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ICT Use and Productivity: A Synthesis from Studies of Australian Firms

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The Productivity Commission

The Productivity Commission, an independent agency, is the Australian Government's principal review and advisory body on microeconomic policy and regulation. It conducts public inquiries and research into a broad range of economic and social issues affecting the welfare of Australians.

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Foreword

The Productivity Commission has undertaken a stream of research on Australia's productivity performance and its drivers. The role of information and communications technology (ICT) in promoting productivity growth is an issue that has attracted particular attention not only in Australia, but also overseas, in the context of the 'new economy' debate. Whilst it is now generally agreed that the use of ICT has a positive influence on productivity growth — at least in industries that use ICT intensively — the observed differences across countries in the extent of ICT uptake and related productivity effects have continued to be a puzzle.

Against this background, the OECD secretariat set up a multi-country firm-level study of ICT use and its productivity effects, in order to provide better understanding of the policy-relevant factors that have contributed to cross-country differences. The secretariat invited the Productivity Commission to provide an Australian contribution. The Commission established a joint research project with the Australian Bureau of Statistics, the Department of Industry, Tourism and Resources and the (then) National Office for the Information Economy.

The joint project produced a number of working papers (listed overleaf), including the Australian contribution to the OECD study. This paper draws on the various working papers, as well as the reports that have emanated from the OECD's multi-country study.

The paper documents Australia's strong uptake of ICT, investigates the reasons for it and confirms that it has contributed to Australia's productivity growth. The paper also explores how ICT has affected productivity growth through a quite complex set of relationships. Finally, it draws some broad implications for government policies.

I would like to record the Commission's thanks to the other agencies for their active participation in and contributions to the project. They have added greatly to the scope and quality of the project's outputs.

Gary Banks
Chairman
Productivity Commission
July 2004

Working papers produced for the project

Working paper 1	Gretton, P., Gali, J. and Parham, D. 2002, *Uptake and Impacts of ICTs in the Australian Economy: Evidence from Aggregate, Sectoral and Firm Levels*. Paper presented to the Workshop on ICT and Business Performance, OECD, Paris, December 2002. (Productivity Commission Staff Working Paper)
Working paper 2	Gretton, P., Gali, J. and Parham, D. 2003, *The Effects of ICTs and Complementary Innovations on Australian Productivity Growth*. (Productivity Commission Staff Working Paper). (Also published in OECD 2004, *The Economic Impact of ICT: Measurement, Evidence and Implications*)
Working paper 3	Gretton, P. and Gali, J. 2003, *The Take Up of Computers in Australia: Firm Level Evidence.* (Productivity Commission Staff Working Paper)
Working paper 4	Gretton, P. and Gali, J. 2003, *Effects of Computer Use on Firm Performance — Some Empirical Evidence.* (Productivity Commission Staff Working Paper)
Working paper 5	Gretton, P. and Gali, J. 2003, *Technical Annex to Firm-Level Analyses of the Uptake and Impact of ICTs in the Australian Economy.* (Productivity Commission Staff Working Paper)
Working paper 6	Rawnsley, T., Lubulwa, G. and Mullaly, D. 2003, *Adopters and Non-Adopters of ICT in the Australian Economy: Experimental Results Based on a Linked Data File for 1999-2000.* (Australian Bureau of Statistics Working Paper)
Working paper 7	Australian Bureau of Statistics 2003, *Statistical Annexe — A Summary of Data that Supported Analyses in the ICT and Firm Level Performance Project*. (Australian Bureau of Statistics Working Paper)
Working paper 8	Bennett, R., Cobbold, T. and Phillips, M. 2003, *ICT Use and Firm Performance in Australia: Evidence from Firm Interviews*. (Department of Industry, Tourism and Resources)

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Whilst the other agencies have contributed to the preparation of this paper, the Productivity Commission is responsible for the content and the views expressed.

Abbreviations

ABS	Australian Bureau of Statistics
B2C	business to consumer
BLS	Business Longitudinal Survey
BUIT	Business Use of Information Technology
CAD	computer-aided design
GDP	gross domestic product
GPS	global positioning system
GPT	general-purpose technology
GST	goods and services tax
ICT	information and communications technology
IMF	International Monetary Fund
IT	information technology
LAN	local area network
MFP	multifactor productivity
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
Y2K	year 2000

Key points

- Compared with their overseas counterparts, Australian firms have been active in their uptake of ICT and successful in their efforts to turn it to productive advantage.
- Australian firms invested more in ICT, especially from the mid-1990s, as technological advances provided cheaper and readier access to more accurate, timely and useful information.
- The gains from use of ICT stem from the opportunities it provides firms:
  - to undertake existing tasks more quickly, cheaply and effectively by substituting ICTs for other inputs, especially labour; and
  - to improve multifactor productivity (the efficiency and effectiveness of input use) by using ICTs as a means to innovate — to develop and introduce new value-adding and efficiency-enhancing products, processes and organisational structures.
- Many of these gains do not come automatically — from the mere purchase and installation of new hardware and software.
  - There can be costly and time-consuming adjustments, for example, in staff dislocation and (re)training.
  - Product, process and organisational innovations require investments in design, development and implementation.
  - Skilled staff and high-order management skills and qualities are needed if potential gains are to be realised.
  - The gains also depend on the accumulation of experience in and learning from the application of ICTs and from the investments in ICT-enabled innovations.
- The acceleration in use of ICT in the 1990s raised the rates of growth in Australia's labour productivity and multifactor productivity.
  - Although the available estimates suggest that the acceleration in use of ICT contributed a relatively small amount to Australia's 1990s productivity acceleration, the estimated productivity gains (especially in multifactor productivity) are high by international standards.
- Firms and industries differ in the intensity of their use of ICTs and in their realisation of productivity gains.
  - This is largely due to differences in the nature and amount of their investment in ICT-enabled innovation, in their access to skilled staff and management, and in their accumulation of learning and experience.
- Countries differ in the intensity of ICT use and associated productivity gains.
  - This is largely due to differences in costs of using ICT, in the ability of firms to absorb new technology and in the policy and institutional environments in which firms operate.
- Tapping ICT's future productivity potential is predominantly in the hands of firms.
  - Whilst specific issues require ongoing government attention, the strong performance of Australian firms suggests that additional widespread government support is not warranted. The main role for governments remains one of ensuring that markets are competitive, firms have flexibility to adjust and to experiment, innovation is appropriately supported and needed skills are developed.

Summary

The project and this paper

The origins of this project lie in an invitation from the OECD to participate in an international study of the uptake of information and communications technology (ICT) and its effects on productivity.

- The OECD convened a multi-country, firm-level study of ICT and productivity performance as part of its follow-on work from the Growth Project and in response to a specific request from the US Secretary of Commerce.
- The OECD invited the Productivity Commission to provide an Australian contribution. The Commission initiated a joint project with the Australian Bureau of Statistics, the Department of Industry, Tourism and Resources and the (then) National Office for the Information Economy in order to take a more comprehensive approach that could draw on expertise in the different agencies.

Several issues determined the focus on firms and the broad method of analysis in both the OECD and Australian studies.

- Aggregate and sectoral growth accounting exercises for a number of countries, including Australia, had revealed seemingly small effects of ICT use on productivity, whereas a number of firm-level (case) studies had revealed quite substantial effects. The use of representative firm-level datasets and more rigorous econometric analysis could help to resolve these differences.
- With evidence that ICT uptake and productivity gains vary across firms, it seemed that many important influences on ICT investment and productivity effects operate at the micro level. Analysis at the firm level could therefore aid understanding of these influences and help to identify any appropriate policy responses.
- From the OECD viewpoint, the availability of studies from a number of countries, undertaken as far as possible in similar fashion, could facilitate international comparisons. These could help to explain why the uptake and performance effects of ICT use differ across countries, even though the same technologies are commonly available. Again, any such explanations could highlight policy-relevant influences.
- For the Australian study, there was particular interest not only in confirming that ICT use has contributed to Australia's productivity growth, but also in exploring the

mechanisms through which it might have done so. Earlier studies had indicated that an acceleration in ICT use in Australia had lifted productivity growth, but they fell short of conclusive proof.

This paper draws together the findings from different streams of work undertaken for the Australian contribution to the international study and subsequently (see the list of working papers on p. IV). It also draws on the completed OECD study in order to provide a more comprehensive picture of how well Australian firms have performed, relative to their overseas counterparts.

Technological advances and information gains

ICT emerged as a general-purpose technology in the late 1980s and early 1990s, akin to the steam engine and electricity in earlier epochs.

- This meant that ICT could be used in widespread and generic applications across a broad range of businesses and that it provided the platforms to enable business users to undertake their own cost-saving and value-adding innovations.
- There were three key technological developments that helped to establish ICT as a general-purpose technology:
  - 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; 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.

Advances in ICT have progressively reduced the costs of gathering, storing, retrieving, processing, analysing and transmitting information. In these ways, they have provided firms with cheaper and readier access to more accurate, timely and useful information.

The information gains have given firms two kinds of opportunity.

- In a 'passive' sense, firms could undertake pre-existing information-related tasks more quickly, effectively and cheaply than by more traditional labour-intensive means.
- In an 'active' sense, firms could use ICTs as a means to develop and introduce value-adding and efficiency-enhancing innovations in:
  - products (for example, customised and new information-hungry products);
  - processes (for example, to improve quality and timeliness of output, to coordinate better with suppliers and customers and to schedule more efficient maintenance); and
  - organisational structures (for example, changes to horizontal and vertical integration, more outsourcing, flatter hierarchies and more active teamwork).

Interviews with firms, conducted as part of the project, provided numerous examples of these kinds of innovations (see box 1).

The rapid uptake of ICT by Australian firms in the 1990s

Australian firms stepped up their investment in ICT in the 1990s as the scope for general application expanded (figure 1).

- Investment in information technology (that is, excluding communications equipment) jumped from 8 per cent of business investment in 1989-90 to 18 per cent in 2000-01.
- Investment in hardware 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. By 2000-01, these proportions had grown to nearly 85 and 70 per cent respectively.

Box 1 **How ICT affects firm performance: insights from interviews with firms**

Interviews with firms were undertaken as part of the project in order to gain better understanding of the mechanisms through which use of ICT has improved firm performance. The following areas were identified as being significant.

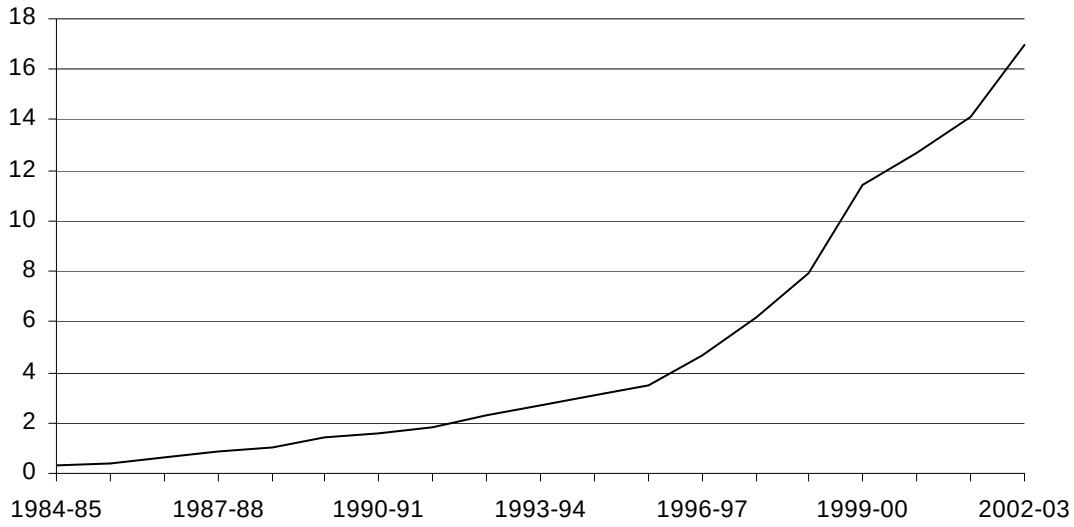
Key area of impact	*Nature of impact*
1. Labour	Staff reduction in some instances, but not all. Enhancements of human capital.
2. Facilities and outsourcing	Reduction of some facilities, and outsourcing of certain functions, sometimes overseas.
3. Production and distribution processes	Greater consistency of product quality as well as quality enhancement. Process change across the spectrum from little change to major re-engineering of entire process.
4. Management practices	More timely and accurate management information. Greater centralisation of decision making. Improved communication and reporting systems. Improved inventory control.
5. Product characteristics and mix	Development of customised products and services (for example, in banking and mining services).
6. Relationship with customers and suppliers	Better and more frequent communication with customers and suppliers. Greater responsiveness to customer needs and more certainty in new product design.

The rate of uptake varied across industries and across firms, even within the same industry.

- The Finance & insurance sector, especially, and Manufacturing were prominent in the 1990s investment in new ICTs. Other major investors were Wholesale trade, Retail trade, Transport & storage and Communication services.
- Large firms were earlier and stronger in the uptake of ICT. Nearly all medium to large firms were using computers by 1996-97. However, the uptake of computers by smaller firms varied substantially across sectors. The introduction of the goods and services tax (GST) in 2000 encouraged many small firms to install computer systems to assist with reporting requirements.

Figure 1 **Real investment in information technology, market sector, 1984-85 to 2002-03**

$ billion (at 2001-02 prices)



Why have firms invested more in ICT?

Firms have invested more in ICT as the anticipated net benefits from doing so have risen. In general, the anticipated benefits have increased, while the costs have declined.

Four main factors have determined the costs and benefits of investing in ICT.

1. *Rapid technological advances and the accompanying rapid decline in ICT prices.*
   - Ongoing rapid technological advances have brought information gains by increasing the capabilities, applications and user-friendliness of ICTs. The enhanced characteristics of ICTs have made them more substitutable for other production inputs — especially labour. With competitive markets for ICT, ongoing technological advances have reduced the purchase costs of ICT capability. Hardware prices have fallen by 10-20 per cent a year — a dramatic decline relative to prices of other inputs.
2. *Growing opportunities for ICT-enabled innovation.*
   - As ICTs have developed, they have provided more opportunities for users to undertake productivity-enhancing innovations. This has raised the potential for benefits.

3. *Costs of adjustment and investments in ICT-enabled innovations.*
   - Productivity gains do not come automatically — from the mere purchase and installation of hardware and software. There are: adjustment costs (for example, associated with staff dislocation and training); and, if other ICT-based innovations are pursued, the costs of investments (complementary to investments in ICT) in product, process and organisational innovation.
   - These costs can decline over time as initial adjustments are made and as experience in ICT-enabled innovation is gained.
4. *The availability of other required inputs (complements to investments in ICT use and ICT-enabled innovations).*
   - Effective use of ICT requires skilled labour. Higher-order management skills and vision are often needed to combine the capacity to recognise the technical potential that ICT offers, the capacity to recognise the business opportunities and the capacity to identify and implement the investments in organisational and other changes that bring about performance improvements. The availability of skilled labour and management affects the magnitude of the gains that can be derived from investments in ICT.
   - There can also be inputs of intangible assets — 'organisational capital' — which are accumulated within a firm, especially through experience and learning. As a relatively new technology, ICT presents considerable scope for 'learning-by-doing', not just in becoming technically and operationally proficient in using it, but also in learning to extract more performance gains over time. Experience can help firms to identify new opportunities for ICT applications and innovations and to pursue them more efficiently and effectively. These intangible inputs therefore influence (amongst other things) the extent to which firms identify and pursue opportunities for beneficial application of ICT, the amount of complementary investments they make in ICT-enabled innovations and the expected net benefits from their investments.

Beyond these four more immediate determinants of ICT uptake, a common theme among the firms interviewed for the project was the importance of competitive pressures as a key underlying driver of their adoption of ICT and its use in innovative ways to improve firm performance.

The effects of ICT use on productivity growth

Consistent with the strong growth in investment in the 1990s, there was rapid growth in the use of ICT as a production input.

- IT capital services grew at 24 per cent a year through the 1990s. There was stronger growth in the second half of the decade (28 per cent a year) than in the first half (19 per cent a year).

Increased ICT use can contribute to increased output and labour productivity growth.

- Increased output growth comes from any effect increased ICT use has on input growth and multifactor productivity (MFP) growth.
- Increased labour productivity growth comes from any effect increased ICT use has on capital deepening and MFP growth (box 2).

The increased use of ICT from the early 1990s contributed to growth in total inputs and to capital deepening.

- Growth accounting estimates suggest that additional inputs of IT contributed around 2 or 3 tenths of a percentage point to the *acceleration* in annual growth in output (aside from any MFP effects) and in capital deepening over the latter part of the 1990s.
- However, some portion, if not all, of these effects was offset by slower growth in the use of other forms of capital. Whilst most of the slower growth appears to have been unrelated to increased ICT use, some growth in ICT use could be expected to substitute for growth in the use of other capital (box 2).

There is also evidence that increased ICT use made a further contribution to output and labour productivity growth by enabling MFP gains.

- Whilst the methodologies used in other studies have limitations, they put the contribution of ICT use to the acceleration in Australia's annual MFP growth in the vicinity of 1 to 2 tenths of a percentage point.
  - Other studies have also found evidence of MFP gains associated with increases in ICT use in Australia's Finance & insurance and Wholesale trade sectors.

Box 2 **The nature of productivity gains from ICT use**

Investment in ICT assets for business use can have two kinds of effect on labour productivity growth:

- a capital deepening effect; and
- a multifactor productivity (MFP) effect.

Capital deepening

Increases in use of ICT capital can raise labour productivity — everything else equal — by raising the ratio of capital to labour (that is, capital deepening). Capital deepening means higher labour productivity because each unit of labour has more capital to use to produce output.

Some investment in ICT can substitute for inputs of labour, bringing a direct capital-deepening effect. However, some investment in ICT can also substitute for use of other forms of capital (for example, use of ICT can enable rationalisation of requirements for building space). Consequently, not all increases in ICT capital translate into equivalent increases in total capital or into equivalent increases in capital-deepening.

The actual extent of capital deepening will also refect numerous other (non-ICT) influences on the use of non-ICT assets and labour.

MFP gains

Use of ICT can enable firms to innovate in processes, products and organisational structures. The countless possible cost-saving and value-adding innovations are 'disembodied' sources of MFP gain. New products add more value. New processes and organisational arrangements improve product quality, timeliness and customer convenience; allow greater product variety and customisation of products to customers' requirements; reduce waste, transactions and coordination costs; allow outsourcing and specialisation; streamline production and distribution; and so on.

The innovations mean that inputs of labour and capital are used more efficiently and effectively to generate output — that is, MFP is raised. MFP growth raises labour productivity because improvements in the efficiency and effectiveness of resource use raise the ratio of output produced to inputs of labour used.

The MFP gains derived by users are sometimes referred to as 'spillovers' (unpriced or uncompensated gains) 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.

Users can also gain from innovations based on their own use of ICTs. The gains stem from the opportunity firms are provided to bring goods and services of greater value to market and/or to reduce the average volume of inputs required to generate output, distribute goods and conduct sales. It is not so clear, however, that these are spillovers. There a several possible reasons (see chapter 4). To give one, 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 their innovations.

- The firm-level econometric analysis in this project also found statistically-significant evidence of ICT-enabled MFP gains.
  - Estimates from the analysis also put the magnitude of the MFP growth effect at around 1½ to 2 tenths of a percentage point — within the same range as estimates from previous studies. However, like the previous estimates, this estimate of magnitude should be treated with some caution.[1]

The project found support for the notion that complementary inputs and complementary investments in ICT-enabled innovations enhanced the productivity gains from ICT use.

- The firms interviewed stressed the importance of worker and management skills and of 'learning-by-doing'. They also confirmed the importance of the product, process and organisational innovations enabled by ICTs (box 1).
- Statistically-significant complementary effects were found in the firm-level econometric analysis associated with manager and worker skills; and measures of innovation, such as use of advanced business practices and organisational change.

There was also evidence of lags between investment in ICT and the realisation of performance gains.

- The firm interviews indicated that the lag between new ICT installation and realisation of associated benefits was between six months and three years.
- The econometric analysis also suggested that gains from adoption of ICT in the mid-1990s were realised with a lag of several years.

Australia's uptake and productive use of ICT in international perspective

Compared with most other OECD countries, Australia's uptake of ICTs from the mid-1990s was strong.

- On a range of indicators, the highest rates of ICT uptake and diffusion were observed in the United States, Canada, New Zealand, Australia, the Nordic countries and the Netherlands.
  - For example, Australia had the third highest investment in ICT in 2001 as a share of total GDP — an increase from its ninth ranking in 1980.

[1] The firm-level econometric analysis did not include firms in the Finance & insurance sector, where ICT use is most intensive; and the extent of productivity gains was related to whether or not firms use ICT and not to the intensity of their use. At a very broad level, there are difficulties in capturing the full and pervasive effects of general-purpose technologies, such as ICT.

The effects of increased ICT use on Australia's output and productivity growth have also been large by international standards.

- Australia had the fourth highest ICT (input growth) contribution to GDP growth in the second half of the 1990s.
  - According to OECD estimates, ICT contributed just over 0.6 of a percentage point to annual GDP growth in Australia. For the United States, Canada and the Netherlands, the contribution ranged (in respective descending order) from around 0.8 to just under 0.7 of a percentage point.
- The effects on labour productivity growth from capital deepening were also relatively high in Australia.
- An ICT-enabled effect on aggregate MFP growth is more firmly established in Australia than in nearly all other countries.
  - According to OECD reviews and analysis, MFP gains in ICT-intensive industries have been found to date only in the United States and Australia.

Reconciliation of aggregate, sectoral and firm-level perspectives

The micro, sectoral and aggregate evidence seems to be more easily reconciled in the case of Australia than in other countries.

- Productivity gains — including MFP gains — have been found in Australia at the aggregate, sectoral and firm-levels. Despite some analytical and data limitations, there is broad consistency in the magnitudes of estimates at the different levels.
- In nearly all other countries, labour productivity gains have been found at all three levels, but the influence of capital deepening, rather than MFP, appears stronger and the firm-level results, which show significant gains, remain in contrast to smaller sectoral and aggregate results.

Difficulties in reconciliation appear to be due in large part to two issues.

- In the sectoral and economy-wide aggregates, high-users/high-gainers are aggregated with others, including low-users/low-gainers, leading to relatively small averages. Comprehensiveness and representativeness of data are therefore important.[2]
- There are measurement issues. National accounts data, which are used for sectoral and national estimates, are based on conventions that record higher volumes of ICT inputs,

[2] The Australian study analysed a range of firms that covered more industry sectors than studies of other countries.

and therefore generate higher capital-deepening effects and lower residual MFP growth effects, than do firm-level data.[3]

Why firms differ in ICT uptake and performance effects

Three factors are particularly important in explaining why firms differ in their intensity of ICT use and in the extent to which they have derived performance gains.

- The general-purpose character of ICT and the scope for ICT-enabled innovation.
  - Like many other inputs, the scope for direct application of ICT varies across firms, especially in different industries. What sets ICT apart, though, is its ability to provide opportunities for innumerable user innovations on a broad front.
  - The scope for ICT-based innovation varies across industries and firms within industries have different technology and innovation strategies. The nature and extent of complementary investments in product, process and organisational innovation by individual firms determines the timing and extent of the productivity gains they individually derive.
- The availability of complementary skills.
  - Differences between firms in their ability to attract and retain required management and employee skills can also affect the anticipated net gains from ICT investment and therefore the extent to which they invest in ICT. They also affect the degree to which productivity gains are realised.
- Learning and 'organisational capital'.
  - Learning effects, such as developing the ability to identify new ICT applications and to extract more performance gains over time, can influence the magnitude and timing of ICT investments by individual firms, the magnitude and timing of their complementary investments in innovation and the magnitude and timing of the performance gains they derive. More generally, differences between firms in their accumulation of organisational capital sets them apart from each other in their adoption of and adaptation to technology.

Why countries differ

The OECD multi-country study pointed to a number of factors that help to explain inter-country differences in uptake and performance effects.

[3] This same issue applies to Australia, but did not show up in the firm-level estimates due to the absence of a measure of the volume of ICT use in the database available for the econometric analysis.

- 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.
- 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.

Tapping ICT's productivity potential in Australia

The experience since the mid-1990s suggests that, in what has become a more conducive business environment, Australian firms have been relatively quick and strong on the uptake of ICT and relatively innovative in the way they use ICT to derive productivity gains.

The prospects for appropriate ICT uptake and realisation of performance gains in the future also seem favourable.

- Firms reported that there are further opportunities for investment in existing technologies, as well as opportunities to use existing technologies more innovatively. Many firms expected the most significant area of potential performance improvement to be in e-commerce.
- Investment and performance gains are also likely to respond to further advances in ICT technologies.

Given the evidence of strong performance of Australian firms since the mid-1990s, the case for any additional widespread action from governments to encourage uptake and productive use of ICT is not strong. The future rate of uptake of ICT and the realisation of potential productivity gains is predominantly in the hands of firms themselves.

Nevertheless, the firms interviewed reported that several factors have limited the realisation of gains from ICT use in specific ways and circumstances.

- There have been skill shortages. While basic ICT skills can be found or developed, some firms found it difficult to find people possessing higher-level ICT knowledge or skills, together with industry experience or business acumen. There is also ABS survey evidence of skill shortages.
- Incompatible information systems have been established in different firms as a result of adoption of different technologies or development of different ICT strategies. The

incompatibilities make it difficult to tap the full potential that could come through integration of ICT systems as part of merger, acquisition or alliance.

- Different regulatory requirements, for example between states and territories, increase the costs of developing ICT systems for nationally-based firms.
- Some government agencies and firms still rely on paper-based systems, which reduce the gains to those firms that could operate solely on ICT-based systems.
- The lack of fast Internet services to some regional and other areas has limited the use of on-line services.

There are issues for ongoing government review. The objective should be to allow or ensure that firms can realise the potential for productivity gains, rather than to encourage ICT adoption or related innovation for their own sake.

- Governments should continue to address issues to do with the extension and use of networks such as the availability and pricing of suitable communications infrastructure, on-line security, privacy, content, appropriate protection of intellectual property, regulation of market power and taxation of e-commerce.
- The main role, however, remains one of ensuring that:
  - the business environment is competitive, in order to provide strong ongoing incentives to raise productivity;
  - the regulatory and institutional environments allows appropriate flexibility for firms to adjust and to experiment;
  - the policy environment provides appropriate support for innovation; and
  - the education and training systems are of high quality and are responsive to changing needs.

1 Background, issues and approach

The Australian economy grew rapidly in the 1990s. Growth in output was sustained at a rate and for a period not seen since the 1960s and early 1970s. A surge in productivity growth underpinned an acceleration in the growth of both GDP and average per capita income.

Australia was one of relatively few OECD economies to show a pickup in growth in the 1990s. Growth accelerated in some countries, including the United States, Canada, Australia, the Netherlands and Norway, but not in others. The pattern was unusual in the sense that, with acceleration in a few of the highest-income countries (the United States in particular) but not elsewhere, the average-income levels of countries tended to diverge, rather than show the convergence of earlier times.

The OECD secretariat undertook a major study — the Growth Project — to investigate the reasons for this different pattern of international growth (OECD 2001, 2003b). There was perhaps particular interest in why growth in the United States had taken off and the role that information and communications technology (ICT) might have played.

The Growth Project found that differences in productivity growth were a key factor that differentiated the better performing countries from the poorer performing countries. Furthermore, the productivity improvements in a number of the better performing countries were associated with ICT — that is, production and use of hardware and software.

ICT can lift national productivity growth in three ways.

- Technological advances, for example in the progressive miniaturisation of microprocessors, raise productivity in the production of ICTs.
  - The ability to produce much more powerful ICTs without commensurate increases in input requirements raises multifactor productivity (MFP) — that is, output per combined input of labour and capital.
  - A combination of rapid technological advances and production on a sufficiently large scale can lift MFP growth at the national level.

- Increased ICT use raises labour productivity in ICT-using industries.
  - An increase in the ratio of capital to labour (capital deepening) raises labour productivity because each unit of labour has more capital to work with to produce output.
  - Growth in ICT use is more likely to raise capital deepening on a national level as the rate of growth in ICT use rises and as ICT rises as a proportion of the total capital stock.
- Increased use of ICTs can raise MFP in ICT-using industries.
  - If use of ICTs enables using firms to introduce cost-saving and value-adding innovations, MFP in using industries can rise. The opportunities for innovation might come from network effects — benefits to existing users from the addition of new users of networks — or from users' own use of ICTs. Innovations can be in products, processes and organisational structures (see next chapter.) The opportunity for MFP gains accords with the view that ICT is a general-purpose technology that enables other (user) innovations.
  - Network effects depend on the diffusion of network-connected ICTs among firms that transact with each other and with consumers and government agencies. Innovations based on own use of ICT are likely to be related to the volumes and types of ICTs in use. The magnitude of national productivity gains depend on the significance of the innovations that users introduce.

Countries clearly differ in the extent to which they engage in production of ICT. The United States, Finland, Ireland and South Korea were among a number of ICT-producing countries to realise sizeable productivity gains in the 1990s. For Australia, on the other hand, local production of ICTs has not been on a sufficient scale to influence national productivity outcomes.

Countries also differ on the use side — the extent to which they invest in ICT and the extent to which their ICT use enables MFP gains. For example, the United States has advanced further in these respects than many European countries, most notably during the ICT 'boom' in the second half of the 1990s.

The case of Australia illustrated that a large participation in ICT production was not necessary to promote ICT-related effects on performance.[1] Even with little production, Australia had one of the strongest rates of investment in ICT. There was evidence that Australia's productivity growth had increased as a result (Cardarelli 2001; Parham, Roberts and Sun 2001; Simon and Wardrop 2002).

[1] Canada is another example.

However, the differences in the rates of uptake of ICT and associated productivity gains across countries presented a puzzle. After all, the same technologies were available to all countries on essentially similar terms.

1.1 The OECD multi-country firm-level study

The puzzle had perpetuated in part because of the method of analysis commonly used. Much of the analysis of the post-1995 'boom' had relied on aggregate growth accounting — a statistical method which accounts for economies' output and productivity growth in terms of input growth and improved efficiency and effectiveness of input use (that is, MFP growth).[2] Whilst growth accounting gives some idea of the importance of growth in ICT inputs in contributing to productivity and output growth, it does not directly capture all ICT effects (for example, MFP gains from use) or indicate what drives increases in ICT use. In short, it cannot explain why countries differ.

Econometric analysis in the Growth Project and elsewhere emerged to suggest that the differing rates of uptake and productivity gains across countries have been influenced by policy and institutional differences (Gust and Marquez 2002; OECD 2003b). Stricter product and labour market regulation were found to be associated with slower ICT uptake and weaker productivity gains.[3] But this analysis was still at an aggregate level.

Insights into causal relationships between ICT and performance, and some of the factors influencing those relationships, were emerging from firm-level analysis. Micro studies highlighted the importance of process, product and organisational innovations that accompany ICT use (see, for example, Bresnahan, Brynjolfsson and Hitt 2002). However, many of the results, showing large performance effects, were difficult to reconcile with macro trends, perhaps in part because they were drawn from unrepresentative cases. Nevertheless, the micro studies did show that uptake and performance effects vary across industries and even across firms within the same industry. It follows that the influences on ICT uptake and linkages to productivity do not operate uniformly across industries or the economy. The firm level of analysis was therefore key to understanding the factors that affect ICT uptake and performance effects.

As part of follow-on work from the Growth Project and in response to a specific request from the US Secretary of Commerce, the OECD initiated a study to bring together the international and the firm-level perspectives through a set of independent country analyses of ICT uptake and its effects on firm productivity. It was thought that the opportunity to discover common and contrasting features across countries could build understanding of the range of factors that influence ICT uptake and performance effects, and that also lead

[2] See chapter 4 for growth accounting estimates for Australia.

[3] The analysis did not take into account any benefit from regulation.

countries to differ. The use of comprehensive and representative firm-level datasets could help reconcile the differences found at the firm and aggregated levels.

1.2 The Australian project

The OECD invited the Productivity Commission to participate in the multi-country study and to provide an Australian contribution. The Commission initiated a joint project with the Australian Bureau of Statistics (ABS), the Department of Industry, Tourism and Resources and the (then) National Office for the Information Economy, as a joint effort would enable a more comprehensive approach that could draw on expertise in the different agencies.

The Australian project was designed to contribute not only to the OECD multi-country study, but also to the analysis of issues of domestic policy relevance.

- There was the challenge to go beyond the previous growth accounting exercises, which had established an association between ICT use and productivity growth, but fell short of a firm conclusion on whether ICTs have had causal links to MFP gains in Australia. An econometric analysis that also controlled for other non-ICT influences on productivity could help.
- Little analytical work had been undertaken to establish the mechanisms through which ICT affects productivity. Capital deepening effects are quite straight forward to identify and measure. However, while MFP gains seemed consistent with the general-purpose or enabling technology view of ICT, again, there was not conclusive evidence. Further investigation of the product, process and organisational innovations that were considered necessary to generate MFP gains was needed.
- The study could also help to identify the factors that help and hinder the uptake of ICTs and their beneficial effects on firm performance.

The Australian project encompassed the following strands of work:

- an examination of trends in the uptake of ICTs through the ABS's Business Use of Information Technology (BUIT) survey;
- an update of earlier growth accounting estimates (aggregate and industry), based on national accounts data;
- the use of a longitudinal firm-level dataset (from the ABS's Business Longitudinal Survey) to investigate the link between ICT use and productivity performance;
- analysis of a specially-constructed database that links unit records from the BUIT survey with performance information from the Economic Activity Survey and from the Australian Taxation Office (conducted within the ABS to preserve confidentiality requirements); and

- interviews with firms to explore the ways in which ICT has improved performance and the factors that have helped and hindered ICT take up and performance improvements. The interviews were conducted with 16 firms in manufacturing, mining services, finance, electricity, transport and logistics and two industry associations.

Working papers were completed throughout the project (see p. IV). Findings from the early stages of the project (Working papers 1 and 2) were delivered as the Australian contribution to the OECD multi-country study and have been drawn upon in OECD (2003a). The OECD has also published a volume of papers undertaken for its multi-country study (OECD 2004) and Working paper 2 is included in that volume. Further work on the Australian project has been completed since the initial working papers were delivered to the OECD. Earlier analysis has been updated and refined. Other streams of work have been completed and documented.

1.3 This paper

This paper draws together the key findings from the Australian project. Rather than summarise the individual streams of work, the paper draws general conclusions on themes and issues from that body of work. It also draws on observations from the OECD reports based on the multi-country firm-level study.

The studies undertaken for the Australian project have confirmed that Australian firms have been active in their uptake of ICTs and that they have used them in ways that generate productivity gains. The studies have identified at least some of the complex array of factors that affect ICT uptake and performance effects. There are complementarities between ICT use and other inputs (for example, skills to use ICT). The performance effects are subject to lags. The studies confirm that ICT use affects productivity through both capital deepening and MFP effects, the latter stemming from ICT's role as a general-purpose technology that enables innovations in products and in processes (of production, distribution, purchasing, marketing and sales) and in organisational arrangements.

2 Australia's rapid uptake of ICT

The evolution and convergence of technologies have broadened the range of business applications of information and communications technology (ICT) and provided opportunities for using firms to innovate (section 2.1). These developments undoubtedly helped to bring about a strong uplift in investment in ICT in Australia in the 1990s (section 2.2). The uptake of ICT was so strong that it put Australia ahead of many other OECD countries in this regard (section 2.3).

2.1 The evolution of ICT as a general-purpose technology for business innovation

Information technology has come a long way since the rudimentary and extremely bulky computers of the 1940s and 1950s (box 2.1). Today's computers are more powerful, compact, versatile, mobile and reliable than earlier mainframes. Developments in software have also expanded the range of applications and made computers more user-friendly.

Advances in hardware and software took computers from comparatively specific-purpose use in a narrow range of institutions to a wide range of uses in a wide range of businesses. Early use of mainframes was largely confined to the storage and analysis of large information banks in government agencies and universities. In the business world, financial institutions were among the first to use mainframes in support of their standard delivery of services. Business use expanded enormously with the development of desk-top and mini computers, which combined computing power with compactness at widely affordable prices, and new application software. The development of more user-friendly software also took the use of computers from the exclusive province of highly-trained specialists to the operational reach of a large section of the general workforce.

Figure 2.1 illustrates the speed and enormity of technological advances in personal computers. The most pronounced feature is the exponential growth in processing power. With companion advances in memory capacity and software, the capabilities and user-friendliness of computers expanded manyfold.

Box 2.1 **Computers: from rarity to ubiquity**

Up until the 1980s, computers seemed to be rare and mysterious machines, locked away in large purpose-built climate-controlled rooms, which were patrolled by specialised staff of seemingly equal mystery. Even the most rudimentary computations required knowledge of computer 'languages' which had strange syntaxes and a disarming intolerance of even the most insignificant typographical slip. These computers were 'fed' programs using masses of cards with the intricate program language encoded through holes punched in the cards. Hopeful programmers could be seen carrying large boxes of these cards to deposit outside the rarefied computer rooms, and suffered nightmares (and some the actual awful experience) in which a box of hundreds of cards in precise and critical order was dropped to the floor. Large and complex programs would have to be scheduled for overnight runs when other demands on the central mainframe were light.

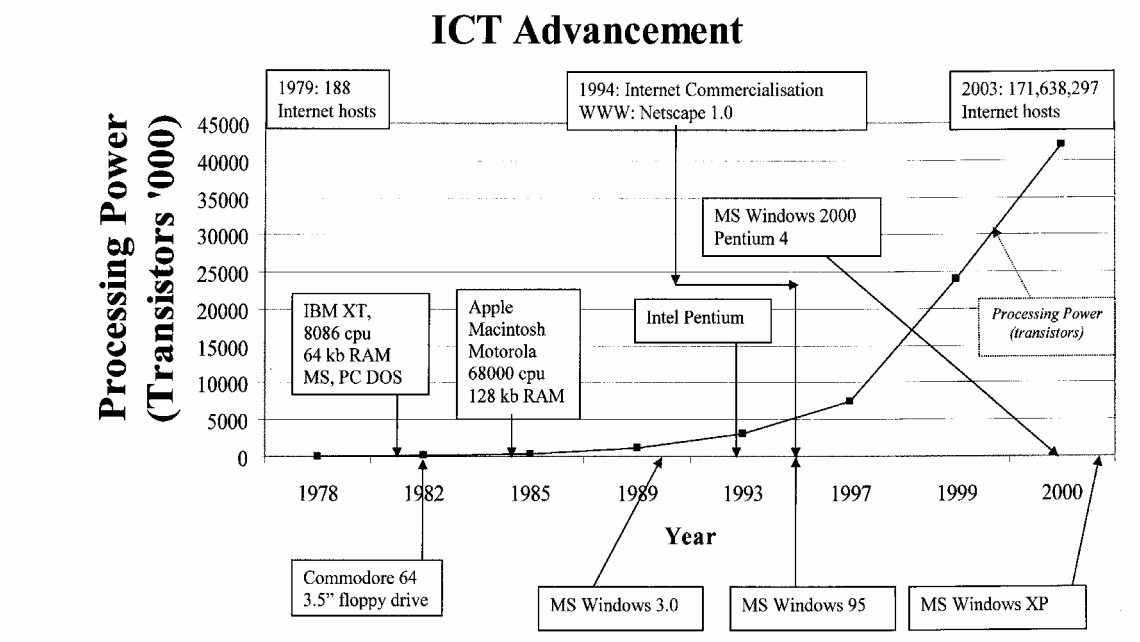
Then in the early 1980s desk-top computers began to appear in the offices of organisations where the core business relied on large amounts of data and relatively complex computational techniques. These machines — not so different in appearance from today's desk-tops — seemed very impressive at the time but were able to boast RAM of only 64K or 128K compared with the typical personal computer of today with around 5,000 times more RAM. They also had no 'hard drives' and different applications were stored on 'floppy disks', which constantly had to be inserted and removed from the single disk drive. The processing speed of computers has also expanded enormously through equally impressive improvements in the technology of microprocessors.

The introduction of user-friendly software also facilitated the wider use of computers. Users could operate desk-top computers without the need for training in computer languages like Fortran, Cobal, Pascal, APL etc.

As the cost of computing power declined at astonishing speed, and user-friendly software began to do more and more for the user in ever more appealing ways, the phenomenon of 'a computer at every desk' became widespread in Australia in the 1990s.

The evolution of telecommunications technology was equally remarkable. Land lines were complemented with satellite-based communication, analogue technology was superseded by digital technology, and mobile telecommunications became commonplace.

Figure 2.1 **Some key milestones in the development of ICT hardware and software**



Sources:
Intel: www.intel.com/research/silicon/mooreslaw.htm
Hobb's Internet Timeline: www.zakon.org/robert/internet/timeline/
A Brief History of Computing: www.ox.compsoc.net/~swhite/history/timeline-INDEX.html

These two technologies converged in the late 1980s and early 1990s to form what is now called information and communications technology. One of the main advances in the convergent technology was the invention of the Internet and its commercialisation. The Internet and other local-area and restricted-access networks are now the dominant means of information and data transfer around the world and are used in constant, every-day fashion by many businesses. Networks are now critical to the efficient operation of global markets, the most obvious being international finance and capital markets. The number of Internet hosts has grown from 188 in 1979 to around 171 million in 2003 (figure 2.1).

The convergence of information and communications technologies expanded the range of business uses in other important ways as well. For example, the local and global operation of transport and logistics firms has been enhanced by a much-improved ability to process and distribute information through ICTs and monitor shipments with global positioning system (GPS) technology. Firms in manufacturing, wholesaling and retail can also use these technologies to implement more efficient 'just-in-time' inventory management systems. Satellite-based data collection is vital in mining exploration and in agricultural pest (locust) control. Video conferencing, computer-aided presentational technologies, and

the centralisation of financial and other data management functions in real time (and sometimes from remote locations) have also become possible.[1]

The miniaturisation of computers, the convergence of information and communications technologies and the breadth and user-friendliness of software applications established ICT as a general-purpose technology (GPT).[2] This meant that it had widespread 'generic' use and that it could be incorporated into business use in a myriad of new ways, many of which were determined by users themselves.

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

The advent of ICT and its further technological development since the late 1980s and early 1990s has provided firms with cheaper and readier access to more accurate, timely and useful information. The advances have progressively reduced the costs of gathering, storing, retrieving, processing, analysing and transmitting information.

The information gains have provided firms with two kinds of opportunity:[3]

- in a 'passive' sense, to undertake pre-existing information-related tasks more effectively and cheaply than by more traditional labour-intensive means; and
- in an 'active' sense, to develop and implement value-adding and efficiency-enhancing innovations in products, processes and organisational structures (see box 2.2 for examples).

But the active use of ICT to generate gains from innovation does not come automatically. The use of ICTs with certain characteristics may be necessary to provide the platforms for innovations, but it is not sufficient to merely install the hardware and software. The ICT-enabled innovations can, in fact, require deliberate and substantial investments on the part of users in order to bring them to fruition (see chapter 3).

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1 Information technologies which have only a rudimentary communications component are also widely used today — for example, robotics in manufacturing, and computer-based diagnostics for highly complex machinery, including the family car!

2 For more on the properties of GPTs, see the collection of essays in Helpman (1998).

3 Chapter 4 has more detailed discussion of these opportunities and chapter 5 provides examples from the firm interviews.

Box 2.2 Examples of product, process and organisational innovation enabled by ICT

ICTs bring firms a number of information gains — in cost and effectiveness in dimensions such as accuracy, timeliness, sophistication, storage, access and transmission. Firms can take advantage by using ICTs to undertake information-related tasks in existing business practices more effectively and cheaply. They can also use ICTs as a platform for their own innovations. The possible user innovations are innumerable. A few illustrative examples follow.

Product innovation

- Development of more information-hungry products, such as financial derivatives.
- Customisation of products to different customer requirements, through closer contact with customers and greater production flexibility enabled by ICTs.
- Service packages, for example in tourism, enabled by easier access to more comprehensive information.
- Greater convenience in purchasing through lower transactions costs on-line.

Process innovation

- Improved quality, efficiency and timeliness of production, through better monitoring and quality control and improved management information that identifies scope for, and enables, 're-engineering' of processes.
- Reduction in inventories and waste, through better coordination with suppliers and customers, less uncertainty about demand and better quality control.
- More efficient scheduling of maintenance, through better diagnostics, ease of monitoring and optimisation of timing and nature of maintenance tasks.

Organisational innovation

- Changes to horizontal and vertical integration (with outsourcing enabling gains from specialisation), through easier and better coordination of activities.
- Flatter hierarchies, because of better internal information and communication flows and greater ease of monitoring and coordination.
- More active teamwork and decentralised responsibility, because objectives can be defined on a micro scale, feedback on performance can be given quickly if not in real time and incentives can be readily aligned with the performance of individual teams.

A quote from an early proponent of the re-engineering approach to business improvement is strongly stated, but captures the essence.

> … heavy investments in information technology have delivered disappointing results — largely because companies tend to use technology to mechanize old ways of doing business. They leave the existing processes intact and use computers simply to speed them up. … It is time to stop paving the cow paths. Instead of embedding outdated processes in silicon and software, we should … use the power of modern information technology to radically redesign our business processes in order to achieve dramatic improvements in their performance. (Hammer 1990)

The use of ICT and its potential to improve business performance are influenced not only by the inventiveness of hardware and software engineers, but also by the inventiveness of users themselves. Technological advances in hardware have enhanced the capabilities of computers to meet a wide range of uses. This general capability is harnessed in many different ways by both general-purpose and specific-purpose software. The hardware/software combinations are, in turn, put to many different applications developed by users themselves. Many of these uses were unimagined by the hardware and software designers.

2.2 The uplift in ICT investment

With the expansion in applications and opportunities for innovation, Australian firms stepped up their investment in ICT in the 1990s.

The best data source on investment in ICT — the ABS national accounts — has one seeming disadvantage and one distinct advantage. The national accounts data have separately identified information technology (IT), but not communications equipment. However, because growth in investment in communications equipment is likely to be similar to growth in investment in IT, trends in IT are likely to indicate trends in ICT quite closely. The advantage of the national accounts data is that they are based on conventions that take account of not only the number of computers and related equipment purchased, but also their increased 'quality'. This means that:

- if, for example, the quality of computers doubled (in terms of processing speed, memory capacity and so on), purchase of the same number of computers would represent double the volume of investment;[4]
- technological advances in ICT hardware and software are treated — quite appropriately — as being embodied in the equipment purchased; and

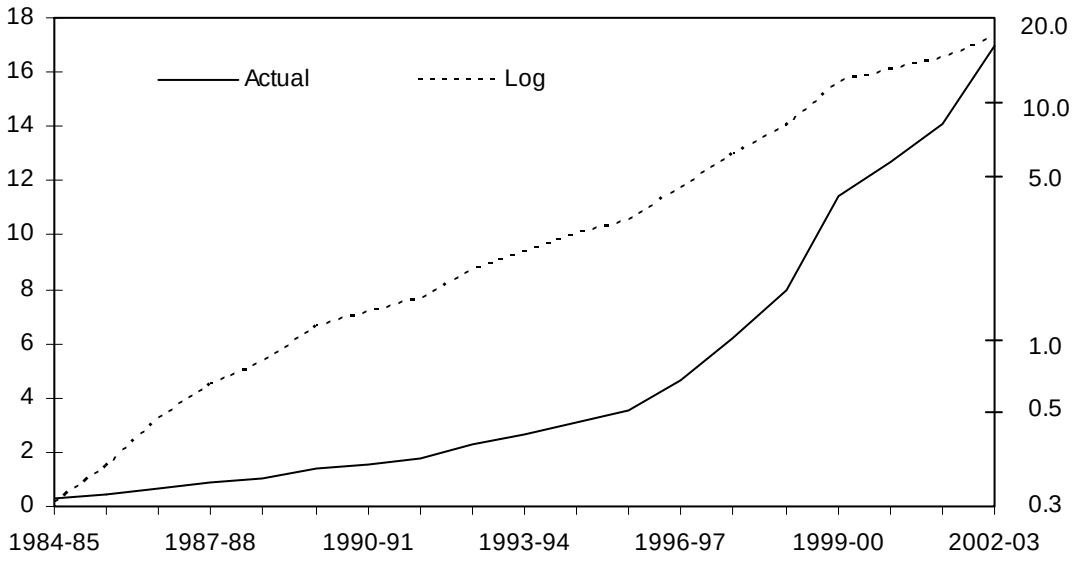
[4] Hedonic price indexes, which take account of quality improvements, are used to deflate nominal expenditure and thereby form volume estimates.

- the increase in volume of investment in IT, as measured in the national accounts, is much greater than the increase in nominal expenditure on ICT that would be shown in the assembly of company financial accounts.

The strong uplift in ICT investment, as indicated by the IT data, is clearly evident in figure 2.2. (Figure 2.2 also includes the investment series drawn on a log scale in order to better convey changes in growth rates.) Investment in IT grew much faster than investment in other capital (table 2.1) and jumped from an 8 per cent share of nominal market sector[5] investment in 1989-90 to an 18 per cent share in 2000-01. Whilst IT investment had been growing strongly before the 1990s (table 2.1), that earlier growth was off a relatively low base (figure 2.2).

Figure 2.2 **Volume of investment in information technology, market sector, 1984-85 to 2002-03**

$ billion (at 2001-02 prices) on left hand side, Log scale on right hand side



Data source: Unpublished ABS national accounts data.

5 The market sector covers about 60 per cent of the measured economy and excludes industries (for example, public administration, health, education, defence) for which output measures are inadequate for use in productivity analysis. A number of non-market sector industries are intensive users of ICTs (some are listed in table 2.3).

Table 2.1 **Growth in information technology investment in the market sector from the mid-1980s**

Per cent per year

	1984-85 to 1989-90	*1989-90 to 1994-95*	*1994-95 to 1999-00*
Information technology	35.2	17.2	29.8
– Hardware	31.4	23.8	41.5
– Software	36.5	14.8	22.8
Other capital	3.9	0.4	4.2
Total	4.3	1.0	6.4

Source: Productivity Commission estimates based on unpublished ABS data.

The volume of IT investment accelerated in the second half of the 1990s (table 2.1) Some cyclical and one-off factors — the dampening effect of the early 1990s recession and the accelerating effects of defensive expenditure to forestall the threat of the 'Y2K bug' and the introduction of the goods and services tax (GST)[6] at the end of the decade — may have contributed to the acceleration. But there were also some structural developments after 1995, including more rapid technological advances. These would have contributed to higher volumes of investment.[7]

Certain service industries and Manufacturing were prominent in the uptake of IT (table 2.2). The Finance & insurance sector stands out, with around a quarter of market sector investment — more than double its output share — while Manufacturing absorbed around 15 per cent in the mid-1980s, climbing to 19 per cent in 2002-03. Other prominent sectors were Wholesale trade, Retail trade, Transport & storage and Communication services.

The diffusion of ICTs across firms was also rapid in the 1990s. 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 2.3). By 2000-01, these proportions had grown to nearly 85 and 70 per cent respectively. Nevertheless, the degree of penetration still varied across industries (table 2.3).

ICT use now permeates almost the whole economy, horizontally across industries and vertically up and down supply chains, all the way to final consumers who use ICTs for

6 As noted later in this report, some smaller businesses introduced computer systems to help them with GST reporting requirements.

7 The growth in IT investment has been uneven over the past few years. There was a spike in 1999-2000, with around 44 per cent more investment than in the previous year. Growth then slowed to 11 per cent over each of the next two years, but picked up again in 2002-03 with an increase of around 20 per cent.

commercial as well as personal purposes. Indeed, personal ownership of ICT equipment and software is vital to the future of business to consumer (B2C) retail business.

Table 2.2 **Volume of IT investment by sector in the 1980s, 1990s and 2000s**

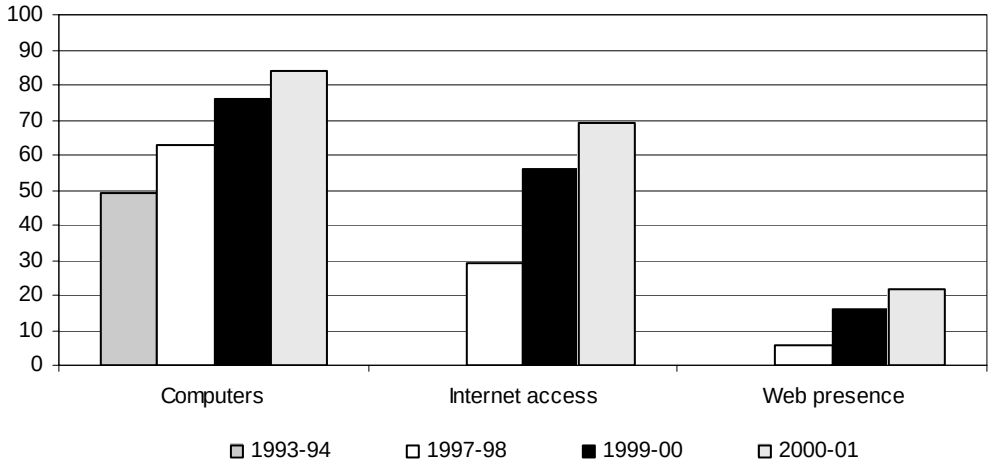
2001-02 prices

	1984-85		*1994-95*		*2002-03*	
	$m	%	$m	%	$m	%
Agriculture	5	(2)	52	(2)	236	(1)
Mining	5	(2)	49	(2)	301	(2)
Manufacturing	46	(15)	516	(17)	3294	(19)
Electricity, gas & water	19	(6)	125	(4)	604	(4)
Construction	17	(6)	183	(6)	830	(5)
Wholesale trade	35	(11)	344	(11)	1673	(10)
Retail trade	27	(9)	332	(11)	1619	(10)
Accom., cafes & restaurants	8	(3)	106	(3)	469	(3)
Transport & storage	31	(10)	298	(10)	1248	(7)
Communication services	29	(9)	280	(9)	1404	(8)
Finance & insurance	81	(26)	736	(24)	4848	(29)
Cultural & rec. services	8	(3)	86	(3)	439	(3)
Market sector	311	(100)	3107	(100)	16963	(100)

Source: Productivity Commission estimates based on unpublished ABS data.

Figure 2.3 **Proportion of Australian businesses using information technology[a], 1993-94 to 2000-01**

Per cent



a All employing businesses in Australia except businesses in Agriculture, forestry & fishing and general government and like activities.

Data source: ABS (*Business Use of Information Technology*, Cat. no. 8129.0).

Table 2.3 **Rates of IT penetration in Australian industries in 2000-01**

	Proportion of firms using		
	Computers	*Internet*	*Web*
	%	%	%
Agriculture	na	na	na
Mining	88	79	30
Manufacturing	81	66	28
Electricity, gas & water	95	89	44
Construction	80	64	10
Wholesale trade	89	77	33
Retail trade	78	57	22
Accom., cafes & restaurants	71	53	26
Transport & storage	76	60	19
Communication services	78	58	20
Finance & insurance	90	81	22
Cultural & rec. services	87	74	30
Property & business services	93	85	25
Health & community services	89	72	14
Personal services	72	52	22
TOTAL	**84**	**69**	**22**

na not available.

Source: ABS (*Business Use of Information Technology,* Cat. no. 8129.0).

2.3 International perspective

Australia's investment in ICT in the 1990s was strong by international standards, particularly in the second half (Colecchia and Shreyer 2002). Australia's investment in ICT as a proportion of GDP was third (to the United States and Japan) among OECD economies in 2001 (Ahmad, Schreyer and Wölfl 2004) — a lift from the ninth ranking in 1980. On a range of indicators of uptake and diffusion, the United States, Canada, New Zealand, Australia, the Nordic countries and the Netherlands were typically at the forefront (OECD 2003a).

Pilat and Devlin (2004) provide an update of indicators assembled by the OECD which show that Australia ranked highly at the end of the 1990s on:

- ICT investment as a proportion of total investment (excluding residential dwellings); and
- Internet penetration among businesses and business use of the Internet and websites.

They also report that the sectoral distribution of ICT investment, with an emphasis on services sectors such as wholesale trade and financial and business services, is fairly common across countries. The greater ICT intensity and Internet use found in large Australian firms was also found among large firms in other countries.

3 Why have firms invested more in ICT?

The project used two methods to investigate the reasons for the strong growth in information and communications technology (ICT) investment in the 1990s: firm interviews and statistical and econometric analysis. The findings are presented in this chapter.

Naturally, firms assess the likely costs and benefits before deciding whether to invest in ICTs or to upgrade or extend their holdings (see box 3.1 for a number of general observations on the investment programs of firms). The expected benefits and costs go beyond those associated immediately with the installation of ICT and include the expected benefits and costs associated with the innovations enabled by ICT.

The firm interviews and firm-level econometric analysis identified four principal factors that affect the magnitudes of costs and benefits (section 3.1):

- advances in the capabilities of ICTs and their falling prices;
- the growing opportunities for ICT-enabled innovation;
- the costs of adjustment associated with adopting ICT and of complementary investment in innovation; and
- the availability of other inputs that are (required) complements to ICT use.

The balance of costs and benefits has fallen in a systematically different way for small and large firms (section 3.2).

Competitive pressures have been an important underlying influence on ICT uptake by providing incentives to adopt technologies and to innovate (section 3.3).

The OECD multi-country study of ICT uptake highlighted some other influences (section 3.4).

Box 3.1 **Some observations from firm interviews on ICT investment**

For the most part, the firms interviewed had been investing in ICT for well over a decade at various stages of development. Many firms have re-invested every three or four years. This was notably so for the manufacturing, mining and transport and logistics services firms.

Major upgrades of ICT have occurred as part of detailed and planned investment programs in all the interviewed firms. ICT continues to account for an increasing proportion of capital expenditure for many of them.

Competitive pressures account for some of the increase in expenditure, but the pressures differ between industries and other drivers are also at work. For example, one large pharmaceutical company noted that its expenditure on ICT had increased significantly over the past few years. While competition has played a part, the main driver of this growth has been the growing requirements placed upon the company by regulatory authorities, particularly drug testing authorities, and especially in the United States.

The logistics firm also reported an increase in expenditure of about 700 per cent in the last three years, following a move into e-commerce and other internet-based technologies. This move was designed to allow better management of data and more centralised management. The main driver in this case was the competitive environment.

In other firms interviewed, expenditure has remained at about the same level or declined in recent years. For example, ICT expenditure in the mining services and automotive firms has been reasonably stable in recent years, whereas it had declined in the electricity firm in recent years.

Source: Working paper 8.

3.1 Four major influences on the costs and benefits of ICT use

Firms have invested more in ICT as the anticipated net benefits from doing so have increased. In general, the anticipated benefits from investing in ICT have increased, while the costs have declined.

Advances in capabilities and falling prices of ICTs

It was noted in the last chapter that rapid and extensive advances in technology have improved the capabilities of ICT to provide additional storage capacity, processing power, functions, applications and user-friendly operability. Hardware and software have advanced enormously in terms of function and variety — including mobile phones, GPS technology, credit and other transactions cards, fibre optics and digital telecommunications

— and has been applied to a much broader range of applications. Applications have been further developed and diffused as user networks have grown and as various technologies have converged and been interfaced.

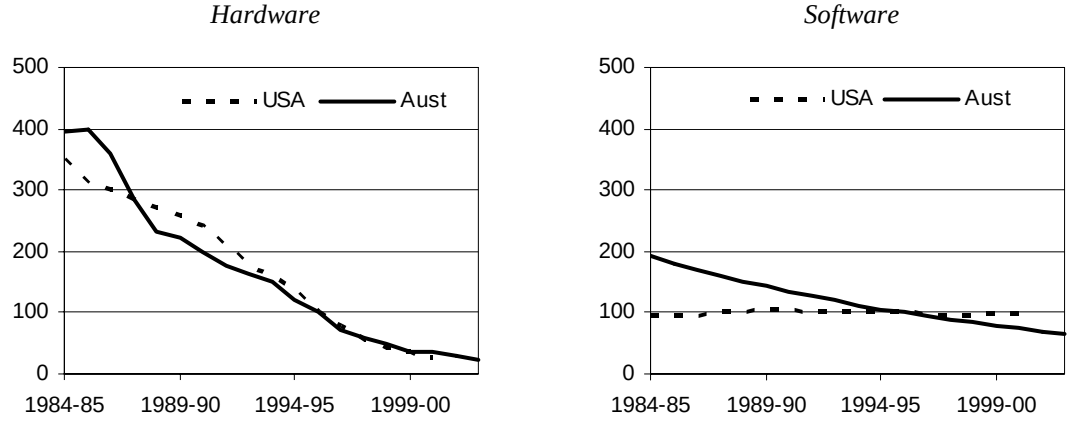
The firm interviews provided examples of ICT use that now span the full range of firm operations — product development, production processes, administration, communication, purchasing, distribution, sales and marketing.

Productivity gains in the production of hardware and software have meant that improvements in the capabilities of ICT have been made without commensurate increases in inputs. Moreover, the markets for hardware and software have been sufficiently competitive that productivity gains in most areas have largely been passed on to users in the form of lower prices.

Hardware prices, in particular, have fallen rapidly (figure 3.1).[1] The average quality-constant price of hardware[2] fell 11 per cent annually over the 10 years to 1994-95 and by 19 per cent annually over the six years thereafter.

Figure 3.1 **Hedonic price deflators for IT, Australia and USA, 1984-85 to 2002-03**

Index 1995-96 = 100



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

Increased capability and applicability of ICTs and falling prices obviously increase the expected benefits to firms from investing in ICT. If and when they provide a sufficient expected net benefit to firms, the growing capabilities and falling prices induce investment in ICT in substitution for other inputs and as platforms for user innovations.

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

2 The use of hedonic price deflators allows for improvements in quality. The constant-quality price reflects the cost of purchasing a 'unit' of computing capacity where, conceptually, a unit is some amalgam of processing speed, memory capacity, portability and other characteristics valued by purchasers.

Falling prices were found to have contributed to the uptake of ICTs in both the firm interviews and the econometric modelling of firm behaviour (box 3.2).

But, the intensity of use of ICT has varied across firms in different industries, suggesting that there are differences in the scope for application, at least across industries. See also section 3.2 on small and large firms.

The econometric analysis found industry differences in the contributions to uptake (as well as industry differences in the extent of uptake). The need to coordinate activities between different locations and the reporting requirements of business incorporation were also factors in some industry sectors. Openness to international trade was also important in Internet use in some sectors.

Opportunities for ICT-enabled innovation

The expected net gains from ICT investment also depend on the anticipated gains from ICT-enabled innovations in products, processes and organisational structures.

The firm-level econometric analysis confirmed that opportunities for related product and process innovation also affected ICT uptake. Stronger uptake was associated with a greater propensity to use advanced business practices and implement organisational change (box 3.2).

The scope for innovation, and innovations of different types, varies across industries. For example, the scope for improved production processes and better inventory management can be large in many manufacturing firms. Savings in costs of storage and handling are potentially large in wholesaling, transport and storage if production and distribution of goods can be better coordinated through ICTs. Information-intensive products have been developed in financial markets and other services industries, such as recreation. Firms in the accommodation industry may be able to access marketing, administration and some supplier benefits, but would have relatively limited scope to use ICT to improve their basic production methods.

The identification of opportunities for ICT-enabled innovations also varies across firms and over time, depending on their experience in and learning from ICT use and related innovation (see below). The vigour with which they pursue opportunities also varies across firms according to their technology and innovation strategies (see chapter 6).

Box 3.2 **Modelling ICT use with Business Longitudinal Survey data**

The econometric analysis of ICT use was based on a longitudinal dataset of firms (from the ABS's Business Longitudinal Survey) spanning the years 1994-95 to 1997-98. Observations were included for eight different industry sectors.

Overall, large firms with more skilled managers and workforce, and 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.

- Firm size (measured in terms of employment) was positively related to the use of computers for all sectors.
- 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.
- 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.
- Firm reorganisation was positively and significantly related to computer use.
- The number of business locations was positively related to computer use for a number of sectors. This suggests that ICTs were useful in the coordination of firms' activities between locations.
- 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.
- The level of educational qualification of the major decision maker was positively and significantly related to computer use for six of the eight sectors.
- 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.

Source: Working Papers 1, 2, 3.

Costs of adjustment and complementary investment

Successful integration of ICTs into a business involves some adjustment costs. It is typically not a simple matter of purchasing and installing hardware and software. New information systems have to be developed. Staff need to be trained. There may also be a need for reorganisations of day-to-day work practices and redeployments of staff.

There are further costs if ICTs are used as platforms for user innovations. The innovations require investment of management time and effort in development, planning and implementation. If ICTs are used to develop new or improved products, other complementary investments in R&D and production redesign may be required. Process innovations can require such investments as the development and introduction of new management and quality-control systems and of performance information and incentive schemes; and the continuous investigation and re-engineering of processes. Organisational innovation can involve restructuring of work groups, introduction of new hierarchies, development of new start-up companies, divestments, mergers, acquisitions and alliances.

The size of adjustment costs and complementary investment costs affects the balance between costs and benefits in the appraisal of ICT investment proposals. This was clearly identified in the firm interviews, but was not explicitly tested in the econometric analysis.

The costs of adjustment and complementary investments can decline over time as comparatively large initial adjustments are made and as experience and learning improve the efficiency with which innovations can be brought to fruition.

Complementary inputs

It has been well established in other studies, and confirmed in this project (chapter 5), that skilled labour is 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, people with high-order skills are needed to see the potential that ICT can offer in the business environment, to integrate it into the firm and to manage and implement organisational changes.

Lack of complementary skills can put a brake on the uptake of ICT. Either the opportunity is not seen or the opportunity is passed up because of the inability to find the required skills to use ICT to advantage.

Complementary investment in staff training was very common among the firms interviewed for the project and is seen by those firms undertaking it as critical to the success of ICT investment strategies. One of the mining services firms stated that it was

vital to have people who can exploit the technology and be innovative in its use, rather than focus on the technology itself. Many other firms made similar statements. The automotive manufacturer has even gone so far as to develop, in conjunction with the relevant State authorities, an in-house training facility for its production and administrative staff to adjust to new ICTs.

The econometric analysis found that ICT uptake had a statistically-significant association with more skilled managers and workforce (box 3.2).

Another potentially important complementary input is of an organisational nature that goes beyond the skills and experience of the personnel within a firm. How firms learnt from the experience of success and failure — a form of accumulation of 'organisational capital' — was also seen as an important influence on investment in ICT over time. 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. Chapter 6 discusses the nature and importance of learning and organisational capital as influences on investment in ICT and the delivery of performance gains. Inputs of organisational capital can be important when technologies and markets are subject to rapid change.

3.2 Firm size has made a difference

Large firms were earlier and stronger in the uptake of ICT. Data from the ABS's Business Longitudinal Survey show that nearly all medium to large firms (that is, firms employing 50 persons or more) used computers by 1996-97. However, the uptake of computers by 'smaller' firms (that is, 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 Retail trade, Accommodation, cafes & restaurants and Transport & storage were computer users.

The statistical analysis of linked survey data on information technology (IT) use found that firm size was positively associated with IT use and use of the Internet (Working paper 6).

The firm-level econometric analysis (box 3.2) also confirmed that larger firms were more likely to have been early adopters of computers and Internet communications.

The different rates of uptake for small and large firms could be due to differences in either expected benefits or costs or both. Expected benefits have been greater in larger firms, with greater scope to apply ICT systems to the array of business practices within the firm and to introduce innovations that tap gains from better management information, better

coordination of staff and activities and so on. The costs of equipment, ICT systems, adjustment and complementary investment tend to be higher relative to turnover for smaller firms, although they may have some advantages in terms of flexibility to adjust. Aside from firms that are set up specifically to focus on experimentation, small firms are generally less financially able to bear the risks of early adoption and early attempts to innovate. They tend to follow the illustrations of success developed by larger firms.

Many small firms were brought into the computer age with the introduction of the goods and services tax (GST). The balance of benefits and costs changed in view of the assistance that ICTs could provide in tracking transactions and compiling information to comply with GST reporting requirements (Working paper 8). Once ICTs were installed, however, they could be used for a variety of purposes.

3.3 The importance of competition

The incentive of competition was identified in the firm interviews as a key underlying driver of the adoption of ICT and its use in innovative ways to improve firm performance (box 3.1). Customers expect better service levels, consistency in product/service quality and reduced costs. Supplying firms have to compete on all these aspects. Firms that adopt ICTs and use them as a basis to deliver better product, quality, value and service at least keep up with competitors, if not get ahead of them for a time. Firms that are slow to adopt and innovate, on the other hand, are likely to fall behind or even become casualties.

The strength of the competitive incentive was not tested in the formal modelling because a firm-specific measure of competitive pressure was not available from the data source used.

Competitive pressures have intensified generally in the Australian economy over the past two decades. Import competition has increased through reductions in trade barriers; competition from foreign firms has increased with easing of foreign investment restrictions; government business enterprises have been commercialised and privatised in some cases; and domestic pro-competition regulation has been broadened in ambit and intensified in application.

3.4 International studies of factors influencing ICT uptake

Overseas studies of the uptake of ICT have come to similar conclusions on the main influencing factors. But, with different data sources and the benefit of international comparisons, they have also provided additional insights.

The OECD (2003a) provided an assessment of the factors that have affected the different rates of ICT uptake across OECD countries (also provided by Pilat and Devlin 2004):

- factors related to the direct user costs of ICT — for example, the costs of ICT equipment, costs, speed and reliability of telecommunications services or the costs of installation of an e-commerce system;
- costs and implementation barriers related to firms' ability to absorb ICTs and to innovate — for example, the availability of know-how and the scope for organisational change — which can be more of a problem for small firms;
- factors related to risk and uncertainty — for example, on-line security — which can reduce the reliance on ICT methods and therefore the gains to be derived;
- factors related to the nature of the business — that is, scope for application; and
- factors related to competition and to the regulatory environment. Competition puts downward pressure on ICT prices and raises the incentive for firms to invest in ICT. Excessive regulation in product and labour markets may reduce the potential benefits from ICT and related innovation and therefore the incentives to invest in ICT.[3]

In one of the OECD-facilitated international studies, Hollenstein (2004) analysed the reasons for ICT uptake among Swiss firms. He found the main determinants of ICT adoption to be: higher anticipated benefits (in particular, improved customer orientation, improved product quality and variety and improved production processes), lower costs of adoption (investment costs), higher absorptive capacity (human capital, innovative activity), information spillovers (from early adopters) and learning effects, competition, larger firm size and industry of application. He also found that introduction of new workplace organisation (team working, decentralised decision making and flatter hierarchical structures) facilitated ICT adoption.

[3] As noted in chapter 1, Gust and Marquez (2002) also came to this finding.

4 ICT and productivity: a broad perspective

Technological advances in hardware and software (chapter 2) have provided a significant and direct form of innovation and productivity growth in those countries that produce information and communications technology (ICT) on a large scale. The ability of ICT producers to develop more and more powerful micro-processors and equipment and better software, without commensurate increase in inputs, has lifted national multifactor productivity (MFP) growth in Finland, Ireland and South Korea, in particular, but also in the United States, Japan and Sweden.

However, since Australia produces comparatively little ICT hardware and software, the potential productivity gains associated with *use* of ICT are more relevant here.

This chapter elaborates on the nature of the productivity gains associated with ICT use and presents estimates of the effect of ICT on productivity growth at the sectoral and aggregate levels. The information gains from use of ICTs can lead to improved labour productivity in two ways — through input substitution, which leads to capital deepening, and by enabling product, process and organisational innovations, which are sources of multifactor productivity growth (section 4.1). Investment in ICT in Australia has contributed to growth in capital inputs and capital deepening (section 4.2) and has enabled additional multifactor productivity growth (section 4.3). These effects can be drawn together in a growth accounting framework (section 4.4). The productivity effects in Australia have been strong by international standards (section 4.5).

A broad perspective on productivity effects is presented in this chapter. The firm-level perspective, which was the main focus of the project, is presented in the next chapter.

4.1 Nature of performance effects — input substitution and innovation effects

Chapter 2 pointed out that the development of ICT has brought information gains to firms in the form of cheaper and readier access to more accurate, timely and useful information. It was also pointed out that these information gains provide opportunities for firms to use ICTs ‘passively’ to substitute for other inputs, especially labour, in performing information-related tasks. But they can also provide opportunities for firms to use ICTs

'actively' as platforms for product, process and organisational innovations. These two forms of opportunity and action have different productivity effects.

'Passive' use — input substitution and capital deepening

The increasing information gains from the rapid development of ICTs mean that firms have increasing incentive to substitute ICTs for labour — where possible — so as to perform information-related tasks more quickly, cheaply and effectively. Substitution of additional ICT capital for labour raises the ratio of total capital to labour (capital deepening) in production, all else equal.[1]

Some of the effect of increased ICT use on capital deepening can, however, be offset if increased ICT capital also substitutes for other forms of capital. For example, use of computers may reduce the need for building space to store physical records. On-board use of ICTs in road transport vehicles can increase use of available truck capacity and therefore reduce the need for investment in additional trucks.[2]

Increases in the capital-labour ratio raise labour productivity, all else equal. They do so because each unit of labour has more capital on average to work with to produce output and so the ratio of output to labour input (labour productivity) is higher.

The degrees to which ICTs can substitute for other inputs depend on the explicitly-designed characteristics embedded in the ICTs themselves.[3] These embedded characteristics are in the hands of the hardware and software developers.

In this input-substitution sense, ICT is no different from other capital inputs. If some other capital input becomes cheaper and more effective, firms will tend to substitute it where possible for labour and other inputs.

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1 Profit-maximising firms employ capital and labour in the ratio that aligns the relative marginal products of the two inputs with their relative costs. If a new technology results in ICT capital with enhanced characteristics or lower price, firms will (provided substitution is possible) increase the ratio of ICT-capital to labour — generating either more output (for given labour) or generating the same output at lower cost (with less labour), all else equal.

2 Hubbard (2003) finds that advanced on-board computers in transport logistics have increased utilisation of trucking capacity in the United States by 13 per cent. That is, for a given tonne/km task fewer 'truck units' are required when combined with the new information technology, leading to billions of dollars of annual benefit.

3 These are technical substitution possibilities. The extent to which ICTs actually do substitute for other inputs depends on movements in relative prices and other cost factors, as spelt out in chapter 3.

‘Active’ use — innovation and additional MFP growth

ICTs also enable firms to be ‘active’ in pursuing opportunities for further productivity gains through innovations in their products, their processes and the ways in which they organise themselves. It is the ability to enable a multitude of innovations across a broad spectrum that makes ICT different from most other capital inputs.[4]

The innovations are enabled, but are not determined, by the explicitly-designed characteristics embedded in ICTs. Those characteristics provide platforms for innovation opportunities in using firms. But the innovations themselves are disembodied advances and their development is in the hands of using firms. For examples of ICT-based innovations, see chapter 2 and, for examples from the firm interviews, see chapter 5.

The countless possible innovations are sources of MFP gains.[5] New products add more value. New processes and organisational arrangements improve product quality, timeliness and customer convenience; allow greater product variety and customisation of products to customers’ requirements; allow outsourcing and specialisation; streamline production and distribution; and so on. The innovations mean that inputs of labour and capital can be used more efficiently and effectively to generate output.

As noted in chapter 1, the ICT-based innovations can stem from network effects, as more users participate in ICT-based networks, or from innovations based on firms’ own use of ICTs. Whilst MFP gains associated with network effects can be regarded as ‘spillovers’ from ICT producers to users, it is not so clear that the gains from user innovations are spillovers (box 4.1).

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

5 To economists, input substitution is conceptually akin to moving along a production function. Firms still produce the same products with essentially the same production method. It is just that more output is produced at a different ratio of inputs. The ICT-related innovations, however, represent a shift of the production function — generating more output from a given use of inputs.

Box 4.1 **Spillovers from ICT producers to users**

The MFP gains that users derive are sometimes referred to as 'spillovers' or externalities from ICT producers to users. Spillovers in this context are any gains that are bestowed on users without compensation to producers.

ICT producers are compensated for the technological advances that they build into ICTs — provided that customers value them. The compensation comes through the payment of the asking price for the goods.

Network effects are clearly a spillover. Users of ICT-based networks gain from the addition of new members to the network, without having to compensate producers of ICT equipment (or providers of the communications infrastructure). For example, there are the well-known communication externalities arising from each additional subscriber to the Internet — as happened with telephone systems in the past. The commercial value is expressed through the reduction in transactions costs of communication. For example, very large documents and collections of information and data can be communicated to many different destinations instantaneously at the same cost as sending a single line of text. As another example, firms already participating in a purchasing network may gain from the additional competition when additional suppliers join the network. But it costs the existing members nothing (unless there become problems with capacity, congestion or security on the network) for the new firms to join.

Users can also gain from innovations based on their own use of ICTs. The gains stem from the assistance ICTs provide to firms to bring goods and services of greater value to market and/or reduce the average volume of inputs required to generate output, distribute goods and conduct sales.

But it is not so clear that these gains constitute spillovers. First, the gains are not automatically bestowed. The ICTs provide platforms and opportunities for innovations, but the innovations are made at the discretion of the user. Second, users do have to pay something in order to benefit from the innovations, although this is in the form of complementary investments, rather than compensation to the ICT producers. Third, it may be that ICT producers are able to capture some of the innovation benefits. Some innovations may be so common and dependent on particular characteristics of ICTs as to be reflected in demand for the desired characteristics and therefore the prices that producers can sustain.

Effects on labour productivity

The capital deepening effect from increased ICT use in substitution for labour (net of substitution for other capital) and the MFP effect from ICT-enabled innovations both raise labour productivity growth.

Observed trends in labour productivity growth, however, also reflect a host of other influences.[6] Employment of labour, investment in other capital (and therefore the observed growth in total capital inputs) and MFP growth respond to many factors, apart from use of ICT capital.

Looking more closely at the employment of labour, the substitution and innovation effects associated with ICT use can both reduce the unit requirements for labour. But they do not necessarily lead to an absolute reduction in employment of labour. As well as a labour-reducing effect from substitution or innovation, there can be an offsetting labour-enhancing effect from increased production, if lower costs lead to lower prices and more demand or if product innovation better meets what the market wants. Other opportunities for the gainful use of displaced labour can arise within the same business, or industry sector, or other industry sectors. Many other factors also affect labour demand. In fact, aggregate employment expanded over the 1990s, coinciding with the strong pick up in use of ICTs.

4.2 Estimates of effects on input growth

Aggregate and sectoral data were examined to determine what effect increased ICT use had on the growth in inputs, particularly in the 1990s.

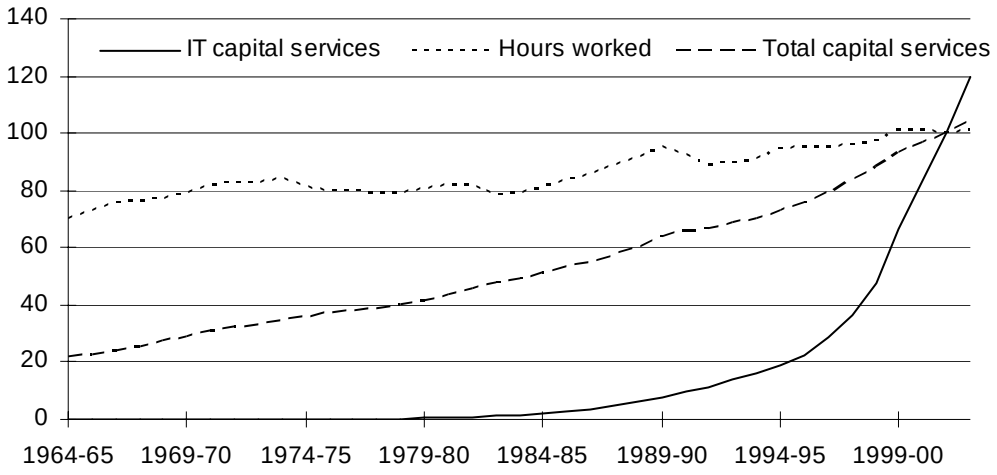
Growth in ICT inputs

Naturally, the strong growth in investment in ICTs (chapter 3) in the 1990s led to strong growth in ICT inputs. This is best seen in national accounts data on the service flows from the productive stocks of information technology (IT), as shown in figure 4.1. IT capital services grew at a very strong rate of 24 per cent a year through the 1990s — much faster than growth in total capital services (also shown in figure 4.1) of 4 per cent a year. Growth in IT use was stronger in the second half of the 1990s (28 per cent a year) than in the first half (19 per cent a year).

6 The ICT-related effects will also induce other effects. Lower costs and new products are likely to induce additional output and therefore demand for capital and labour inputs.

Figure 4.1 **IT 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).

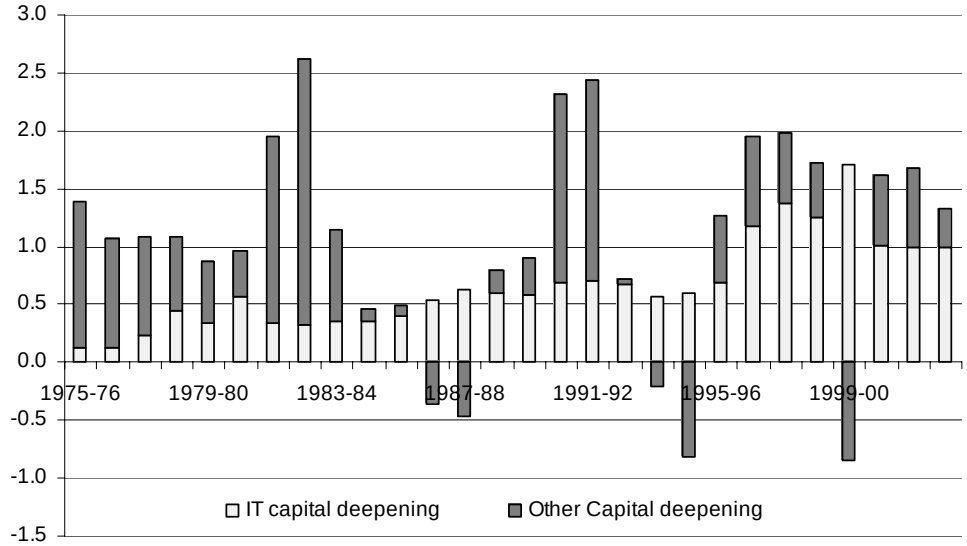
Two industry sectors in particular were responsible for the more rapid input of service flows from ICT capital — Finance & insurance and Manufacturing. With strong growth in IT capital services in the 1990s, and because of their relatively large size, these sectors contributed the bulk of the acceleration in market sector IT capital services (Working papers 1 and 2).

Growth in other inputs

Labour input has grown in response to many influences, but more slowly than IT capital services over the long term (figure 4.1). In other words, there has been IT-capital deepening. Moreover, the rate of IT-capital deepening increased from 1995-96 (figure 4.2).

Figure 4.2 **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.

Growth in other capital has also been much slower than growth in IT capital over the long term (figure 4.1). Furthermore, the growth in other capital services decelerated over the 1990s, offsetting at least to some degree the effect of the acceleration in use of ICT on growth in total inputs. Figure 4.2 shows how the acceleration in IT-capital deepening did not always translate fully into additional total-capital deepening (especially in 1999-00).

4.3 Estimates of effects on MFP growth

The strong acceleration in ICT use in the 1990s occurred at the same time as a strong acceleration of over 1 percentage point in Australia's MFP growth. Were these trends linked or mere coincidence?

There is sufficient circumstantial and formal evidence to conclude that an increase in ICT use has lifted Australia's MFP growth. However, the evidence also suggests that the size of the contribution from ICT use falls well short of the 1 percentage point acceleration in MFP growth.[7]

This project has provided confirmation (through the firm interviews) that firms have used ICTs in ways that would generate MFP growth (see chapter 5). There is also circumstantial

[7] In a review of available analysis and evidence, Parham (2004) found that, although the three sources are likely to be inter-related, the increased openness of the economy to trade and increased R&D provided larger contributions than increased ICT use.

support from the evidence that the same industries have shown the combination of higher ICT use and productivity acceleration in both the United States and Australia.

US industries that have been high on the uptake of ICT and that have also shown strong productivity improvements include financial intermediation, distribution (wholesale and retail trade) and business services (Bosworth and Triplett 2002; OECD 2003a).

In Australia, the positive association between higher ICT use and productivity acceleration is most evident in Finance & insurance and, to a lesser degree, in Wholesale trade (Working paper 1). For example, Finance & insurance underwent substantial restructuring alongside greater use of electronic transactions and a reduction in face-to-face transactions. Output has grown with fewer unit requirements for physical offices and staff (Weir 2002; Oster and Antioch 1995). Enhanced information dissemination and power of ICTs have enabled financial institutions to introduce new financial instruments (derivatives) to assist purchasers to manage a range of risks, from exchange rate movements to changes in the weather. Some Wholesale trade activities have been transformed from storage-based configurations to 'fast flow-through' systems (Johnston et al. 2000). 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.

In a formal analysis of the productivity effects of 'high-tech' capital (predominantly ICT capital), Connolly and Fox (2004) found a robust and statistically-significant relationship between high-tech capital use and MFP in Australia's aggregate market sector, Finance & insurance and Agriculture. A significant relationship, albeit less robust, was also found in Wholesale trade, Retail trade, Construction and Accommodation, cafes & restaurants.

The econometric analysis of firms, undertaken for this project, has also confirmed a link between ICT use and MFP growth. A statistically-significant link was found in nearly all of the eight industry sectors analysed (see chapter 5).

The magnitude of the effect on Australia's aggregate MFP growth has not been estimated with great precision.[8] Bean (2000) estimated that the uplift in ICT investment contributed 0.12 of a percentage point to MFP growth, based on a simple cross-country regression. Parham, Roberts and Sun (2001) and Parham (2002) drew on United States 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 IT use.

Recently, Connolly and Fox (2004) adopted a more rigorous approach by formally estimating a production function, which included inputs of quality-constant high-tech capital. Their specification identified the response of output growth to growth in high-tech capital, but did not readily permit identification of the specific effect of high-tech capital on MFP growth. However, upon request, the authors kindly re-estimated their model to identify MFP elasticities and produced estimates of 0.17 for the market sector and 0.08 for Finance & insurance.[9] Applying these elasticities to national-accounts based estimates of the growth in ICT capital and MFP evident in the second half of the 1990s, these estimates suggest that growth in ICT use accounted for about 0.07 of a percentage point of annual market sector MFP growth and about 0.02 of a percentage point of annual Finance & insurance MFP growth.[10] Whilst these estimates could be on the low side, they nevertheless suggest that growth in ICT use has had a small MFP effect.[11]

An aggregate estimate was also derived from the firm-level econometric analysis undertaken for this project (see chapter 5). Whilst it needs to be treated with caution, the estimate suggests that ICT use accounted for around 1½ to 2 tenths of a percentage point of annual MFP growth in the mid-1990s.

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8 Estimation of the magnitude of the link between ICT use and MFP growth is not straightforward. Other potential contributors to MFP growth must be taken into account. On ICT-related effects, allowance has to be made for the complex interactions between ICTs and complementary investments and for the existence of lags between investments and performance (chapter 6). More broadly, it is difficult to capture the full and pervasive effects of a general-purpose technology that can be used in a myriad of ways.

9 Elasticities for other industries, excluding Agriculture, were in the range 0.02 to 0.36, but suffered similar problems with statistical significance as Connolly and Fox had encountered in the models presented in their paper.

10 Growth in ICT was 28 and 31 per cent a year in the market sector and in Finance & insurance, respectively, and growth in MFP was 1.6 and 0.8 per cent a year, respectively.

11 Ellis Connolly pointed out that the MFP elasticities could be on the low side, because they were estimated from data spanning the mid-1960s to the early 2000s and would not account for any structural break in the 1990s. As argued in chapter 2, the scope for MFP gains through ICT-enabled innovation may only have opened up when ICT emerged as a GPT in the late 1980s and early 1990s.

4.4 Accounting for labour productivity growth

There have been many analyses over the past few years that have used a growth accounting framework to assess the contribution of ICT to productivity growth in various countries. 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.

Based on Australian national accounts data, the IT-capital deepening contribution to labour productivity growth accounted for about a third of the very strong labour productivity growth of 3.2 per cent a year in the latter part of the 1990s (table 4.1).

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 faster growth in IT capital in the latter part of the 1990s has contributed (as an input rather than MFP effect) around 2 or 3 tenths of a percentage point to an *acceleration* in output growth and stronger IT-capital deepening has contributed about 2 or 3 tenths of a percentage point to an *acceleration* in labour productivity growth.

However, at least some of that IT contribution was offset by a weaker contribution from other capital. How much was offset depends on which periods are used. Parham, Roberts and Sun (2001) and Parham (2002) prefer 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 — to isolate spurious cyclical effects from the assessment. Their estimates are updated in table 4.1. Over these periods, the contribution of increased IT use (0.3 of a percentage point) to the acceleration in labour productivity growth is completely offset by the effect of slower growth in other capital. However, they also provide other periods for comparison (updated in table 4.2). The contribution of IT to the labour productivity acceleration between the first and second halves of the 1990s (0.5 of a percentage point) is partially offset by a negative contribution (-0.1 of a percentage point) from other capital. Note, however, that although this IT contribution to the labour productivity acceleration is higher than when productivity-cycle periods are used, it is associated with a smaller acceleration in MFP growth.[12]

These tables also show that the majority, if not all, of the labour productivity acceleration is accounted for by increased MFP growth of around 1 percentage point. As noted in the previous section, the best available evidence suggests ICT-related MFP gains account for something around 2 tenths of a percentage point of the acceleration.

[12] This supports the view that a large part of the MFP acceleration was due to factors other than increased ICT use.

Table 4.1 **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
– 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: Updated from Parham, Roberts and Sun (2001) and Parham (2002).

Table 4.2 **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
– information technology	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).

4.5 International perspective

The ICT contributions to 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 (2003a) found that the United

States, Australia, the Netherlands and Canada received the largest GDP boost from growth in ICT use.

Ahmad, Schreyer and Wölfl (2004) provide updated estimates for the OECD. 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). However, Australia's growth in total capital services over the 1990s was relatively low. This is consistent with there being slower growth in other forms of capital to offset at least some of the effect of increased ICT use on total capital input. But the fact that the other-capital offset was not nearly as marked in 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.[13]

The overall effect of ICT use on aggregate MFP growth has been found to be small in OECD countries (OECD 2003a). 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.

[13] It was noted in Working paper 2 that there was no clear relationship between faster growth in ICT use and slower growth in use of other capital across industry sectors within Australia.

5 How has ICT affected firm performance?

Chapter 1 made the point that a firm-level perspective is needed to gain a deeper understanding of the relationship between information and communications technology (ICT) use and productivity performance. Data used in the project have shown that there have been wide variations in performance across firms, even within the same industry and even among those with the same duration of ICT use (Working papers 1 and 6). This suggests that the performance effects of ICTs depend on the different conditions and actions that operate at the firm level.

This chapter takes the firm-level perspective, drawing on the firm interviews and the econometric analysis of firm-level data. Some general observations on performance effects from the firm interviews are presented in box 5.1. The interviews provided examples of the ways in which ICTs have helped firms to improve performance through a combination of input substitution and product, process and organisational innovations (section 5.1). The econometric analysis found significant links between ICT use and firm productivity (section 5.2). It found evidence that ICT use, in combination with skills and investments in user innovations, had positive effects on firms' performance. The analysis also established that there were lags between initial ICT use and the realisation of performance gains. Findings from international firm-level studies provide some further insights (section 5.3).

5.1 Sources of performance gains — illustrations from firms' experience

The interviews with firms conducted for the project provided important insights into the mechanisms through which ICT can improve productivity and profitability in particular firms. Table 5.1 summarises the key areas and nature of the impact of ICT use on business performance (see Working paper 8 for details). The ensuing discussion notes how examples fit into categories of input substitution and innovations in products, processes and organisational structures.

Box 5.1 Some effects of ICTs on firm performance identified in interviews

All the firms interviewed as part of the project acknowledged that their performance had improved as a result of greater use of ICTs. Some of the firms attempted to quantify the performance improvements and in several cases these were large. For example, it was reported that ICT had helped one mining services firm increase revenue and profit by 30 per cent a year over three years compared with 10 per cent a year in the preceding three years. Another mining services firm reported a 15 per cent increase in production after going from manual to automated production systems, while a transport and logistics firm reported improved performance of more than 15 per cent.

Firm performance has been improved through cost reductions and innovations in products facilitated by increased use of ICTs. Cost reductions have occurred through the reduction of waste of both materials and labour time because tasks were able to be performed quicker and more accurately with ICTs. When it is matched with complementary innovation, ICT has further reduced downtime of staff and machines, production turnaround time, and improved monitoring of activities. Innovation in anticipation of customer needs, made possible by ICT, has also helped improve the performance of many of the firms interviewed. For example, in the automotive firm, ICTs have improved the customer-supplier relationship by enabling supplying firms to bid for contracts on-line using a system devised by the industry. Several manufacturing and pharmaceutical companies also noted that ICTs had facilitated speed to market and this had a positive impact on firm performance.

In many cases, firm performance also benefited from the availability of a range of innovative new services made possible by the introduction of ICTs. This is a significant feature in the financial, property and business services firms but was also apparent in the mining services and transport firms. Even for those firms where the core products have remained essentially unaffected by the use of ICT, additional value-added services have been developed around the product.

Investment in change management and re-engineering processes were reported by some firms to be a very important way of maximising the benefits obtained from ICT investment. For example, in one case ICT has enabled the company not only to globalise its business operations but also globalise its management system. Through an ICT-based communication system, it has been able to successfully connect and integrate its various international centres of management.

On the other side of the coin, it was reported that failure to institute complementary organisational change has, in some instances, limited the extent to which firms were able to benefit from new technology. For example, the reluctance of some firms in the mining industry to institute timely change management reduced their ability to take full advantage of newly-developed ICT applications.

Source: Working paper 8.

Table 5.1 **Area and nature of impact of ICT uptake on firm performance**

Key area of impact	*Nature of impact*
1. Labour	Staff reduction in some instances, but not all. Enhancements of human capital.
2. Facilities and outsourcing	Reduction of some facilities, and outsourcing of certain functions, sometimes overseas.
3. Production and distribution processes	Greater consistency of product quality as well as quality enhancement. Process change across the spectrum from little change to major re-engineering of entire process.
4. Management practices	More timely and accurate management information. Greater centralisation of decision making. Improved communication and reporting systems. Improved inventory control.
5. Product characteristics and mix	Development of customised products and services (for example, in banking and mining services).
6. Relationship with customers and suppliers	Better and more frequent communication with customers and suppliers. Greater responsiveness to customer needs and more certainty in new product design.

Source: Working paper 8.

Labour

Most examples of the impact of ICT on firm performance that affected labour input involved substitution of ICTs for staff numbers, particularly in administrative and clerical areas. More technically oriented trades were also sometimes affected. However, staff reductions were not always the outcome.

Investment in ICT involved, in most cases, a shift to more highly-skilled labour. Required entry-level skills in numeracy and literacy had increased. In the manufacturing firms interviewed there had been a shift towards workers with diagnostic skills, and in the heavy engineering firm a shift from semi-skilled to skilled employees who now operate computer numerically-controlled lathes.

One example of an organisational innovation that affected labour use, reported by a mining services company, was that it now used e-mail to facilitate more team-based work groups even though team members were sometimes at considerable distance from one another. This process was also utilised by a pharmaceuticals firm in creating 'virtual teams' across different countries.

Facilities and outsourcing

Investment in ICT led to greater outsourcing (an organisational innovation) in a number of the firms interviewed. The reorganisation of mining firms resulting from the uptake of ICTs has allowed the transfer of activities to mining services firms, leaving the miners to concentrate on mining. In a similar vein, firms are increasingly outsourcing work to outside specialists in warehousing, logistics, and recruitment.

As might be expected, ICT services are commonly outsourced. In the case of one pharmaceutical firm, many ICT activities were outsourced overseas. However, some large firms retain a significant in-house component in order to better identify and resolve ICT issues specific to them.

Production and distribution processes

All the firms interviewed reported that they had used ICT to facilitate process innovations. Though varying in nature quite widely across businesses, the innovations provided improved and more consistent quality of product and greater standardisation of process.

In a building products manufacturing firm, increased mechanisation and automation of routine tasks, as well as redesign and re-engineering of production processes, has reduced error tolerances and better matched work-flow to the availability of raw materials.

In some firms, better information on production machine use has facilitated improved planning and programming of maintenance, and consequent reductions in maintenance costs. In the automotive and petrochemicals firms, ICT has facilitated shorter production runs with more efficient change-over technology, reducing costs associated with idle capital and labour.

The banking firm reported that ICT systems allowed for more continuous processes in some cases, and for checking and auditing functions to be run automatically overnight.

Management practices

Management information systems have facilitated process innovation through improvements in planning, work process monitoring, product quality, input supply management, and customer service. In some cases, the improvements to management systems have been instrumental in bringing about significant cultural or organisational change.

A logistics firm reported that ICT provided it with real-time management reporting tools, which enable rapid change in areas where quick responses to timely information has a

direct bearing on profitability and performance. An automotive firm and a pharmaceutical firm noted that the increasing amount of information pertaining to inventories, customer-supplier relationships, production processes and the like is the most significant change in their business. The speed with which this information can be sourced and analysed is one of the most important outcomes from advances in ICT, and the one that has had the biggest impact on firm performance.

A mining services firm reported a vast increase in the speed of the information cycle, and said that improvements in electronic data collection and transmission between mine sites and the headquarters of the mining services firm significantly increased the speed of information flow and reduced travel costs.

A pharmaceutical firm said that it saw itself as an information management firm in which information is critical to each stage of its business: clinical trials, meeting regulatory requirements, production, marketing, and distribution.

Product characteristics and mix

Firms reported that the use of ICT had created scope for product innovation, leading to the introduction of new products and services, particularly in the development of customised products.

For example, a mining services firm described how mining companies had introduced live despatch on trucks with GPS, which enables them to specify and transmit the quality of ore required direct to computer screen maps on bulldozers showing exactly where to excavate.

Among many new products and services on offer, transport logistics firms now offer freight tracking, fleet resource planning, and integrated warehousing and distribution services. The building products manufacturer reported that ICT had facilitated increased opportunities for cooperative work with architects and engineers seeking to use its products to develop solutions to particular problems.

The pharmaceutical firms interviewed reported using their databases to create new services for customers of their traditional products. One firm has provided ICTs to hospitals to monitor patient haemoglobin levels with aggregate data later fed back to the firm. This ICT-based monitoring assists in providing better outcomes for patients and hospitals.

Relationships with customers and suppliers

ICTs have permitted more frequent communication with customers and allowed quicker and more cost-effective responses to customer demands for new products and services. This is most readily classified as an organisational innovation.

Mining services firms reported that a specialised information system links mining companies to suppliers and customers. The system is a type of e-commerce hub, which utilises key information relating to mining companies and their suppliers and customers. A transport and logistics firm reported that it had access to parts of its clients' computer systems in order to communicate efficiently and effectively on sales, deliveries, and so on.

An example of the impact of ICT on the development of new customised products arises in the mining services firms where software is developing towards a modular/component form with clients building the applications themselves. With modular-based software technology, firms can now develop 'mini' solutions to plug into another software system.

E-commerce is an increasing component of sales for transport logistics, banking, and recruitment firms interviewed, as well as for some of the pharmaceutical companies. On-line recruitment has been made possible by the new ICTs and video streaming of interviews is in its early stages. E-commerce is also important in the electricity industry, with the national electricity market being essentially an e-commerce trading system.

5.2 Econometric analysis of firm-level performance

The significance of ICT's effects on firm performance was tested through econometric analysis of firm-level data. The ABS's Business Longitudinal Survey provided suitable data on ICT use and performance for a group of firms over the period 1994-95 to 1997-98. This was a period of rapid uptake of ICT (chapter 3). The survey data did not, however, identify firms' intensity of ICT use, but was restricted to information on whether or not they used ICT and the duration of use.

The objective of the analysis was to determine whether use of ICT had influenced productivity performance over the period, while taking into account a range of other influences on productivity growth (see box 5.2 for an outline of the modelling).

Box 5.2 Firm-level econometric analysis of performance effects of ICT use

The project included econometric analysis of data from the Business Longitudinal Survey (BLS). The Survey provided observations of performance and operating characteristics for a set of firms over the four years 1994-95 to 1997-98.

The regression model adopted is based on a production function approach derived from a formal growth framework in which technological progress shows up as a new basic innovation or general-purpose technology.

Within this framework, the analysis sought to explain growth in labour productivity among firms in eight industry sectors taking into account:

- the impact of ICT use during the mid-1990s as measured by computer use and use of the Internet;
- dynamics and lags by allowing the impact of computer use to vary with the duration of use;
- other factors that are conventionally regarded as influencing growth — including growth in fixed capital, the lagged level of labour productivity (to allow for the possibility of conditional convergence of firms to a longer-run growth path) and firm size (to take account of within-firm synergies in computer use); and
- complementarities between ICT use and firm characteristics — including management and employee skill, innovativeness, propensity to undertake organisational change and intensity of use of 'advanced' business practices.

To test the sensitivity of results to different specifications of ICT use, the regression analysis was undertaken using two variants. For the first variant, simple measures of whether firms used computers or not (by duration of use) or had an Internet connection or not were derived directly from BLS data. For the second variant, measures that take into account the variability in take up and use characteristics between firms (that is, firm heterogeneity) were derived from predictions of the likelihood of a firm using ICT subdivided by duration of use, as appropriate.

The analysis suggested that ICT use contributed positively to growth and that the duration of use was found to be significant and described by a clear dynamic pattern (figure 5.3). While the positive contribution to growth was suggested by both measures of computer use, the measure reflecting the adoption characteristics of firms (or firm heterogeneity) suggested that ICTs made a greater contribution to growth than basic data measures. In all simulations conducted, capital growth and the other variables considered were found to influence labour productivity growth.

Finally, complementary factors were found to have a positive impact on firm productivity additional to that afforded by ICT use (figure 5.2).

For more details, see Working papers 1, 2 and 4.

Statistically-significant links between ICT use and firm performance were found and they were found in all industries tested. There was industry variation, but mostly it was within a reasonably narrow band, perhaps because the ICT use variable (whether or not ICTs were used) did not vary greatly across industries.[1] The evidence for the existence of ICT performance effects was robust across a number of variants of the basic model used.

The results for the basic model are shown in figure 5.1. According to the estimates, the effect of ICT use varied across industries in a range from around ½ of 1 tenth of a percentage point to about 3 tenths of a percentage point of annual MFP growth.[2] Estimates for most industries, however, fell within the range of around 1 tenth to 1½ tenths of a percentage point. When the industry estimates were weighted and summed, the aggregate effect was mid-way in the latter range.[3]

One of the variants of the basic model was to include a different specification of the ICT-use variable. This captured the probability of ICT use (which depends on firm characteristics), rather than just whether firms actually did or did not use ICT, on productivity growth (see box 5.2 and, for details and justification[4], see Working paper 4). This variant presented somewhat higher estimates (figure 5.2).

1 It is likely that there would be greater variation in intensity of ICT use across industries.

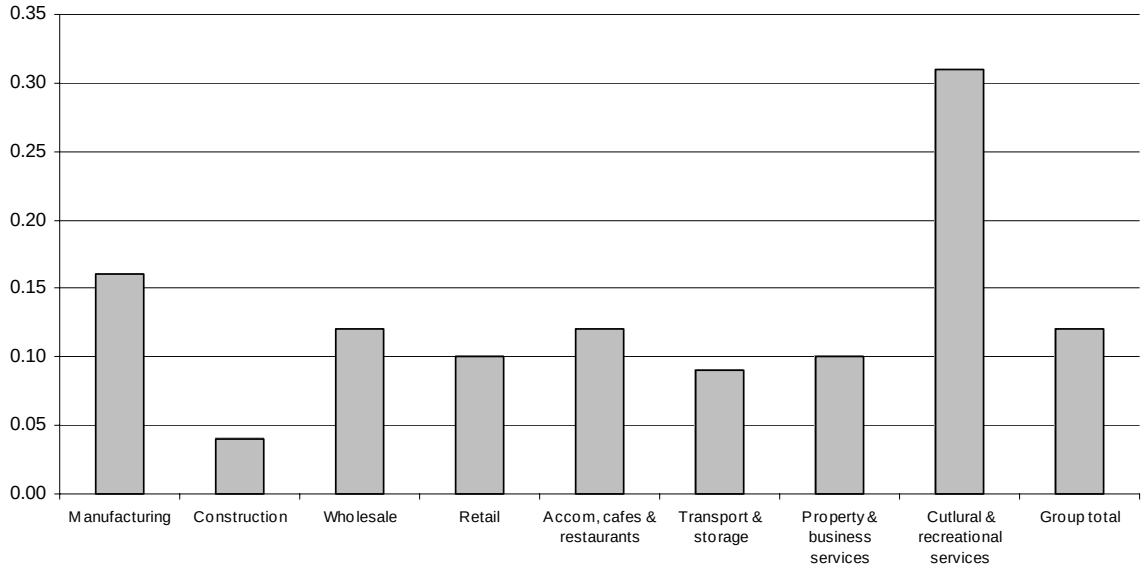
2 Limitations that were forced on the specification of the model pose some difficulties in interpretation of the effects on annual productivity growth. According to the theoretical specification, they should be interpreted as MFP gains associated with ICT-enabled innovations. In practice, the amount of ICT in use was not available as a separate measure, but was implicitly included in the total capital measure — although even that measure would not have accurately reflected the volume of ICTs in use, as there would have been no quality adjustment to reflect the enormous technological advances embedded in the ICTs (see chapter 3). There is thus some uncertainty about the extent to which the amount of ICT use is reflected in coefficients that capture MFP and capital-deepening effects.

3 The contributions to MFP growth as shown in figure 5.1 refer to the mid-1990s. As a rough comparator, the trend rate of MFP growth between 1993-94 and 1998-99 (estimated with a Hodrick-Prescott filter) in the same industries and group total were — in the left-to-right order shown in figure 5.1 — 1.2, 0.8, 3.1, 1.0, -0.3, 2.0, not available, -3.2 and 1.2 per cent a year. This group total excludes Property & business services.

4 It is argued that this approach better reflects a theory of technological development and adoption.

Figure 5.1 **Estimated contribution of ICT use to annual MFP growth**

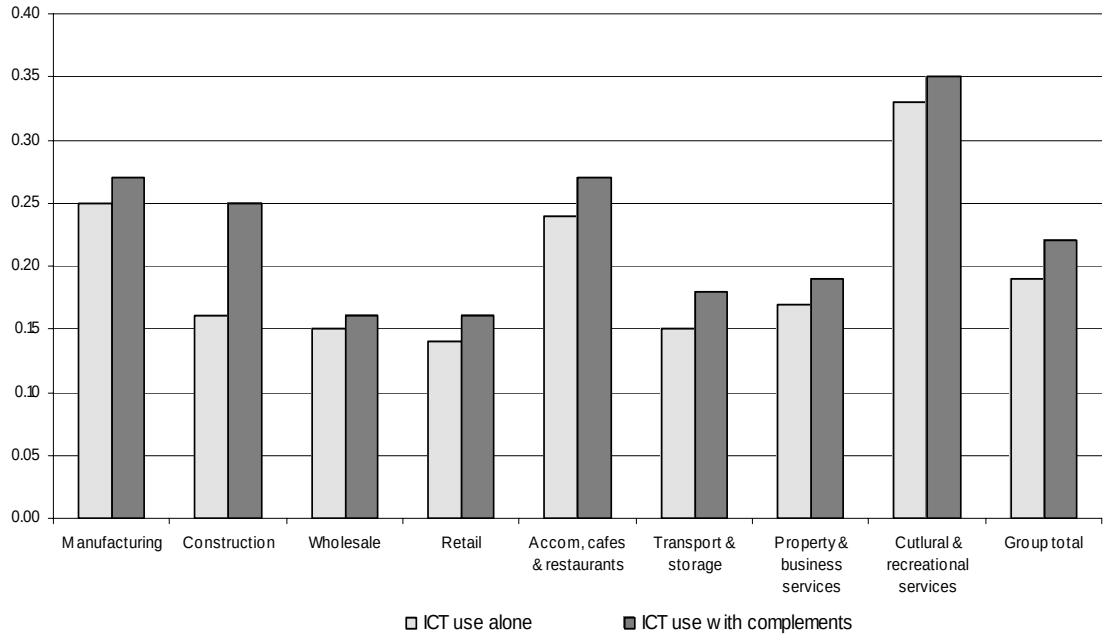
Percentage points



Source: Working paper 4.

Figure 5.2 **Model variation on estimated contribution of ICTs to annual MFP growth[a]**

Percentage points



a Expected ICT use used as explanatory variable.

Source: Working paper 4.

All results from the econometric analysis should be taken more as an indication of significant links between ICT use and productivity, rather than as precise indicators of the magnitude of effects. For one thing, the ICT variable does not capture the intensity of use, which is likely to have increased at different rates among firms identified as users. Variations in productivity may not be well matched with variation in intensity of ICT use. For another thing, the analysis excluded firms in Finance & insurance, an industry in which other studies have indicated high productivity gains associated with ICT use.

Complementarities

As has been discussed, ICTs do not act alone in bringing about performance improvements. Chapter 3 outlined three kinds of complementary factors that work alongside ICTs:

- input complementarities, which stem from relationships between ICT inputs, on the one hand, and skilled labour or some forms of other capital, on the other;
- complementary inputs of intangible organisational assets accumulated through experience and learning and through previous organisational change (see next chapter for further discussion); and
- complementary investments in product, process and organisational innovations, enabled by ICTs.

The existence of complementarities was tested in another variant of the basic econometric model. The complementarities that could be included were limited by the availability of data. They covered management education and worker skills, use of advanced business practices and various measures of product and organisational change. The measures of complementary investments were less than perfect in terms of coverage of possible dimensions and the extent to which the complements were actually linked to ICT use in timing and extent. Nevertheless, the analysis did provide empirical support for the existence of complementary effects — that is, the compounding effect on productivity growth of complementary inputs of skills and investments in innovations. The results are presented in figure 5.2. Although caution on magnitudes is again needed, typically, the set of complementary variables that could be included added less than ½ of 1 tenth of a percentage point to annual industry productivity growth.

Lags in performance response

The firm interviews provided examples of variations in the time lags between the introduction of ICT and the manifestation of associated performance improvements. From six months to two or three years appears to have been the general lag, but was up to four years in some cases in the mining industry. A factor determining the length of the performance lag was reported to be the extent to which the organisation had to change.

The econometric analysis also found a response lag. The productivity response formed an inverted 'U' pattern as the duration of ICT use increased (figure 5.3). The initial impact of take-up tended to be negligible (or a small negative/positive). As the duration of use increased, so did the positive effects on firm performance. But, after a period of adjustment of around five years, the productivity growth stimulus of take-up was largely completed.

Again, these results should be interpreted cautiously as they are based on approximate measures of duration of ICT use and take no account of the marked increases in intensity of use or the advent of new technologies beyond the mid-1990s. Because the intensity of use has increased further and there have been major technological developments, the above results are likely to understate the total performance effects of increased ICT use to date. To put it another way, there have been further 'waves' of ICT development and take-up, since the mid-1990s, that are likely to have had further performance effects. The firm interviews confirmed that, even now, at least some firms continue to expect that there will be ongoing substantial investment in, and gains from, new ICT technology.

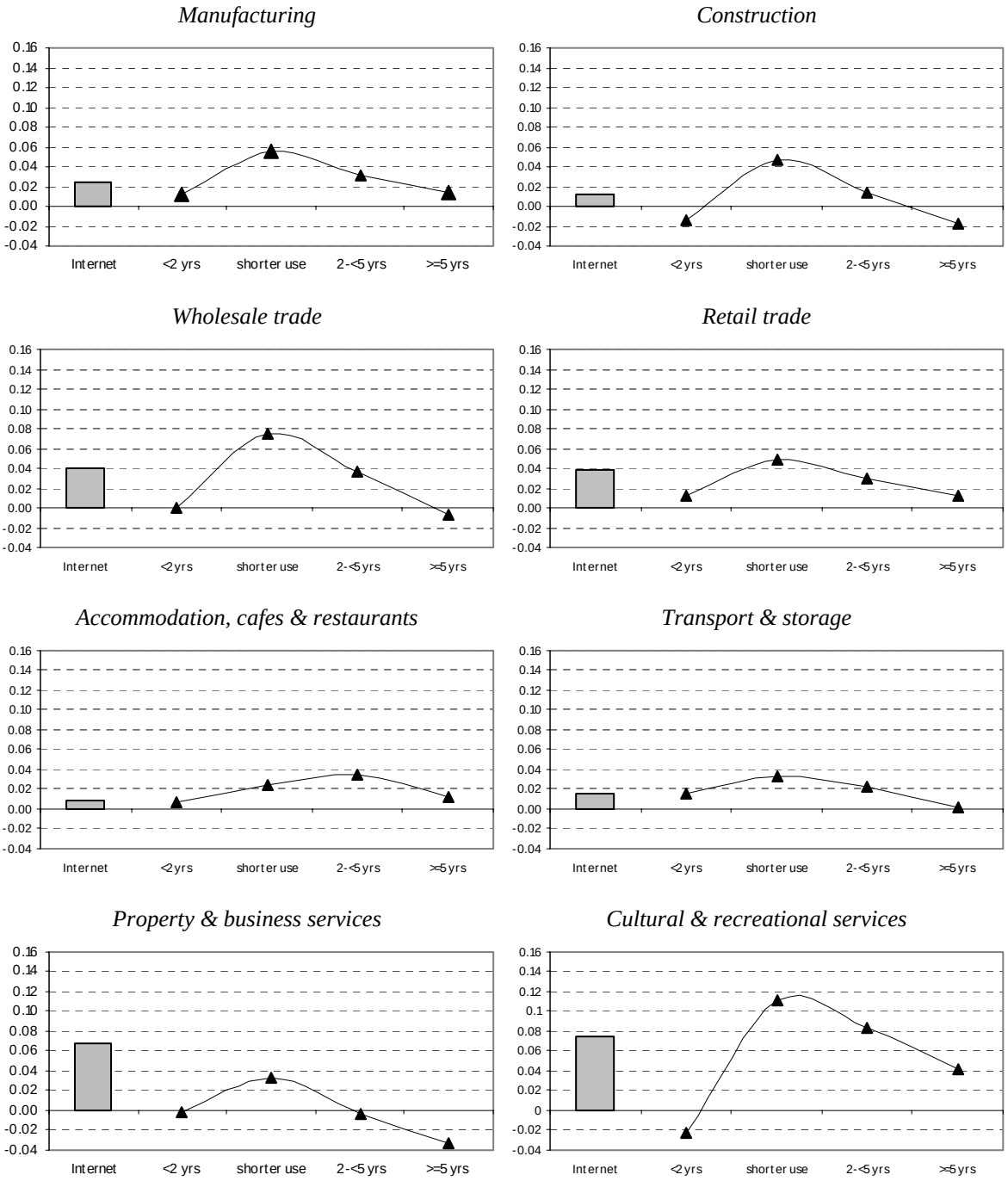
5.3 Findings from international research

The set of country studies undertaken for the OECD firm-level study (see chapter 1) all found that ICT had had positive effects on performance among firms, at least in terms of labour productivity (OECD 2004). The strength of the effects, however, varied as did factors affecting performance.

In several countries, the improvements went beyond capital deepening effects and included MFP improvements. A number of studies where comparisons were made found stronger effects in services than in manufacturing.

Figure 5.3 **Contribution of ICT to productivity growth found in the regression analysis**

Percentage points



Source: Working paper 2.

The performance effects were associated with ICT and complementary investments in skills, changes in organisation and innovation. One study found complementary innovation spillovers associated with ICT capital, but not with other capital. Another study found that combinations of technologies involving ICT were important, suggesting that ICTs facilitate the effectiveness of other advanced technologies.

A number of studies concentrated on the contribution of networks. One study found local area networks (LANs) were more important in manufacturing, whereas the open-source Internet was more important in services. Another study found the performance effects associated with the Internet were larger for purchasing firms (through lower search costs, greater price transparency and quicker supplier reaction) than for selling firms.

Firm dynamics — a factor that could not be tested in the Australian study — were also found to be an influence. For example, ICTs help some better-performing firms to gain market share, thereby raising average productivity. Many of the organisational changes needed to gain maximum benefit from ICTs were found to be made more easily in young than old firms, and even more easily in new firms. The growth of some successful new and young firms and the failure of others pointed to a role for experimentation and selection (firm start-ups and failures) in generating productivity gains (Pilat 2004).

For nearly all countries, however, it was difficult to reconcile the strong firm-level results with the weak aggregate and sectoral evidence. As noted in section 4.5, the evidence that ICT-using industry sectors have experienced more rapid productivity growth has only been established in the United States and Australia. (For Australia, the evidence of productivity effects is broadly reconcilable at the firm, sectoral and aggregate levels.)

Pilat (2004) attributed the difficulty in reconciling the estimates for most countries to: aggregation of firms with different ICT strategies and experiences; larger firm-level benefits in countries where ICT investment has been stronger; differences in measurement between countries, particularly in relation to output and productivity measurement in services; differences across countries in network and other spillovers not captured by individual firms; and differences across countries in competitive pressures, which have a role in determining the size of spillover effects.

6 Why firms differ

As stated in chapter 1, a central motivation for this project was to improve understanding of why firms differ so much in the extent to which they use information and communications technology (ICT) and in the extent to which they derive productivity gains from ICT use.

Like many inputs, the scope for application of ICT varies across firms, particularly in different industries. But one feature that sets ICT apart is its general-purpose or platform characteristics — its ability to enable other innovations on a broad front. Firms vary in the extent to which they can and do pursue ICT-based innovations (section 6.1).

ICT is also a relatively new and rapidly-changing production input. There are learning and other effects, which mean that firms can extract more performance gains from a given amount of investment in ICT and complementary investment in innovation over time; and, as experience enables them to identify and successfully pursue more opportunities to innovate, they can increase or bring forward their ICT investments (section 6.2). Differences between firms in their access to needed human capital, in the amount and nature of learning that they accumulate and in their technology and innovation strategies affect their rate of investment in ICT.

Differences between firms in the extent and timing of their investments in ICT and of their complementary investments in productivity-enhancing innovations also generates inter-firm differences in the extent and timing of performance effects.

6.1 Differences in the scope for application and innovation

The speed and intensity of uptake of ICTs has varied across firms according to the scope for application of ICTs in different industries and in firms of different size (chapter 3).

There are other idiosyncratic characteristics of firms that make for differences. For example, firms with a more integrated operation (either vertically or horizontally) may be more likely to make greater use of ICTs than their less integrated counterparts.

Geographical factors can also inject differences. Businesses in the more remote regions of Australia are less likely to be fast adopters than businesses located closer to the major

population centres, not least because the availability of technology, service support and guidance from examples of successful use in other firms are likely to be more limited than in the major centres.

Another factor mentioned in chapter 3 was the price of ICTs. For some firms, the net benefits from a new ICT are sufficient to warrant immediate adoption. For others, the balance of costs against anticipated benefits is such that it is optimal to wait until the price of an ICT system or upgrade has declined.

Chapter 3 also noted that there is industry variation in the scope for ICT-enabled innovation. The savings that ICTs can bring in costs of coordination in production and distribution or in transactions costs in sales and purchasing have different relevance to different industries. Development of information-intensive products tends to have more application in services industries.

The inter-firm variation in use and performance effects is also linked to ICT's general-purpose character. Other specific-purpose technologies will tend to have well-defined profiles for adoption and performance effects in their given area of application. Use of a general-purpose technology, however, is diffuse and diverse. Performance effects reflect this variation in use, but also depend on the innovativeness and nature and extent of complementary actions by different users. The profiles of use, complementary investment and performance are neither fixed nor pre-determined.

In summary, the rate and timing of initial uptake of an ICT can vary across firms because of differences in: the scope for application of ICT; the balance of anticipated costs and benefits; the scope for ICT-enabled innovation; and the different investments that firms make in ICT-enabled innovation. These differences in uptake and complementary investment also generate differences in the timing and extent of performance effects.

6.2 Human and organisational capital

ICT is relatively new in its widespread application and use in business. It is also subject to marked and rapid advance in characteristics and capabilities. ICT therefore presents considerable scope for learning in terms of how firms can best utilise technologies to improve their performance. It also presents challenges for firms in how best to adapt to marked and rapid change, not only in technologies, but also increasingly in the markets they supply.

Human capital

Chapter 3 spelt out how there are complementarities between use of ICT and skilled labour, both from a general operational point of view and from a strategic management point of view. If firms face differences in the availabilities of employee skills, the potential gains from ICT and related investment can differ between firms. Differences in management ability to identify technical and business opportunities and to successfully implement complementary organisational changes and investments in innovation also affect the size of ICT investment across firms and the magnitude of benefits derived.

Differences in human capital can also have a dynamic effect. Differences in firms' ability to absorb and adapt to technology through their people can affect the degree to which they invest and derive gains over time.

Technology and innovation strategy

Even in otherwise similar circumstances, firms have different technology and innovation strategies. Decisions about investment in ICTs and in ICT-enabled innovations can be influenced by perceptions of how important particular ICTs and innovations are to the future direction of the business.

In this vein, there are 'vanguard' firms, fast-follower firms and risk-averse firms (that adopt only when failing to do so would put their survival at risk). While early adoption and a focus on innovation are central to vanguard firms, they are less central to the others, at least initially.

Similarly, there are differences in attitudes toward risks. The 'vanguard' firms bear most of the risk and carry most of the initial costs of searching for the optimal methods of employing the technology. But, where the ICT-enabled innovations are successful, they also get 'the jump' on those who follow, allowing them the earliest and usually most significant opportunities to gain profit and market share. From the point of view of broader economic stability, however, some distribution of firms across the spectrum from risk-averse to vanguard categories is appropriate as a spread reduces the overall risks involved in adoption and innovation.

Large firms have generally been earlier adopters than smaller firms in part due to their superior capacity to absorb the financial costs and risks of adopting and adapting to these new technologies.

Learning

The firms interviewed stressed the importance of 'learning-by-doing'.[1] Valuable learning came from gaining familiarity with ICTs in terms of their operation and capabilities and from gaining experience in their innovative application.

Learning effects feed back into decisions about further investments in ICTs and in complementary investments in innovation (box 6.1). For example, an ICT investment may prove to be inadequate to an anticipated or to a newly-identified application. Further investments in existing technology and/or custom-designed technology, and associated skilling of the workforce, may be required. These new investments can again stimulate new ideas for further improvement, and so on, but they will also take time.

Familiarity with a technology can also lead to discovery of new unanticipated applications, which in turn can lead to further investment in ICT and complementary changes. New processes, products and services developed by businesses as a result of the opportunities arising from the adoption of ICTs are frequently not anticipated at the time of initial investment. This evolutionary and catalytic characteristic of ICT is typical of generic, enabling technologies.

Instituting processes for learning can also be a way of managing risk. The firm interviews provided examples, not only of successful large-scale investment programs, but also of large-scale projects that failed.[2] In the face of uncertainty and prospect of further failure, firms have scaled down the rate of investment over time to allow time for additional learning and greater certainty on certain critical parameters.

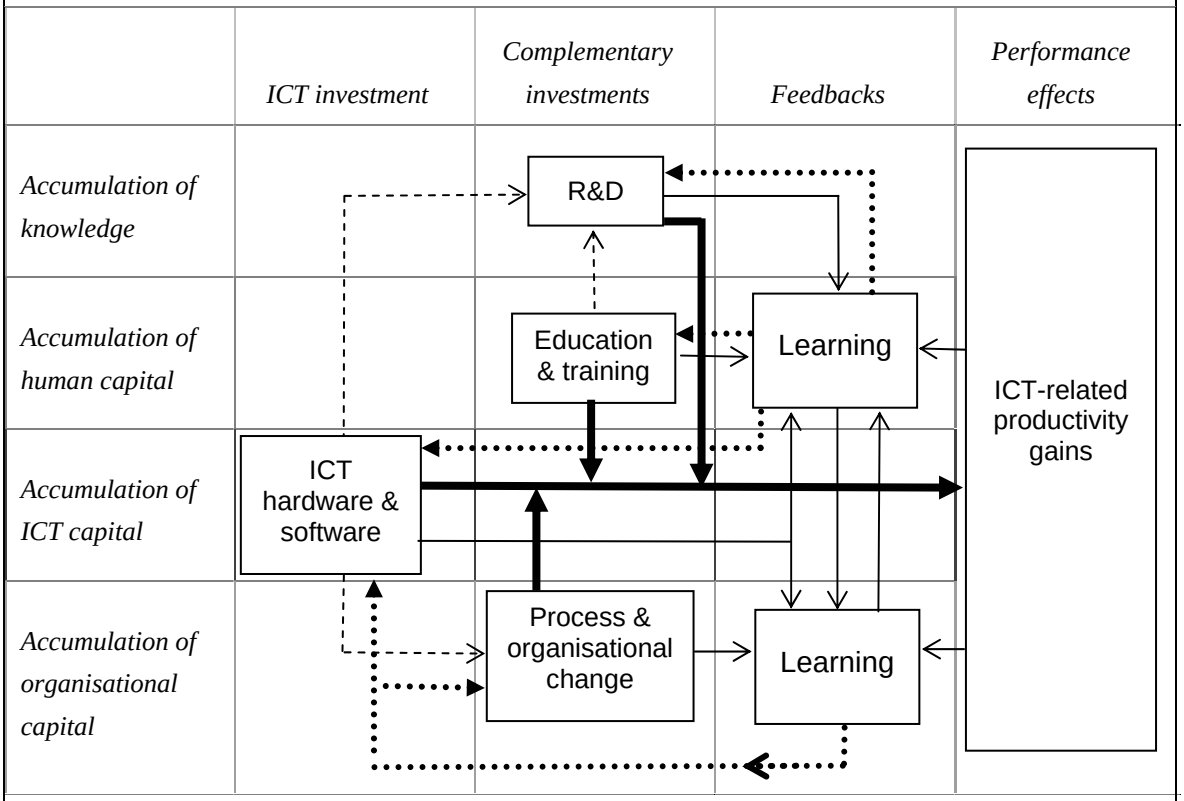
The many facets to the adoption of technology and to organisational adaptation provide the opportunity for different businesses to express themselves in a wide variety of ways. This variety leads firms in different directions, which develop into new efficiency opportunities, differentiated products and services, and greater choice for customers.

[1] The learning process is not necessarily confined to firms using ICT for production of goods and services. In B2C, customers can often be the source of significant lags in technology adoption. For example, a high proportion of the orders in both a manufacturing and a pharmaceutical firm in the case studies were still placed by fax or phone, largely, it was reported, as a result of customer preference.

[2] The examples were a 'failed' full system integration by a finance sector firm and a pharmaceutical firm where the urgency for improved performance returns imposed unrealistic time pressures on a highly complex systems installation, resulting ultimately in an outcome below that which had been anticipated.

Box 6.1 **The dynamics of adoption, adaptation, learning and productivity performance**

The relationships that link ICT use and productivity gains are complex and dynamic, largely because ICT is rapidly-changing, relatively new and provides platforms for a wide range of innovations in a wide range of circumstances. Not only are complementary investments in innovation important in determining performance gains, but learning effects also feed back into decisions on ICT use and on complementary investments.



Some of the major links are represented schematically in the above diagram.

The solid thick lines show the combination of uptake of ICT and complementary investments leading to productivity gains. The complementary investments depicted cover: R&D (for product innovation, although it could also be directed toward process innovation); education and training for skills formation (to support the use of ICT although, again, it could also support process and organisational change); and process and organisational change.

The thin solid lines represent links to learning. These can be from increased familiarity with ICTs and their capabilities; experience from investing in complementary activities; from the experience of success and failure of investment programs; and the feedback from successes and failures in product markets. Learning from experience can also foster the ability to recognise new opportunities for application of ICT.

(continued next page)

Box 6.1 (continued)

The thick dotted line represents the feedback from learning to subsequent ICT and complementary investments. These complementary actions will further lift productivity. And so the process continues.

The diagram also shows links, represented by the thin dashed lines. These capture the fact that use of ICT can influence the efficiency and effectiveness of R&D activity and can provide information that assists process and organisational innovation.

To limit the complexity of the diagram, links to and from other types of capital are not shown.

There is also learning across firms. The demonstration of the vanguards' successes reduces the costs and the risks for the following firms, leading to subsequent adoption of the same technology and innovations. The marketplace responded early on to the existence of adjustment costs through the creation of specialist ICT systems design and installation firms whose core function was to bring the experiences of 'vanguard' adoptions, combined with the specialist firms' in-depth technical knowledge, to the rest of the marketplace. This reduced the adjustment costs of follower firms.[3]

The processes of learning and accumulation of organisational capital take time. They alter the profiles of firms' investments in ICTs and in complementary innovation activities and therefore their realisation of performance gains.

In summary, the time path and rate of ICT uptake and performance effects differ across firms, even in similar circumstances, due to differences in: the implementation of organisational adjustments to new technology and of investment in complementary changes; and feedbacks from processes of 'learning-by-doing', including experience in complementary activities, that develop familiarity with technologies, their capabilities and potential to improve performance.

Organisational capital

Development and implementation of technology and innovation strategies and processes of learning are ways of accumulating 'organisational capital'. The concept of organisational capital recognises that there are intangible assets in a firm that have value beyond the income stream that the firm could derive solely from the physical and human capital at its disposal. Organisational capital is not just pertinent to ICT, but the ICT context has

[3] Specialist firms could also reduce adjustment costs for vanguard firms in technical knowledge and from the experience of vanguards in other applications.

highlighted its potential importance to firms that aim to prosper in a more complex, competitive and rapidly-changing business world.

The significance of organisational capital in the ICT context is that it reflects a firm's ability to recognise the opportunities that ICT provides and its ability to respond efficiently and effectively in order to generate net gains over time. It is argued that these abilities are especially significant when the firm operates in markets and relies heavily on technologies that are subject to rapid changes.

Broadly, firms with relatively high organisational capital have a prime focus on market trends and the ability to discern new opportunities; skills and experience in the effective use of technology and in related innovation; and the flexibility to implement needed and ongoing changes to products, processes and organisational structures. The changes can, in some instances, be radical and may even involve redefinition of the organisation's core functions.

Accumulation of organisational capital also requires such organisational qualities as effective leadership, good management, development of skills, teamwork, good internal and external communications, and effective incentives and work arrangements. See, for example, Brynjolfsson, Hitt and Yang (2002). A workforce that is accepting of, and able to handle, change is an important asset to a firm.

The introduction of ICT systems can of itself help the accumulation of organisational capital. A number of firms noted that the increased use of ICTs led to increased corporate knowledge of the product and its market, the production process, inventory management and logistics. This improved firm performance significantly by providing management with up-to-date and accurate information, which they used to re-engineer processes, facilitate flows of information within the company, and implement organisational changes.

As has been pointed out above in the separate discussions of strategy and learning, differences between firms in their accumulation and use of organisational capital will lead to different profiles of ICT investment and performance effects over time, even for firms in otherwise similar circumstances.

7 Tapping ICT's productivity potential

There is further scope for ICT-related productivity gains, as advances in technology continue apace and as firms continue to identify opportunities for innovation (section 7.1). The capacity to tap the business potential of ICT is predominantly in the hands of using firms, in part because there is little evidence to support the need for further widespread government intervention (section 7.2). Whilst some impediments to the uptake and productive use of ICTs have been identified (section 7.3), the main role for governments remains one of ensuring that the business environment is conducive to innovative use of ICT (section 7.4).

7.1 Prospects for further uptake and productive use of ICTs

The firms interviewed were quite optimistic about the scope for future performance gains.

Some firms expected that there will be further opportunities for investment in existing technologies. The logistics firm, for example, was exploring the potential benefits to be gained from investing in GPS technology to help keep track of its fleet. The building products firm expected that investment in ICT would continue, with greater use of wireless and handheld equipment in the factory and in delivery trucks.

On the other hand, a number of firms felt that they had made their major investments in ICT and that more benefits in the future are to come through learning from experience and being more innovative in the way they use ICTs. Many firms expected that e-commerce will be the most significant area of potential performance improvement. These firms considered that, as consumers and suppliers became more familiar with the capabilities of the Internet, new packages of e-commerce services and pricing regimes would be developed.

Investment will also respond to new technological developments. Whilst these are not yet known, history suggests that many firms step up investment in new technologies as they become available. These developments are likely to benefit firms both in 'passive' use of ICT in existing business practices and in 'active' innovative uses.

It is also likely that the costs associated with investment in ICT will decline in the future. Acquisition costs are likely to continue to decline with further technological advances in

the production of hardware and software. For many firms that have already undertaken major restructuring, further required adjustments and associated costs may be less significant in the future. With experience gained, firms may also become more efficient and effective in undertaking ICT-enabled innovations. The costs of complementary investments in innovation would then decline relative to the gains derived.

7.2 The central role of firms

The key influences on the rates of ICT uptake and realisation of productivity gains are in the hands of firms themselves. Because of its general-purpose nature, the influences on the uptake and performance effects of ICT are more complex and multi-dimensional than those that influence most other technologies. The potential for ICT-related productivity gains is tapped, not so much by common occurrences amongst firms, but by heterogeneous firm-by-firm strategies, decisions and processes that are 'organic' or 'evolutionary' in nature. There is interplay at the level of individual firms between factors such as ICT acquisition, complementary investments, skills and creativity; and the interactions change over time through learning and feedback loops. This heterogeneity and complexity puts the role of firms at the centre of the determinants of ICT-related productivity gains.

The role of firms is especially important in the context that ICT is a relatively new and fast-changing technology. Firms provide the essential vehicle for experimentation and learning to get the most out of ICT use in the business environment.

The broad evidence, especially from international comparisons, is that Australian firms have been very active in their uptake and innovative in their use of ICT. They have been relatively quick and intense in their uptake of ICT, both in terms of the volume and diffusion of ICT, and in the use of networks (chapter 2).

From this perspective, there would seem to be little cause for concern about the rates of ICT uptake and realisation of ICT-enabled performance gains in Australia. Furthermore, there would seem to be little basis to argue that any further widespread government intervention is needed to support more rapid uptake or greater diffusion of technologies or to encourage more ICT-based innovation. (See section 7.4 for more discussion.)

Even with such generally good performance to date, however, it is important that Australian firms continue to look for and pursue further worthwhile opportunities to invest in ICT and related innovations. As noted in chapter 6, this ability can be enhanced through experience and learning, and accumulation of other dimensions of human and organisational capital. This in turn can be enhanced by such qualities and actions as: leadership and strategic vision; creative technical and human resources management; employee training and retraining; and new work arrangements to respond positively to the demands of a new technology and associated changes.

7.3 Factors that might hinder uptake and productive use of ICTs

Even though firms will continue to play the central role, there could still be issues 'at the margin' that affect the realisation of worthwhile performance gains and that might therefore warrant consideration for further government action.

One of the purposes in undertaking the interviews with firms was to identify any factors than might hinder the realisation of performance gains associated with ICT use.

A shortage of IT skills has been a factor for some of the firms interviewed. One mining services firm suggested that they were facing a shortage of people with the combination of IT skills and industry experience. Sourcing skilled people to use computer-aided design (CAD) systems was an issue raised by the automotive firm, while the education and skills of drivers was reported to sometimes be a limiting factor for firms seeking the most effective use of ICT in transport and logistics.

The inability to attract employees with the right mix of business management and IT skills to fully utilise the potential of ICT has been a constraint in some cases. Business managers need to have a deep understanding of ICT systems. For example, a building products firm stated that business managers do not always see the full potential for ICT use and IT managers are not focused on business strategy and vision.

Another limiting factor for some firms wishing to merge operations has been the different and incompatible information systems that have accumulated as a result of different stages of ICT development and different firm strategies. A good example was in the banking and finance sector where it has been common for firms to have different software systems for different products. The incompatible systems make it very difficult for merging firms to realise the potential gains from integration of data, processes and products.

Government regulatory requirements may limit the use of ICTs in a variety of ways. Different state regulatory systems can increase the costs of developing ICT systems for nationally-based firms. For example, different state-based privacy regulations and credit codes have implications for the design of ICT systems in banking. One of the pharmaceutical firms said that the dependence of regulatory agencies on paper-based lodgement required 'truck loads' of paper. A petrochemical company noted that different jurisdictional requirements for paper-based or electronic lodgement inhibited its gains from, and therefore investment in, more ICT.

The dependence on paper, however, is not limited to government agencies. Some firms also pointed out that some of their customers still preferred to use faxes rather than e-mails.

Industrial relations was generally not seen to be a significant factor restricting the introduction of ICT. The building products firm stated that its workforce had a positive attitude towards increasing the use of ICTs. This attitude was echoed by many other firms, perhaps reflecting greater flexibility in the workplace than had previously existed. The manufacturing-based industry association interviewed did not consider that industrial relations issues were holding back the introduction of ICTs, although there may be some problems in particular industries. However, the banking firm interviewed stated that there are problems in re-locating staff in conjunction with the introduction of ICT. In effect, 'staff have become a fixed cost and capital a variable cost with the introduction of ICT'.

For regional firms, the lack of fast Internet services has been a barrier to the take up of on-line services. However, this is becoming less of an issue with increased funding for regional telecommunications.

Working paper 6 reported ABS survey information on firms' reasons for non-adoption of ICT and non-use of the Internet. It also statistically analysed the characteristics of firms that reported various reasons for non-adoption and non-use. The most prevalent reasons for non-use of computers in 1999-2000 were: not suited to nature of business (32 per cent of non-adopters); lack of skills or appropriate training (26 per cent) and high costs of computers (16 per cent). The most prevalent reasons for non-use of the Internet were: not suited to the nature of the business (33 per cent of non-users) and lack of interest (17 per cent). There were industry differences in the reasons. For example, lack of skills was a relatively more prominent reason for non-adoption in firms in Manufacturing, Construction and Transport & storage.[1]

7.4 Issues for governments

Aside from possible social and environmental issues,[2] the principal concern for governments in relation to business use of ICT is to allow or ensure that firms can realise the potential for productivity gains. The focus should not be on the rates of adoption of technology, technological progress and innovation for their own sake.

Aside from the issue of whether further government action is warranted, potential risks in governments intervening would need to be taken into account. First, there is the risk that unwarranted action is taken. It could be difficult for governments even to recognise where there might be deficiencies in the complex processes. What may seem to be a deficiency may instead just be a lag associated with the dynamics in train. Indeed, there are 'speed limits' on the appropriate rate of technology adoption and related innovation. The time-

[1] Firm characteristics, such as legal incorporation and firm size, were also found to have had stronger associations with the major reasons for non-adoption of ICT and non-use of the Internet.

[2] Examples of such issues are the 'digital divide' and the disposal of used ICTs.

consuming aspects of adoption of, and adaptation to, a general-purpose technology apply a degree of restraint on the economically viable speed at which the best practice frontier can be expanded.[3] If governments break these speed limits by specifically stimulating ICT uptake and related innovation, too many resources are likely to be diverted into activities that are at risk of yielding insufficient progress or of failure.

Second, there is the risk that the form of intervention may be ineffective and costly. The complexity and heterogeneity of the relationships would make it extremely difficult for governments to formulate specific, direct and cost-effective policy measures to accelerate the rate of uptake and performance gains.

The findings from this project and the OECD study suggest, however, that governments can and do play an important role in ensuring that the general business climate is conducive to the uptake of ICT and its innovative use, rather than intervening in specific ways.

Fostering a climate conducive to productive use of ICT

The evidence gathered in this project, as well as the OECD study, point to four general areas for governments to ensure that the business environment is conducive to investment in ICT and related innovation in order for firms to realise the potential for productivity gains:

- remove unnecessary barriers to competitive pressures to strengthen incentives to lift performance by, amongst other things, adopting technologies and using them innovatively;
- remove unnecessary regulatory and institutional restraints on firms to enhance their flexibility to adjust their business operations to take best advantage of ICT;
- provide appropriate support for innovation; and
- facilitate the development of needed skills of workers and managers through education and training to enhance the ability of firms to identify innovative opportunities, implement changes and adjust to new technologies.

Whilst Australia seems to have made considerable progress in each of these areas, there may nevertheless be scope for further improvement.

The evidence gathered suggests that stronger competitive pressures in the Australian business environment have spurred firms to invest in ICT and to undertake complementary

[3] On the other hand, it must also be recognised that this 'speed limit' is likely itself to be a function of the general technological sophistication of the economy at the time, including the ability to absorb the new technologies.

innovations in order to keep ahead (or at least up with) market rivals. Competitive pressures have increased over the past decade or so through reductions in restrictions on imports and foreign direct investment, through the review of anti-competitive regulation and through broadening and strengthening the enforcement of competition and related policies. The increased use of the Internet itself has also had an effect on strengthening competition, especially in services, by increasing price transparency and expanding potential sources of supply.[4]

The application of pro-competitive policies to the provision of Australia's communications infrastructure and communications services is of particular importance and relevance to firms' ability to realise the potential for ICT-related productivity gains.

Firms need flexibility to adjust and to innovate. The OECD study, in particular, highlighted that excessive product and labour market regulation can restrict firms' ability to innovate and therefore to benefit from ICT. In this respect, Australia has taken important steps to reduce the unnecessary restriction of product market regulations. Flexibility in Australian labour markets has also been enhanced with greater enterprise focus in the determination of wages and workplace arrangements. Nevertheless, some issues remain. As noted before, inconsistency between states and territories on regulatory requirements was said to reduce the potential benefits from streamlining business and reporting systems with ICT. Whilst most firms interviewed reported that industrial relations was not a major remaining impediment to ICT-enabled innovation, it was still an issue for at least the financial services firm.

A further general regulatory issue is whether there are unnecessary intrusions on firms' abilities to experiment as part of the innovation process. As noted in section 5.3, the OECD reported that, in some circumstances, experimentation and innovation is best pursued through the creation of new firms. Unnecessary regulatory restrictions and burdens on firm creation and closure would limit the scope for desirable experimentation. Again, this study has not gathered evidence on this issue.

In theory, governments can also adjust innovation policies to ensure that optimal levels and forms of innovation (including ICT-enabled innovation) are undertaken. However, this study did not attempt any assessment of current innovation policies.

The project did not go into any detail on possible deficiencies in skills. The clearest requirements expressed were for further refinement of 'on-the-job' skills through experience and for high-level management skills that embraced combinations of technical ICT knowledge, industry experience and business acumen. Further, with rapid changes in

[4] There is a counter-argument that 'reputation effects' concentrate transaction activity over the Internet toward large established suppliers.

technology and skill requirements, it is vital that the education and training infrastructure be flexible, responsive and of high quality.

Issues more specific to ICT

Australian firms require timely and ready access to advances in ICT hardware and software in order to maximise ongoing productivity gains. This is especially important for firms that operate and compete in global markets. Because so many of the technological advances take place in other countries, timely and ready access depends on the absence of avoidable regulatory or trade barriers on imports and use of ICTs.

In principle, the presence of network spillovers can lead to sub-optimal diffusion of network technologies and provide a rationale for governments to encourage further uptake. The optimal extension and use of networks requires that continuing attention be given to such issues as the cost and availability of suitable communications infrastructure (for example, broadband), on-line security, privacy, content, appropriate protection of intellectual property, regulation of market power and taxation of e-commerce. (Again, any deficiencies in these areas were not investigated in the project.)

Governments can also play a role in the use of networks through their dealings with businesses and individuals. The provision of information and administrative arrangements through ICTs might encourage faster and wider uptake in the business community. However, it is important, at least in the short term, to provide firms with options and allow scope for experimentation and innovation, rather than force a single technological path.

7.5 Conclusion

The evidence gathered in this project is that Australian firms have responded well to the opportunities for productivity improvements that ICTs have offered to date. In international terms, they have put Australia toward the forefront of ICT uptake and related productivity gains.

Future prospects are also favourable. To a large extent, this is in the hands of firms and depends on the extent to which they choose to further develop their business strategies and capabilities. There are some specific issues that governments should continue to address. However, because the factors affecting ICT use and productivity gains are complex and diffuse, the appropriate stance for governments is largely to ensure that the general business environment supports the innovative use of ICT.

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