly prominent in the absorption of ICTs.

The firm-level analysis of four years from 1994-95 has pointed to the 'march of time' as a significant explanator of ICT uptake and Internet access. This covers the influence of time-related factors, which could include the continual decline in ICT prices, lower adjustment costs (learning) and network effects (advantages from more users joining computer networks). Lower prices, at least, are likely to be a major influence.

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, although the relative importance of management and worker skills varied across industries. 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.

Both the aggregate growth accounting and a re-aggregation of the firm-based results suggest that ICTs and related effects raised Australia's annual productivity growth by around two-tenths of a percentage point. This contribution is significant, but a relatively small part of Australia's 1990s rate of MFP growth of 1.8 per cent a year.

However, the aggregate view masks more prominent effects at the micro level. At the sectoral level, the association between ICT use and productivity growth seems from casual observation to be clearest in Finance & insurance. Importantly, however, the firm-level econometric analysis, which controls for other influences, found positive links between ICT use and productivity growth in all industry sectors examined.

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 one form or generation 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.

Significant interactions between ICT use and complementary organisational variables were also found in nearly all sectors. The complementary factors for which there were 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.

4.2 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 analysis also supports the general purpose technology view of ICTs — that is, that there are productivity-enhancing complementarities between ICTs and product and process innovations. There could also be network economies, but the paper has not specifically tested for their existence.

The view of ICTs as general-purpose, enabling technologies means 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, a micro or firm-based view is needed to develop better understanding of the technological, organisational and policy influences — and their interaction — on restructuring and productivity growth.

The aggregate, sectoral and firm-level perspectives give somewhat different views on the importance of ICT-related productivity effects. The micro results suggest the modest aggregate productivity effects are due to aggregation — the strong positive effects in some firms and industries are counterbalanced by weaker effects in other firms and industries. But, as a corollary, with further development of ICTs, further diffusion and complementary changes, the aggregate productivity effects of ICTs could, in principle, increase above that found in the time periods analysed here.

The firm-level results help to resolve the puzzle about the apparent lack of productivity response to the strong uplift in ICT use in Manufacturing. Controlling for other factors, a relatively large and significant relationship between ICT use and productivity was found. In other words, the analysis suggests that the drop in Manufacturing productivity performance in the 1990s was due to factors unrelated to ICT use and associated factors. Again, it could be at least partly due to aggregation within the sector.

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 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 the duration of ICT use, rather than in volume terms. Even with the difference in approach, however, there is remarkable similarity in the aggregate productivity effects derived from both the econometric and growth accounting methods.

Turning to broad policy implications, the use of ICTs can be fostered by ensuring access to the latest technological advances and with the full flow-through benefit of price reductions. 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 productive use of ICTs. It confirms previous research, which found ICT use to be biased toward higher levels of skills. This has implications for education and training. Decision makers require not only ICT-related skills (seeing the opportunities that ICTs provide) but also the management skills to implement the necessary structural changes.

The links between ICTs and restructuring also points to the importance of flexibility in delivering productivity gains. 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.

A number of these elements have been picked up in policy approaches over the past two decades. Policy reforms in Australia 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. The analysis in this paper points to success in facilitating the absorption of technology and raising productivity growth by encouraging and enabling businesses to change what they do and how they do it.

Appendix 1: Overview of methodology for micro analysis of uptake and productivity effects of ICTs

This appendix describes the general features of the models used to analyse firms' uptake of ICTs and their productivity effects. Details are provided in Gretton, Gali and Parham (2002).

Uptake of ICTs

Binary choice (this is 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.

The independent, or explanatory variables, upon which ICT use was considered to be conditional include firm size and firm age, 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. Groupings of characteristics and a rationale for their inclusion in the analysis are outlined in the table below.

The regression analysis on the characteristics of firms using cover eight industry sectors in the BLS: 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 or 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.

Table 7 **Firm-characteristic groups**

Balance panel indicator	
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. 1997 and 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

Productivity effects

The regression model for performance effects 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 (Romer (1986), (1990), Barro and Sala-I-Martin (1995)). 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 with Cobb-Douglas technology. Formally, labour productivity is defined as $y = \frac{Y}{L}$ where Y is the

level of value added output[11] 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:

$$\dot{y} = \beta_0 + \beta_1 \dot{k} + \beta_2 ICT + \varepsilon \quad (4.1)$$

where the dot over y and k indicates the logarithmic change between years in labour productivity and capital intensity, respectively.[12] The coefficient β_1 is the elasticity of labour productivity with respect to a change in capital intensity. β_1 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. 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 differs from that of traditional growth accounting studies.

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.

Formally, the basic estimation model can be written as:

$$\dot{y} = \beta_0 + \beta_1 log(y_{t-1}) + \beta_2 Size + \beta_3 \dot{k} + \beta_{4,1} ICT\_d1 + \beta_{4,2} ICT\_d2 + \beta_{4,3} ICT\_d3 + \beta_{4,4} ICT\_d4 + \beta_{5\_} netacc$$

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.

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

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

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.

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

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

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).*

Panel regression methods were used to estimate of the basic and augmented models.

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