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ICT: An engine or enabler of Australia's productivity growth?

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Abstract

This paper seeks to clarify debate about the links between use of information and communications technology (ICT) and productivity growth — specifically, whether or not ICT is a driver of a 'new economy' — and about the significance of ICT use in Australia's recent strong productivity growth. The central issue is the existence and strength of any effect of ICT on multifactor productivity (MFP) growth.

The paper finds that ICT use in Australia has made: a very strong contribution to capital deepening (although some, if not all, of this has been offset by weaker growth in other forms of capital); and a small contribution to MFP growth. Among studies to date, a contribution of around 1 or 2 tenths of a percentage point of annual MFP growth appears robust across different methods and data. The link to MFP growth is consistent with ICT being an enabler of productivity growth. But it is not so clear that ICT is an engine or driver of productivity growth. ICT use has complements and there is evidence to suggest that at least some of them drive ICT investment.

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* This paper draws heavily on work undertaken for a project on ICT use and productivity in Australia. The project was a team effort and the papers produced reflect the contributions of a number of people from a number of agencies. I am grateful for comments on, and suggestions for, this paper from Don Brunker, Ralph Lattimore, Jonathan Pincus and Dave Gilbert; and for assistance from Paula Barnes and Tracey Horsfall. All errors and omissions are my responsibility. The views expressed are mine and should not be attributed to the Productivity Commission.

1 Background

The combination of an unexpectedly strong US productivity acceleration and a boom in use of information and communications technology (ICT) in the second half of the 1990s stimulated a vigorous debate about whether ICT was the source of a 'new economy'. Several camps emerged.

- The new economy *enthusiasts* took a technology 'push' view that advances in ICT and its widespread use had heralded a new economic paradigm. This view essentially relied on the proposition that ICT use generates substantial gains in both labour productivity and multifactor productivity (MFP).
- The *sceptics* accepted that lower prices of computing could lead to capital deepening and labour productivity growth through substitution of ICT capital assets for labour, but considered that ICT use played no significant role in stimulating MFP growth (eg Gordon 2000; Jorgenson 2001).
- The '*semi-sceptics*' did not dismiss ICT as having a role in stronger MFP growth, but viewed increased ICT use more as the effect of a driver of productivity growth than as the driver itself. This group identified stronger competition as the underlying driver, which, amongst other things, prompted good managers to invest in and absorb technology in order to improve performance (eg MGI 2001). In relation to ICT, this was more of a technology 'pull' view.

The interest in the productivity effects of ICT use has endured, even though attention diverted for a while to the ICT supply side. First, the conclusion of Gordon (2000) that the US MFP gains were entirely due to the production and not use of ICT equipment was widely reported. Second, the high-tech stock market bubble, which was essentially about the supply of 'digital' goods and services, engendered widespread exuberance. But with the 'tech-wreck', attention has reverted to the use side.

Australia's productivity growth also surged in the 1990s — indeed more so than in the United States. There was a misguided concern in some quarters that Australia could not access the productivity gains of the 'information age' because it is not an ICT producer either in national or (especially) international terms (eg AIG 2000). However, as the evidence emerged that Australia was a high user of ICT in international terms, interest heightened in the role that ICT use may have played in Australia's productivity surge. There is now general agreement that ICT use did contribute to Australia's productivity acceleration (ABS 2001; Cardarelli 2001; Parham, Roberts and Sun 2001; Simon and Wardrop 2002; OECD 2003).

Against this background, this paper addresses the following questions.

- What has been the nature of ICT's contribution to Australia's productivity growth?
  - Has it been to labour productivity growth, but only through capital deepening?
  - Or did ICT use also make an MFP contribution?
- How much has ICT contributed to Australia's productivity growth?
- Is ICT rightly seen as an enabler of productivity growth?
- Is ICT more appropriately viewed as having a technology 'push' effect on productivity growth, or a technology 'pull' effect? That is, is ICT an engine of productivity growth?

In the rest of the paper, I make a number of references to a project on ICT and Firm Performance (ICTaFP). This project was initiated by the Productivity Commission, and also involved the Department of Industry, Tourism and Resources, the Australian Bureau of Statistics (ABS) and the former National Office for the Information Economy. PC (2004) provides a synthesis of the work undertaken for the project.

The next section outlines how ICT use can affect productivity growth in principle. Section 3 examines the evidence. Section 4 discusses a number of issues that bear on the interpretation of the evidence. Section 5 concludes the paper, by specifically addressing the above questions.

2 Links between ICT use and productivity growth

ICT can have two possible effects on productivity. First, increased use of ICT can substitute for other inputs, especially labour, leading to capital deepening and labour productivity growth. Second, ICT can raise MFP, through network effects and user innovations.

These effects are non-exclusive, but the existence of the MFP effect is more controversial. Neither new economy enthusiasts nor sceptics argue against a capital-deepening effect. But the sceptics essentially argue that the decline in the relative price of computing has induced input substitution and movements around production frontiers, without shifts *of* the frontiers. The sceptical view therefore sees little if anything to distinguish ICT from any other input that changes in relative price. The enthusiasts and the semi-sceptics, on the other hand, argue or allow for an additional MFP effect. The enthusiasts argue that ICT is a driver of widespread economic transformation of firms and industries that generates MFP gains. The semi-sceptics acknowledge the transformation, but attribute the MFP gains to other driver(s).

Establishing the existence of an MFP effect is therefore a central piece of evidence in the case as to whether or not there is something 'new' and different about ICT.

'Passive' use — input substitution and capital deepening

Technological advances in ICT have progressively reduced the costs of gathering, storing, retrieving, processing, analysing and transmitting information and have thereby provided firms with cheaper and readier access to more accurate, timely and useful information. Firms can tap these information gains in a 'passive' way by using ICTs to undertake pre-existing information-related tasks more quickly, effectively and cheaply than by more traditional labour-intensive means.

Increases in use of ICT capital can therefore lift the rate of capital deepening (increases in the capital-to-labour ratio). Investment in ICT can substitute for inputs of capital as well as labour. For example, use of computers may reduce the need for building space to store physical records; and on-board use of ICTs can increase use of available truck capacity for road transport and therefore reduce the need for investment in additional trucks.[1] Consequently, not all increases in ICT capital translate into equivalent increases in total capital or into equivalent rates of capital deepening.

The degree to which ICT substitutes for other inputs depends on advances in the explicitly-designed characteristics embodied in ICTs and on changes in their relative price. The characteristics of the ICTs, which are in the hands of the hardware and software developers, determine the degree to which substitution is technically possible. The change in relative prices is determined by the ability of ICT producers to generate substantial MFP gains through technological advances and by the degree to which producer productivity gains are passed on to users in the form of lower prices (because of competition in markets). The price of computing has fallen in absolute and relative terms. Hardware prices in Australia have fallen annually by the order of 10-20 per cent over the past few decades.

'Active' use — innovation and additional MFP growth

The case for MFP gains starts with the observation that technological advances in ICT have greatly increased its capability, functionality, reliability, user-friendliness and scope for application. ICT is now commonly viewed as a general-purpose technology (GPT) — a characteristic that distinguishes it from most other capital inputs.[2] It is used generically in a wide variety of applications across a broad range of businesses; and it enables firms to tap the information gains in an 'active' way by using ICTs as platforms for a myriad of their own value-adding and efficiency-enhancing innovations.

> Most GPTs play the role of 'enabling technologies', opening up new opportunities rather than offering complete, final solutions. (Bresnahan and Trajtenberg 1995)

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[1] Hubbard (2003) found that advanced on-board computers in transport logistics increased utilisation of trucking capacity in the United States by 13 per cent.

[2] Other general-purpose technologies include electricity, the internal combustion engine and railways (Lipsey, Bekar and Carlaw 1998).

ICT-enabled innovations cover products (eg customised and new information-hungry products), processes (eg better quality control and inventory management) and organisational structures (eg flatter hierarchies and contracting out).

We took the view in the ICTaFP project that there were three key technological developments that helped to establish ICT as a GPT in the late 1980s and early 1990s:

- technological advances that combined computing power with compact size (mini-computers and desktops) at widely affordable prices;
- the convergence of information technologies and communications technologies (to form what is now known as ICT), notably in the form of the Internet and other networks;[3] and
- software advances that not only expanded the range of general and specific applications but also made computers more user-friendly and brought them within the operational reach of a much larger proportion of the workforce. (See PC 2004.)

In other words, it was not until quite recently that computers were 'everywhere' — in a generic and multi-function form — to provide a possible basis for significant and widespread change in what firms do and how they do it.

The user innovations are enabled, but are not determined, by the explicitly-designed characteristics embodied in the ICTs. Those characteristics may be necessary to provide platforms for ICT-enabled innovations. But they are not sufficient. The innovations themselves are in the hands of using firms.

The countless possible ICT-enabled innovations represent disembodied sources of MFP gains. New products can add more value. New processes and organisational arrangements can: improve product quality, timeliness and customer convenience; allow greater product variety and customisation of products to customers' requirements; reduce waste, inventories and transactions and coordination costs; allow outsourcing and specialisation; streamline production and distribution; and so on.

MFP gains derived by users are sometimes referred to as 'spillovers' from ICT producers to users. Network effects are clearly a spillover. Users of ICT-based networks gain from the addition of new members of the network, without having to compensate producers of ICT equipment (or providers of communications infrastructure). The commercial value is expressed through the reduction in transactions costs of communication. It is not so clear, however, that users' gains from ICT-enabled innovations are spillovers. First, the gains are user determined, rather than 'bestowed', and require user effort and investment. Second, if the gains from ICT-enabled innovations are widely tapped and are closely related to the characteristics of the ICTs (and therefore the demand for them), ICT producers may be able to extract at least some of the net gains to users from those innovations.

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[3] The protocols for the Internet were signed in 1992 (Daveri 2003).

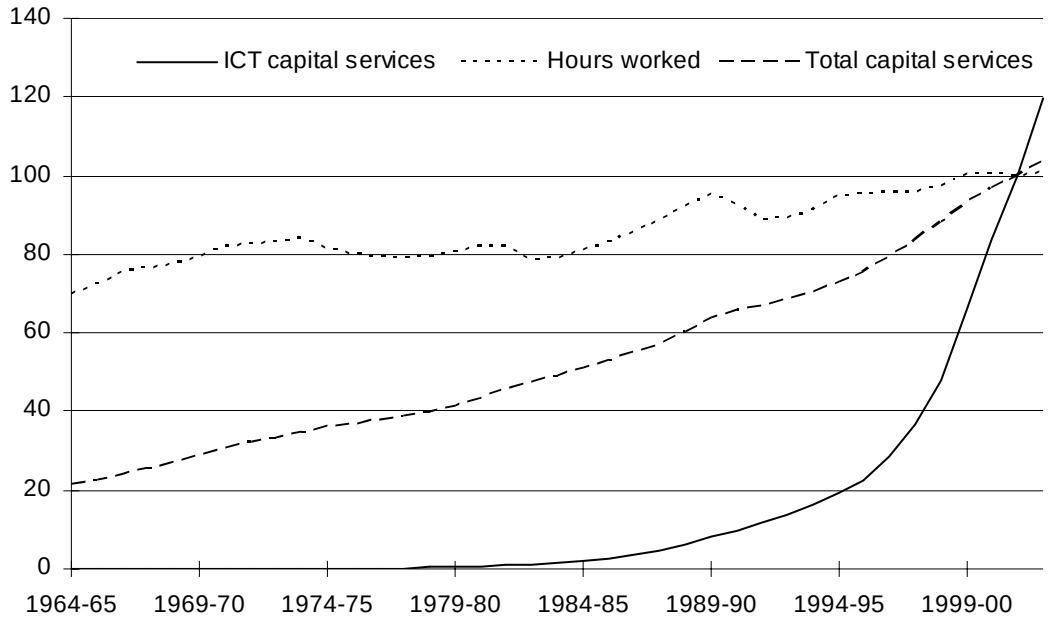
3. Evidence

Australian firms stepped up their investment in ICT in the 1990s. Investment in information technology (that is, excluding communications equipment) jumped from 8 per cent of nominal business investment in 1989-90 to 18 per cent in 2000-01. Hardware investment grew at over 40 per cent a year in the second half of the 1990s, while software investment grew at over 20 per cent a year. In 1993-94, around 50 per cent of firms used computers and around 30 per cent had Internet access. But, by 2000-01, these proportions had grown to nearly 85 and 70 per cent respectively.

According to national accounts data, the service flows from the constant-quality productive stocks of ICT[4] grew much faster than total capital services and hours worked (figure 1). ICT capital services grew at the very strong rate of 24 per cent a year through the 1990s — 19 per cent a year in the first half and 28 per cent a year in the second half.

Figure 1 **ICT capital services, total capital services and labour input, 1964–65 to 2002–03**

Indexes (2001–02 = 100)



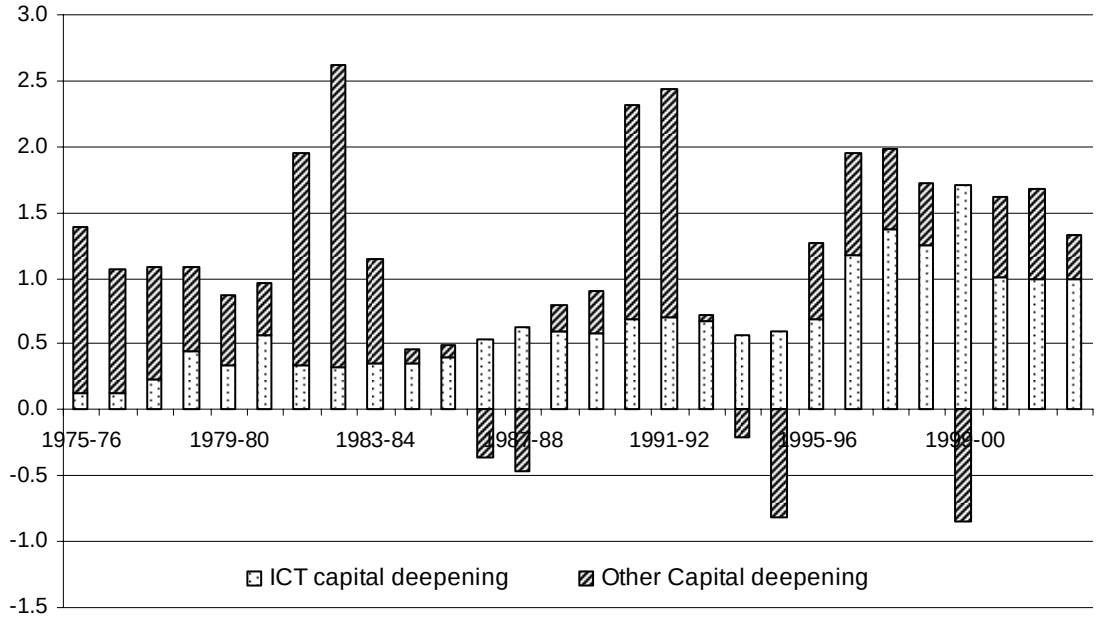
Data source: ABS (*Australian System of National Accounts*, Cat. no. 5204.0).

[4] To date, national accounts data have not separately identified communications equipment and grouped it with IT equipment. However, on the assumption that growth in communications equipment has been close to growth in IT equipment, the ICT acronym is used throughout to avoid confusion.

Effects on capital deepening

As is clearly implied by the series in figure 1, there has been ICT-capital deepening. Moreover, the rate of ICT-capital deepening increased from 1995-96 (figure 2). According to growth accounting estimates[5], ICT-capital deepening contributed 1 percentage point or more to the very strong labour productivity growth of 3.2 per cent a year in the latter part of the 1990s (tables 1 and 2).

Figure 2 **Annual contribution of capital deepening to labour productivity growth, market sector, 1975–76 to 2002–03**
Percentage points



Data source: Productivity Commission estimates based on unpublished ABS data.

Various growth accounting studies for Australia — ABS (2001), Cardarelli (2001), Parham, Roberts and Sun (2001), Simon and Wardrop (2002) and Parham (2002) — have shown that stronger ICT-capital deepening in the latter part of the 1990s has contributed around 2 or 3 tenths of a percentage point to an *acceleration* in labour productivity growth.

However, the effect on overall capital deepening was not as great, because at least some of that ICT contribution was offset by a weaker contribution from other capital. Other-capital deepening slowed over the 1990s (figure 2). Whilst the overall rate of capital deepening picked up initially after 1995, it declined and stabilised from around 1998.

[5] Growth accounting involves a statistical decomposition of growth in output or labour productivity. Based on assumptions of an aggregate production function exhibiting constant returns to scale and factors paid according their marginal products, data usually available from national accounts can be used to decompose labour productivity growth into contributions from capital deepening and MFP growth.

Table 1 **Contributions to the acceleration in average annual labour productivity growth[a] over productivity cycles**

Per cent per year and percentage points

	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)	1.3	(42)	0.0
– ICT	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: Updated from Parham, Roberts and Sun (2001) and Parham (2002).

Table 2 **Contributions to the acceleration in average annual labour 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	3.2	1.0
Capital deepening	1.1	1.6	0.4
– ICT	0.6	1.2	0.6
.. Hardware	0.3	0.8	0.5
.. Software	0.4	0.4	0.0
– Other	0.5	0.4	-0.1
MFP growth	1.1	1.6	0.6

Source: Updated from Parham, Roberts and Sun (2001) and Parham (2002).

Effects on MFP growth

There is a range of evidence — from casual empirics, the growth accounting framework and econometric analysis — that supports a conclusion that an increase in ICT use has lifted Australia's MFP growth. Four empirical studies, based on different methods and data, found a remarkably similar order of magnitude — 1 to 2 tenths of a percentage point — for the contribution of ICT to annual MFP growth.

Bean (2000) estimated that the uplift in ICT investment contributed 0.12 of a percentage point to Australia's MFP growth, based on a simple cross-country regression.

Parham, Roberts and Sun (2001) and Parham (2002) drew on US data and analysis to infer, in an approximate way, that around 1 or 2 tenths of a percentage point of the MFP acceleration could be associated with ICT use. The analysis was cast in a growth accounting framework. But, because it does not identify any sources of MFP growth, growth accounting itself cannot be used to determine the amount of MFP growth that can be attributed to ICT use. The attribution was inferred by subtracting external estimates (from Oliner and Sichel 2000) of MFP gains due to ICT production from the growth accounting estimates of total US MFP growth. Oliner and Sichel estimated the MFP gains in ICT production from observations of price reductions, employing the assumptions of the cost 'dual'.

Connolly and Fox (2004) adopted a more rigorous approach by formally estimating a production function, which included inputs of quality-constant high-tech capital (essentially a national-accounts measure of ICT). They found a robust and statistically-significant relationship between high-tech capital use and MFP in Australia's market sector. They estimated an MFP elasticity with respect to high-tech capital of 0.17.[6] Using national-accounts based estimates of the growth in ICT capital and MFP evident in the second half of the 1990s, this elasticity suggests that growth in ICT use accounted for about 0.07 of a percentage point of annual market sector MFP growth. This estimate could be on the low side, however, given that it was derived from data that spanned the mid-1960s to the early 2000s and did not account for any structural break in the 1990s associated with ICT's emergence as a GPT.

Estimates were also derived from an econometric analysis undertaken for the ICTaFP project (Gretton, Gali and Parham 2003; Gretton and Gali 2004). The analysis estimated production functions for different industries, based on panels of firm-level observations drawn from the ABS's Business Longitudinal Survey. Because of data limitations, ICT use was measured from observations on whether or not firms used ICT and not by the volume of ICT used. A weighted average of industry estimates indicated that ICT use accounted for around 1½ to 2 tenths of a percentage point of aggregate annual MFP growth in the mid-1990s. (Paul Gretton is presenting this analysis at APPC 2004.)

International perspective

The uptake of ICT by Australian firms in the 1990s was high by international standards, according to a range of indicators (OECD 2003). For example, Australia had the third highest investment in ICT in proportion to GDP in 2001 — up from a ranking of nine in 1980.

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6 Upon request, Connolly and Fox kindly re-estimated their model to directly identify and measure these elasticities.

The ICT contributions to 1990s output and labour productivity growth were large in Australia by international standards. For example, Cardarelli (2001) found that Australia's ICT capital deepening contribution in the second half of the 1990s was as large as it was in the United States and well above the European average. The OECD (2003) found that the United States, Australia, the Netherlands and Canada received the largest GDP contribution from growth in ICT use.

Ahmad, Schreyer and Wölfl (2004) provided updated estimates for OECD countries. Based on standardised measurement, Australia had the fourth highest ICT contribution to annual GDP growth over 1995 to 2001 — at just over 0.6 of a percentage point — behind the United States (just over 0.8 of a percentage point), Canada (just over 0.7) and the Netherlands (just under 0.7).

The overall effect of ICT use on aggregate MFP growth has been found to be small in OECD countries (OECD 2003). An ICT-enabled effect on aggregate MFP growth is more firmly established in Australia than in nearly all other countries. Pilat and Wölfl (2004) found that ICT-using industries made strong contributions to labour productivity growth in countries (including Australia) where productivity growth improved over the 1990s. However, Pilat and Wölfl attributed this result in general to a dominant capital-deepening effect. An MFP effect in high-using industries has been found only in the United States and Australia.

4. Discussion

Several issues warrant further discussion in order to interpret this evidence.

Cyclical effects

Gordon (2000) drew attention to cyclical influences in the assessment of ICT's contribution to US productivity growth. The uplift in ICT use began in 1995 in the United States (and Australia), but labour productivity went from a trough in 1995 to a peak at the end of the decade (Parham, Roberts and Sun 2001). Consequently, growth accounting studies (apart from Gordon's) that analysed the period from 1995 maximised the ICT contribution, but did not decompose *underlying* productivity growth into its various contributions.

Parham, Roberts and Sun (2001) and Parham (2002) preferred to compare changes in growth rates between successive productivity cycles — the period from 1993-94 to 1998-99 compared with the period from 1988-89 to 1993-94 — in order to isolate spurious cyclical effects from the assessment. Updated estimates are in table 1. Over these periods, the contribution of faster growth in ICT use to increased capital deepening (0.3 of a percentage point) is completely offset by the effect of slower growth in other capital.

However, if the first and second halves of the 1990s are used for comparison (table 2), the contribution of ICT-capital deepening to the labour productivity acceleration (0.6 of a percentage point) is only partially offset by a negative contribution (-0.1 of a percentage point) from other-capital deepening.[7] Comparison of tables 1 and 2 shows that, although the ICT contribution to the labour productivity acceleration is higher when the first and second halves of the 1990s are used than when productivity-cycle periods are used, the acceleration in ICT use is associated with a smaller acceleration in MFP growth. This does not tell us how much of the total MFP acceleration was due to ICT but, unless long lags between greater ICT use and MFP gains are involved, it does suggest that a large part of Australia's MFP acceleration was due to factors other than increased ICT use.

Other forms of capital

Is there a causal relationship between increased ICT use and slower growth in use of other capital? Whilst these trends are linked to some degree, it is more likely that the degree is small than large.

Although Australia had relatively strong growth in ICT over the 1990s, it had relatively slow growth in total capital services — because of offsetting slower growth in other capital. But the fact that the other-capital offset was not nearly as marked in other countries at the forefront of ICT uptake — the United States, Canada and the Netherlands — suggests that factors unrelated to increased use of ICT dominated the change in demand for other capital in Australia.[8]

On the other hand, Daveri (2003) suggests that the offsetting pattern observed in Europe and Japan in the 1990s was an adjustment phase in which greater ICT use displaced use of other capital. He also suggests that this adjustment phase took place earlier in the United States.

This issue warrants further investigation, as it determines the extent to which ICT capital has contributed to overall capital accumulation and capital deepening.

Methodology and measurement

As noted above, the evidence on MFP effects is not confined to the one methodology. Different studies have used casual empirics, the growth accounting framework and

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[7] The difference in deceleration in other-capital deepening between tables 1 and 2 is due to a different rate of capital deepening in the earlier period in each table, rather than in the later period.

[8] As further evidence, there was no clear relationship between faster growth in ICT use and slower growth in use of other capital across industry sectors within Australia (Gretton, Gali and Parham 2003)

econometric approaches that have greater or lesser degree of formal specification and sophistication.

The growth accounting estimates have attracted some contention. Several issues in measurement and index number methodology are subject to investigation in consultancies sponsored by the former National Office for the Information Economy and presented in other papers in this session. Earlier, Simon and Wardrop (2002) discussed a number of measurement issues — accuracy of price deflators and the possibility of 'disequilibrium' between rental prices and marginal products of ICT during a period of rapid change — in the context of their own growth accounting work. (See also Brunker 2001.)

At the Productivity Commission, we have started to investigate the sensitivity of growth accounting estimates to the constant-quality (hedonic) ICT price deflators and the assumed asset lives of ICT. Appropriately, use of hedonic deflators has the effect of treating quality improvements in ICT as embodied technological change, which raises the volume of ICT inputs. This is especially appropriate in the Australian context, given that quality improvements are embodied in equipment that is mostly imported. Failure to account for the quality improvements in this way would mean that the technological advances of overseas producers would show up as MFP gains generated by Australian users.

Whilst hedonic price deflation is appropriate, the issues of the accuracy of the deflators and the influence they have on the relative sizes of capital deepening and MFP effects remain.[9] The ABS has adopted a US price deflator for hardware, adjusted for a lag and exchange rate movements, and has assumed a 6 per cent a year decline in software prices. It has work underway to estimate new hardware and software deflators.

A colleague at the Productivity Commission has undertaken some preliminary testing of the sensitivity of growth accounting estimates to price deflators, asset lives and age-efficiency profiles. Although it is preliminary, so far, this work suggests that the total capital deepening and MFP effects are not very sensitive to changes in price deflators, at least for credible variations, or to changes in other parameters.

This work can only investigate the sensitivity of ICT-capital deepening, total-capital deepening and total MFP gains. As noted before, the growth accounting framework does not identify the magnitude of ICT-related MFP gains.

Industry or economy-wide effects?

In response to Gordon (2000) and his conclusion that there was no ICT effect on US MFP growth, it has been argued that his aggregate approach would have masked ICT-related MFP effects in ICT-intensive industries. At the aggregate level, gains in ICT-intensive industries could be offset by negative effects (for a range of reasons) in other industries.

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9 Simon and Wardrop (2002) estimated that half of the increase in ICT volumes in the 1990s was due to declining prices and half was due to increased nominal expenditure.

There is evidence to support the existence of MFP gains in ICT-intensive industries in the United States (eg Bosworth and Triplett 2002; OECD 2003). The industries include financial intermediation, distribution (wholesale and retail trade) and business services.

A positive association between higher ICT use and productivity acceleration is also evident in Australia's Finance & insurance and, to a lesser degree, in Wholesale trade (Parham, Roberts and Sun 2001; Gretton, Gali and Parham 2002). Finance & insurance and Manufacturing were the most prominent sectors in the uptake of ICTs in the 1990s. Other prominent sectors were Wholesale trade, Retail trade, Transport & storage and Communication services (PC 2004). Finance & insurance, by far, and Communication services are Australia's most ICT-intensive sectors (within the market sector).[10]

Connolly and Fox (2004) found a significant MFP effect in Finance & insurance and Agriculture. A significant relationship, albeit less robust, was also found in Wholesale trade, Retail trade, Construction and Accommodation, cafes & restaurants. But they found no significant effect on MFP in Manufacturing, Transport, storage & communication, and Cultural & recreational services.[11]

In the ICTaFP project, Gretton and Gali (2004) found statistically-significant evidence, in nearly all models estimated for 8 industry sectors, that firms that used ICT had higher MFP growth than firms that did not.[12] MFP effects were mostly in the range of around 0.1 to 0.3 of a percentage point of annual growth.

A link between increased ICT intensity and MFP growth in Finance & insurance is unsurprising as, for example, electronic banking has replaced a lot of face-to-face transactions, enabling branch closures and staff reductions. However, Connolly and Fox supplied an elasticity for Finance & insurance, which implied that ICT use contributed only about 0.02 of a percentage point to annual MFP growth in that sector. Again, this is likely to be on the low side, because it does not allow for a structural break in the 1990s. Furthermore, output and MFP growth could be underestimated in this sector (in ABS data), because of unmeasured quality improvements.

In wholesaling, Johnston et al. (2000) found that it was not so much that the industry had become more ICT-intensive, but ICTs did play a part in the transformation of some wholesaling activities from storage-based configurations to 'fast flow-through' systems through the increased use of bar-coding and scanning technology, communications and tracking systems and inventory management systems. Less storage and handling reduced input requirements.

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[10] The ICT cost share in Finance & insurance has been about three times the ICT cost share in the market sector. Communication services is the next most intensive at a little less than twice the market sector average.

[11] There was evidence of a negative relationship in Electricity, gas & water and in Mining.

[12] Sectors modelled were: Manufacturing, Construction, Wholesale trade, Retail trade, Accommodation, cafes & restaurants, Transport & storage, Property & business services and Cultural & recreational services.

Manufacturing is of some interest, given its prominence in the ICT uptake — although it is no more ICT-intensive than the market sector average. Manufacturing was one of the sectors in which a significant relationship between ICT use and MFP (around 0.15 to 0.25 of a percentage point) was found in the ICTaFP project. NOIE (2004) found that technological factors explained a large part of MFP growth in Manufacturing. However, the technological factors investigated were broader than ICT and there were aspects of the data and methodology, that the report itself acknowledged to be less than fully satisfactory.[13] Connolly and Fox did not find a significant relationship between the volume of ICT used and MFP in Manufacturing.

In sum, the evidence is somewhat mixed and further empirical work is needed to clarify the picture. But, to date, Australian evidence of a much stronger relationship between ICT use and MFP at the sectoral level, than at the aggregate level, has not been forthcoming.

Complementarities, adjustment costs and learning

The productivity gains from ICT use do not come automatically, from the mere installation of hardware and software.

Successful integration of ICTs into a business involves some adjustment costs. For example, new work practices need to be developed, and staff need to be (re)trained, redeployed or retrenched.

ICT-enabled innovations usually require complementary investments. Examples include: management time and effort in development, planning and implementation; R&D into redesign of products and production systems; development and introduction of new management and quality-control systems; restructuring of work groups, introduction of new hierarchies and performance information and incentive schemes; and development of new start-up companies, divestments, mergers, acquisitions and alliances.

Skilled labour is also complementary to the input of ICT. In routine applications, ICT can substitute for unskilled labour. Skills of a more general nature (including literacy and numeracy) are needed to operate ICT equipment and systems and to interpret the flow of information and communications that are generated. Beyond that, and especially when it comes to ICT-enabled innovation, managers with high-order skills are needed to see both the technical and business potential that ICT can offer, to integrate ICT into the firm and to manage and implement challenging organisational changes.

Because ICT is a relatively new and rapid-changing technology, there is considerable scope for learning and adaptation. Complementary inputs of accumulated experience can affect the rates of investment in ICT and improvement in productivity growth over time. Staff learn and develop skills by becoming technically and operationally proficient in using

[13] In particular, MFP data were not available at the level of aggregation adopted and were imputed from labour productivity trends.

the technology. Firms can accumulate experience that helps them to identify new opportunities for ICT applications and ICT-enabled innovations and to pursue those opportunities more efficiently and effectively. Learning can be an important means of accumulating 'organisational capital'.[14]

The firm-level econometric analysis in the ICTaFP project found evidence of complements to ICT use. Statistically-significant complementary effects were associated with manager and worker skills and with various measures of innovation, such as the use of advanced business practices and organisational change.

Aggregation issues: why firms differ

Aggregation can explain much of the difference between, on the one hand, anecdotal and case study evidence of large productivity effects in individual firms and, on the other hand, the seemingly small effects at the sectoral and aggregate levels. In the aggregates, high-users/high-gainers are combined with low-users/low-gainers.

Why do firms, even within the same industry, differ in terms of ICT intensity and productivity gains? We found three main reasons in the ICTaFP project. First, because of its platform characteristics, ICT can enable a wide variety of innovations. The nature and amount of complementary investments in innovation can vary accordingly across firms. Second, the availability of complementary skills can vary across firms. Third, the amount of accumulated learning and other dimensions of organisational capital can vary widely across firms.

A question then is whether the variation across firms will narrow over time with further diffusion of technology and adaptation to it. It could be argued that this would be consistent with the view that ICT is a driver of productivity growth.

A significant narrowing is unlikely. The net gains from further investment in ICT could well increase, all other things equal, if adjustment costs decline and complementary investments become more efficient and effective through learning. But other things do not remain equal. Technologies will continue to evolve rapidly for some time. Different firms will continue to have different technology and innovation strategies. Some will continue to accept more risk than others in pursuing further possible productivity improvements.

Differences between firm-level and aggregated evidence can also be due to differences in measurement of ICT. Studies of individual firms and those relying on firm-level data often

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[14] The concept of organisational capital recognises that there are intangible assets of importance to firms that go beyond the skills and experience of the personnel within the firm. How firms learn from the experience of success and failure is one way to accumulate organisational capital. The 'readiness' of a firm to embrace change through application of ICT and related innovation, perhaps through prior restructuring and development of corporate culture, is another possible dimension. Organisational capital is especially important to firms that deal in major ways with rapidly-changing markets and technologies.

use book-value measures of ICTs used. Aggregate and sectoral analyses, on the other hand, often use national accounts data, which use constant-quality and efficiency-depreciated measures of the volumes of ICT. Since quantities measured by the latter method are much greater than those measured by the former method, they can have marked effect on performance estimates — be they rates of return or productivity.

Why countries differ

The ICTaFP project made a contribution to an OECD multi-country study of ICT and productivity. The OECD assessment pointed to a number of factors that help to explain inter-country differences in ICT uptake and its productivity effects (OECD 2004).

- The direct costs of using ICT and associated networks. The available data point to persistent differences in the costs of ICT across OECD countries, despite heavy international trade in ICT and liberalisation of their telecommunications industries.
- The ability of firms to absorb new technology. This includes the availability of know-how and qualified personnel, the scope for organisational change and the capacity to innovate. (The OECD has also made the point that some investment in ICT had not been very productive because it tended to be in compensation for poor management (OECD 2003).)
- Competition and the regulatory environment. A competitive environment is more likely to lead to ICT uptake as a way for firms to strengthen performance. Excessive product and labour market regulation may make it more difficult for firms to realise the potential benefits and therefore reduce the incentives to invest in ICT. (See also Gust and Marquez 2002).

In a broad sense, the policy and institutional environment acts as another complement to ICT use. The business environment needs to be conducive to investment in ICT in the sense that firms need clear and strong incentives to improve performance and the flexibility to adjust their businesses in order to tap the potential that ICT offers.

5. Conclusion

In conclusion, I return to address the questions posed at the outset.

There is no doubt that ICT is bringing widespread change and reorganisation of the way the economy operates. But whether this represents a phase of ‘input substitution’ or something ‘new’ and different depends in large degree on the existence and strength of an MFP effect.

There is a range of evidence that, together, strongly supports the conclusion that ICT has contributed to Australia’s labour productivity growth through both a capital deepening effect and an MFP effect.

On available estimates, the size of the ICT-capital deepening effect has been quite large. ICT use contributed 1 percentage point or more to labour productivity growth in the latter part of the 1990s through capital deepening. ICT-capital deepening contributed 2 or 3 tenths of a percentage point to the acceleration in labour productivity growth in the 1990s.

However, not all of the additional use of ICT translated into additional accumulation of total capital or to overall capital deepening. Some, if not all, of the ICT contribution was offset by slower growth in use of other capital assets. The degree to which this offset is causally related to ICT use warrants further investigation, but casual empirics suggests that it is not large. In any case, any causal effect could in part be a transitional adjustment.

There has been some contention about the accuracy of growth accounting estimates of MFP effects. But the order of magnitude does not depend on one particular methodology and, indeed, is very robust across a number of methodologies and datasets used to date. Growth accounting itself does not and cannot identify the magnitude of the link between ICT use and MFP growth.

The available evidence puts the MFP gains in the vicinity of 1 to 2 tenths of a percentage point of annual growth. The order of magnitude can be interpreted broadly as a contribution to both the growth and the acceleration in MFP in the later part of the 1990s. There was unlikely to have been any MFP contribution until after ICT became a GPT from the late 1980s and early 1990s.

The evidence is that the ICT-capital deepening contribution is far stronger than the ICT-enabled MFP contribution. This is turn suggests that ICT has had a far greater cost-saving labour-substitution effect than 'new' frontier effect.

The evidence that ICT has brought MFP gains supports the proposition that ICT has been an enabler of productivity growth. It is consistent with ICT's status as a GPT that enables users to introduce their own efficiency-enhancing and value-adding innovations.

However, the evidence that ICT is an engine of productivity growth is not as strong. It is not clear that ICT made a net contribution to capital accumulation in the 1990s. In any case, input-substitution and capital deepening could be seen, perhaps a bit unfairly, as a large but otherwise mostly unremarkable response to technological advances in ICT production and attendant changes in relative prices. On ICT-enabled MFP gains, use of ICT may be necessary, but it is not sufficient. ICT-enabled MFP gains depend heavily on a range of complementary factors. Some complements, such as investments in employee training are closely related to, and perhaps led by, investments in ICT. But, for other complements, such as management and the policy and institutional environment, the relationship is more likely to run in the opposite direction. The importance of management skill in being able to identify and realise the opportunities that ICT (and presumably other technologies) could offer was a strong message to come out of the ICTaFP project. The available evidence in an international context is that competitive incentives and flexibilities provided by the policy and institutional environment have been a strong element driving

ICT uptake and productivity effects. In the Australian context, the focus on productivity, technology and innovation was much stronger from the second half of the 1980s than it had previously been. A process of more vigorous restructuring got underway in a more competitive, open and flexible business environment, fostered by microeconomic reforms (PC 1999). In this business environment, firms were much more ready to invest in ICT and to put it to productive use.

References

ABS (Australian Bureau of Statistics) 2001, 'Further Developments in the Analysis of Productivity Growth in Australia', *Australian National Accounts: National Income, Expenditure and Product*, Cat. no. 5206.0, September Quarter, ABS, Canberra.

Ahmad, N., Schreyer, P. and Wölfl, A. 2004, 'ICT Investment in OECD Countries and its Economic Impacts', in OECD, *The Economic Impact of ICT: Measurement, Evidence and Implications*, OECD, Paris, pp. 61–83.

AIG (Australian Industry Group) 2000, *How Fast Can Australia Grow? Mark II*, AIG Discussion Paper, December.

Bean, C. 2000, 'The Australian Economic 'Miracle': A View from the North' in Gruen, D. and Shrestha, S. (eds), *The Australian Economy in the 1990s*, Conference Proceedings, 24-25 July, Reserve Bank of Australia, Sydney, pp. 73–114.

Bosworth, B. and Triplett, J. 2002, ''Baumol's Disease' has been Cured: IT and Multifactor Productivity in US Services Industries', Paper prepared for Brookings Workshop on Services Industry Productivity, Washington DC, 17 May.

Brunker, D. 2001, Issues in the Measurement of Productivity Growth in Information Technology Using Industries, Paper presented at the 30th Annual Conference of Economists, Perth, 24-26 September.

Bresnahan, T. and Trajtenberg, M. 1995, 'General Purpose Technologies: Engines of Growth,' *Journal of Econometrics*, vol. 65, pp. 83–108.

Cardarelli, R. 2001, 'Is Australia a 'New Economy'?', in International Monetary Fund, 'Australia: Selected Issues and Statistical Appendix', *IMF Country Report*, No. 01/55, IMF, Washington DC, pp. 5–26.

Connolly, E. and Fox, K. 2004, 'The Impact of High-Tech Capital on Productivity: Evidence from Australia', April (mimeo), revised version of School of Economics Discussion Paper 2003/4, University of New South Wales, Sydney.

Daveri, F. 2003, 'Information Technology and Productivity Growth Across Countries and Sectors', in Jones, D. (ed.), *New Economy Handbook*, Academic Press, San Diego, pp. 101–20.

Gordon, R. 2000 'Does the "New Economy" Measure up to the Great Inventions of the Past?', *Journal of Economic Perspectives*, vol. 14, no. 4, Fall, pp. 49–74.

Gretton, P. and Gali, J. 2004, Effects of ICT Use on the Performance of Australian Firms: Evidence from a Business Longitudinal Data Set, Paper presented at the Asia Pacific Productivity Conference, Brisbane, 14-16 July.

——, —— and Parham, D. 2003, *The Effects of ICTs and Complementary Innovations on Australian Productivity Growth*, Productivity Commission Staff Working Paper, Canberra. (Also published in OECD 2004, *The Economic Impact of ICT: Measurement, Evidence and Implications*, OECD, Paris)

——, —— and —— 2002, Uptake and Impacts of ICTs in the Australian Economy: Evidence from Aggregate, Sectoral and Firm Levels, Paper prepared for the Workshop on ICT and Business Performance OECD, Paris, 9 December.

Gust, C. and Marquez, J. 2002, *International Comparisons of Productivity Growth: The Role of Information Technology and Regulatory Practices*, International Finance Discussion Paper no. 727, Board of Governors of the Federal Reserve System, Washington DC.

Hubbard, T. 2003, 'Information, Decisions, and Productivity: On-Board Computers and Capacity Utilization in Trucking', *American Economic Review*, vol. 93, no. 4, pp. 1328–53.

Johnston, A., Porter, D., Cobbold, T. and Dolamore, R. 2000, *Productivity in Australia's Wholesale and Retail Trade*, Productivity Commission Staff Research Paper, AusInfo, Canberra.

Jorgenson D. 2001, 'Information Technology and the US Economy', *American Economic Review*, vol. 91, no. 1, pp. 1–32.

Lipsey, R., Bekar, C. and Carlaw, K. 1998, 'What requires explanation?', in Helpman, E. (ed.), *General Purpose Technologies and Economic Growth*, Massachusetts Institute of Technology Press, Cambridge, pp. 15–54.

MGI (McKinsey Global Institute) 2001, *US Productivity Growth 1995-2000*: *Understanding the Contribution of Information Technology Relative to Other Factors*, McKinsey and Company, Inc., Washington DC.

NOIE (National Office for the Information Economy) 2004, *Productivity Growth in Australian Manufacturing*, NOIE Occasional Economic Paper, Canberra.

OECD (Organisation for Economic Co-operation and Development) 2004, *The Economic Impact of ICT: Measurement, Evidence and Implications*, OECD, Paris.

—— 2003, *ICT and Economic Growth: Evidence from OECD Countries, Industries and Firms*, OECD, Paris.

Oliner, S. and Sichel, D. 2000, 'The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?', *Journal of Economic Perspectives* , vol. 14, no. 4, Fall.

Parham, D. 2002, 'Productivity Gains: Importance of ICTs', *Agenda*, vol. 9, no. 3, pp. 195–210.

——, Roberts, P. and Sun, H. 2001, *Information Technology and Australia's Productivity Surge*, Productivity Commission Staff Research Paper, AusInfo, Canberra.

PC (Productivity Commission) 2004, *ICT Use and Productivity: A Synthesis from Studies of Australian Firms*, Commission Research Paper, Canberra.

—— 1999, *Microeconomic Reform and Australian Productivity: Exploring the Links*, Research Paper, AusInfo, Canberra

Pilat, D. and Wölfl, A. 2004, 'ICT Production and ICT Use: What Role in Aggregate Productivity Growth?', in OECD, *The Economic Impact of ICT: Measurement, Evidence and Implications*, OECD, Paris, pp. 85–104.

Simon, J. and Wardrop, S. 2002, *Australian Use of Information Technology and its Contribution to Growth*, Research Discussion Paper RDP 2002-02, Reserve Bank of Australia, Sydney, January.