ICT AS A DRIVER OF PRODUCTIVITY

> A WHITE PAPER
PREPARED FOR TELSTRA BY ACIL TASMAN
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EXECUTIVE SUMMARY

ACIL Tasman has been commissioned by Telstra to undertake a review of Australian and international evidence on the role of Information and Communication Technology (ICT) as a driver of economic productivity, and to distil the findings of this review into a Productivity White Paper.

AUSTRALIA'S PRODUCTIVITY PERFORMANCE

Australia's recent productivity performance has been average at best

Australia's current productivity performance is average among OECD countries. In the last four decades, Australia's productivity growth has been lower than in many other OECD countries. After accelerating in the 1990s, Australian productivity growth has since slowed.

There is a persistent gap between Australian and US productivity

The United States is still considered to be world's productivity leader in a 'technological sense'. In the last five decades, there has been a persistent gap in aggregate productivity between the US and Australia. Some Australian industry sectors (such as mining, construction and transport) have performed at or close to the productivity frontier or even exceeded their US counterparts. However, sizeable gaps remain in other areas such as manufacturing, wholesale trade, retail trade, utilities, communications and finance.

ICT AND PRODUCTIVITY: SUMMARY OF THE EVIDENCE

The preponderance of empirical evidence suggests that investment in ICT has significant effects on productivity at various levels in many different countries.

MACROECONOMIC EVIDENCE

The majority of Australian studies have found a macro-level relationship between ICT and productivity

While there remains academic argument about the link between ICT investment and productivity growth, most Australian studies have found that there is a significant relationship between them.

Recent US studies have also mostly found that ICT has a significant impact on aggregate productivity, with a key underlying factor being falling ICT prices.

INDUSTRY-LEVEL EVIDENCE

At the industry level ICT has been a strong driver of productivity growth in Australia

Australian studies have shown that ICT influences labour productivity growth via its effect on MFP[1] growth through technological changes, capital investment in ICT and falling ICT prices. In Australian service industries, 33–65 per cent of MFP growth has been driven by ICT-related technology factors. The contribution for manufacturing industries is 45–75 per cent. It has also been shown that ICT investment is worth more to Australian producers than the market price, after adjusting for quality.

Some recent industry-level US studies have found significant returns to ICT investment, as have UK and French studies. While the US has experienced productivity accelerations in both ICT-producing and ICT-using sectors since the 1990s, there has been no productivity acceleration in European ICT-using sectors. Consensus has not yet emerged about the reason for this productivity divergence between Europe and the US.

However, it is worth noting that many industry-level studies are affected by problems of aggregate industry data and statistical biases. For this reason attention has shifted to more micro-level studies.

FIRM-LEVEL EVIDENCE

Using micro- or firm-level data allows firm-level variation in productivity and investment patterns to be taken into account. This is important as ICT may have different impacts on firms' productivity depending upon characteristics such as organisational structure and skill sets.

ICT confers informational, strategic, transactional and transformational benefits

Australian studies have found significant productivity impacts from ICT at the firm level. ICT confers informational, strategic, transactional and transformational benefits. However, investment in ICT requires consistent organisational and ICT strategies, effective internal and external communication, and careful risk assessment. ICT is an enabler, a necessary but not sufficient condition for productivity growth and transformational improvements.

Most US firm-level studies of the link between ICT and productivity reveal a positive and statistically significant relationship that is often fairly large in magnitude, although the estimates vary widely. European studies have also, on balance, demonstrated a statistically significant relationship between ICT and productivity.

EVIDENCE AT THE INDIVIDUAL AND WORKGROUP LEVEL

ICT's impact on individual workers depends on job characteristics

ICT is likely to boost the productivity levels of most workers. The type of ICT required by a worker and the productivity impact of that ICT is likely to vary considerably according to job characteristics.

Telstra has segmented workers into six different types according to their ICT needs: mobile workers, roaming professionals, decision makers, trade workers and service providers, informational processors and office knowledge workers. More micro-level research needs to be undertaken to quantify the impact of particular types of ICT on each type of worker.

Communication and collaboration technologies have made workers more productive

Electronic communication methods (such as email and mobile phones) have enabled individual workers to connect quickly to deal with and respond to others. Communicating with people both inside and outside the company has become more timely and thus more productive.

Mobile phones allow people to make better use of the time they spend travelling and waiting, keeping in touch with colleagues, friends and family, or performing a range of work-related tasks. In addition to being a communications tool, a mobile phone can increase worker flexibility, efficiency and productivity. Mobile telephony enhances business productivity by enabling employees to remain up-to-date with project news and developments while they are away from the office.

Broadband increases worker productivity by enabling more flexible work practices

Broadband enables more flexible work practices, hours and location, which can increase productivity and contribute to easing congestion and pollution challenges faced by large cities. Broadband access also benefits consumers by reducing search and information costs and giving greater access to information, making price comparisons easier, facilitating competition and creating downward pressure on prices. More generally, broadband changes the role of individuals in production, facilitating user-driven innovation and the development of user-created content.

ICT also enhances workgroup productivity via Web 2.0 collaboration tools (such as social networking sites and wikis that allow collective editing and modifying of on-line content) and by facilitating teleworking. Global studies on teleworking have found that both teleworkers and their employers report substantial productivity gains associated with their home access to ICT.

CONCLUSION

ICT can help Australia catch up with leading edge countries

While investment in ICT has boosted the productivity of workers, Australian firms, industries and the national economy, productivity levels in Australia remain below those of many OECD countries. There is room for improvement and catch-up through increased and smarter adoption of the latest ICT innovations by businesses and organisations, particularly in areas such as manufacturing, wholesale trade, retail trade, utilities, communications and finance.

More Australian micro-level studies are required

While there have been a significant number of Australian studies on the impact of ICT on productivity at the macroeconomic and industry levels (many of which have been commissioned by the Australian Government), there have been relatively few Australian studies of the relationship at the individual and workgroup levels.

Similarly, while good data exists on Australian productivity at the national level, and while the ABS has produced experimental estimates of productivity at the industry level, there has been an absence of Australian micro-productivity measures at the individual, workgroup, and firm levels. Where they do exist, they are inconsistently applied and understood and hence their mapping to macro-measures is not always apparent.

An Australian business productivity index should be developed

The real impact of ICT on business productivity analysed via a bottom-up approach thus requires careful consideration and possibly a common or unified methodology. A simplified cross-industry tool or index would provide Australian businesses and governments with the kind of information that would assist them in making sound ICT investment decisions that would likely result in improved productivity.

1. Multi-factor Productivity.

1. INTRODUCTION

ACIL Tasman has been commissioned by Telstra to undertake a review of Australian and international evidence on the role of Information and Communication Technology (ICT) as a driver of economic productivity, and to distil the findings of this review into a Productivity White Paper.

Productivity growth is a major determinant of economic growth

In the long history of human civilisation, sustained productivity growth is a relatively recent phenomenon. Productivity growth is a major determinant of economic growth and rising prosperity, and productivity differences explain a large part of the enormous variations in income levels and living standards among countries. At the firm or enterprise level, productivity is a key driver of profitability and business growth. At the individual level, productivity gains usually lead to higher income and consumption levels.

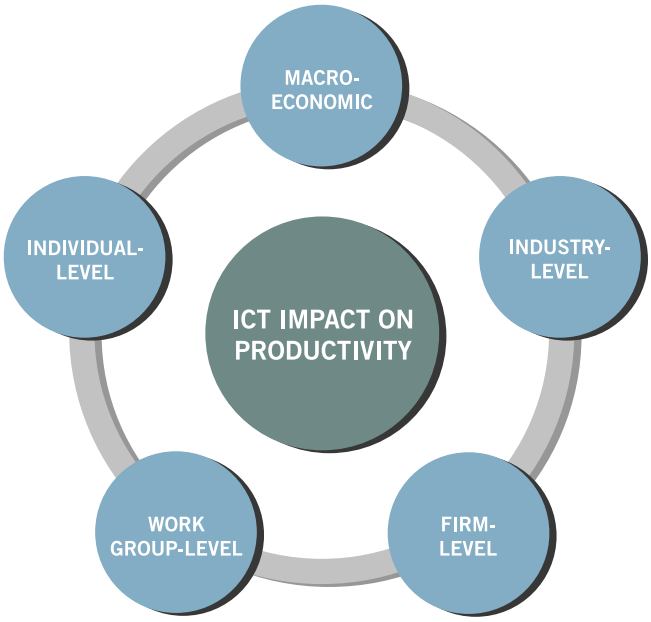
In the last several decades, ICT such as computers, telecommunication systems and the Internet have brought profound and revolutionary changes to businesses, consumers, education, health, entertainment and many other aspects of life. A striking feature of ICT is that the costs of storing, accessing and exchanging information have greatly diminished over time while computing power has continued to increase at an exponential rate. This has enabled ICT to reduce the costs of coordination, communications and information processing. Increasingly, ICT has also facilitated changes in what businesses do and how they do it, in the process boosting their productivity.

This paper examines the impact of ICT on productivity at various levels

This White Paper examines the evidence for linkages between productivity and ICT at multiple levels, from the national macroeconomy through the industry/sectoral level and the business/enterprise level, to the level of the workgroup and the individual. The paper examines evidence from both Australian studies and international studies based on a variety of methodologies and approaches.

This paper is structured as follows: Chapter 2 provides an introduction to ICT and productivity, including how productivity is measured and why productivity matters. Chapters 3 and 4 examine the evidence on the impact of ICT on productivity at the macroeconomic (national) level and the industry or sectoral levels respectively. Chapter 5 analyses the link between ICT and productivity at the firm/enterprise level, while Chapter 6 examines the link at the individual and workgroup levels. Chapter 7 presents the main conclusions of the paper.

Impact of ICT on productivity at various levels



Source: ACIL Tasman

2. PRODUCTIVITY & ICT

This chapter provides an introduction to the economic concept of productivity. It explains the different measures of productivity and the importance of productivity to nations, industries, businesses and individuals. This chapter also defines ICT and discusses developments that are on the horizon and their potential impacts on productivity.

2.1 WHAT IS PRODUCTIVITY?

Productivity is output per given quantity of inputs

An economist would define productivity as a measure of the physical output produced from the use of a given quantity of inputs. The man in the street might explain productivity as a measure of how effectively and efficiently an individual or firm can turn a set of inputs (materials, energy, knowledge, etc.) into a product that a consumer will buy.

In one way, productivity could be regarded as doing more with less, but it is also about being smarter about how we do things, and being more responsive and adaptive to changing situations and consumer needs.

If a firm is not using its inputs as efficiently as possible, then there is scope to lower costs and increase profitability through productivity improvements. This may come about through the use of better quality inputs (including a better trained workforce), adoption of technological advances, changes in work practices, and better management through a more efficient organisational and institutional structure.

2.2 MEASURES OF PRODUCTIVITY

In practice, productivity is measured by expressing output as a ratio of inputs used. There are two types of productivity measures: partial factor productivity and multi-factor productivity.

Partial factor productivity

Partial factor productivity is output relative to each input

Partial factor productivity measures include labour productivity and capital productivity. They measure one or more outputs relative to one particular input. For example, labour productivity is the ratio of output to labour input while capital productivity is the ratio of output to capital input.

Multi-factor productivity

Output can be increased by using more inputs, making better use of the current level of inputs, technological improvements and by exploiting economies of scale.

MFP measures the efficiency by which inputs are combined in production

Multi-factor productivity (MFP), sometimes referred to as total factor productivity (TFP), represents the residual portion of output growth that cannot be explained by increases in inputs such as labour and capital (DCITA 2007). Mathematically, MFP growth is equal to labour productivity growth minus the effect on productivity of a change in the amount of capital for each worker. MFP growth in the long run is explained by factors such as technological progress, rising education standards and changes in the socio-economic environment.

2.3 WHY DOES PRODUCTIVITY MATTER?

A historical perspective

Sustained growth in income and productivity is a relatively recent phenomenon

Prior to the Industrial Revolution in Britain, which historians date to the 1760s onwards, significant and sustained growth in per capita income was relatively unknown.

In the last two centuries, however, labour productivity, or output per worker, has accelerated enormously. Researchers have estimated that world per capita Gross Domestic Product (GDP) increased from about US$500 in the year 1500 to more than US$5,000 in 2000 (see Figure 1). Output per worker grew by an average of 0.08 per cent a year between 1500 and 1750, doubled to about 0.17 per cent a year between 1750 and 1850, accelerated to 0.88 per cent a year between 1850 and 1950 and to 2.20 per cent a year since 1950.

What has enabled this acceleration in economic growth? Researchers believe that the development of institutions that allowed individual inventors to reap a fair share of the benefits of their inventions has encouraged the development and deployment of new ideas and new technologies.

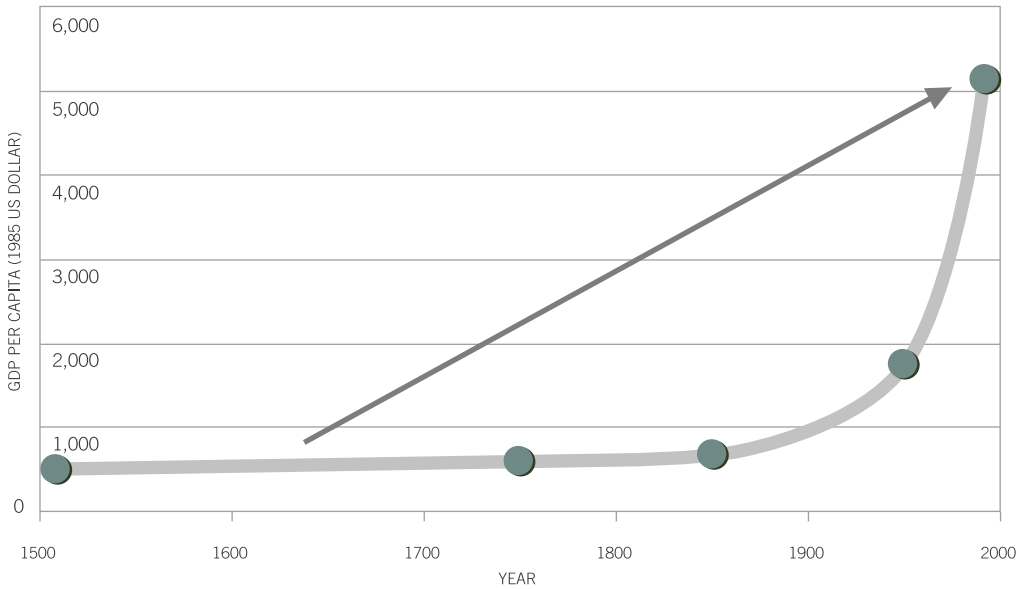
ICT has contributed to productivity growth

Information and communications technologies are among the technology developments that have contributed to the rapid productivity growth seen over the last several decades. These are discussed in Section 2.4.

At the national level

At the national level, productivity matters because it ultimately determines a country's standard of living. The greater the output per worker (that is, the higher the labour productivity) the higher per capita income will be, for a given labour participation rate.

Figure 1 World per capita GDP, 1500–2000



Data source: Lucas (1998) and Maddison (1995), updated by ACIL Tasman

Economists have estimated that productivity among the poorest one-fifth of countries in the world is about a quarter of that in Australia (Weil 2005 and author's calculations). Even among richer countries, there are surprisingly large differences in productivity. For example, productivity in the United Kingdom is 87 per cent of the level of the United States, and productivity in Japan is only 73 per cent of the US level (Weil 2005).

How much of the variation in per capita income among countries is explained by productivity differences? It has been estimated that 57 per cent of the variation is explained by differences in factor accumulation (that is, increases in capital, labour and other inputs) and 43 per cent by differences in productivity (Weil 2005).

Productivity growth keeps inflationary pressures in check

Apart from raising a country's standard of living, productivity increases also allow for aggregate wages to increase without triggering inflation. By restraining inflationary pressures, productivity gains reduce the need for central banks to adopt monetary policies to constrict growth in order to keep inflation within acceptable target ranges. In other words, productivity gains can lead to lower interest rates than would otherwise be the case.

At the business and firm level

At the level of the individual business or firm, productivity matters because it is a key driver of profitability and business growth.

Productivity gains mean that a firm is able to produce a given amount of goods and services with a smaller quantity of inputs (and hence with lower overall costs). This makes the firm more competitive, both locally and internationally, enabling it to gain market share at the expense of competitors who have not been able to achieve the same magnitude of productivity improvements, and to achieve greater profits and hence greater returns for shareholders.

At the individual level

Productivity growth enables greater consumption by individuals

In a market economy such as Australia, a worker's wage and salary are usually proportional to his or her productivity, as companies reward employees based on their contribution to the firm's profitability. By enabling workers to accomplish more for their employers in the course of a work week, increases in productivity will likely translate into higher incomes, resulting in a higher material standard of living and greater consumption of goods and services.

In addition, an individual with a higher productivity level is able to produce the same amount of goods and services while working fewer hours. This potentially allows for time to be devoted to further

production-oriented activity or to family and recreational activities. In other words, productivity growth can help individuals strike the right work/life balance.

The national benefits of greater productivity outlined above, such as lower interest rates, are also of course factors that have a very direct impact on individuals.

2.4 WHAT IS ICT?

Information and communications technology (ICT) is the term used to denote a wide range of services, applications and technologies, using various types of equipment and software, often running over telecommunication networks (EC 2001).

ICT includes well known telecommunication services such as fixed line telephony, mobile telephony and faxes running over a variety of networks including copper or fibre-optic cable, wireless or cellular mobile links, and satellite links. These services and networks, when used together with relevant hardware (such as desktop and portable personal computers and servers) and software, form the basis for a range of other services, including email, the transfer of video, audio and other data files from one computer to another within firms or between firms utilising the Internet.

ICT applications are wide-ranging – they include videoconferencing, teleworking, distance learning, management information systems and stock control.

ICT is an enabler of information and knowledge access

The importance of ICT is not the technology as such, but rather its role as an enabler for accessing knowledge, information and communications, which are increasingly important elements in today's economic and social interactions between people, firms and nations. ICT is a means for making the world a smaller and better informed place by expanding businesses' and individuals' networks and access to information.

ICT as a General Purpose Technology

General Purpose Technologies (GPTs) are radical new ideas or techniques that have the potential to have an important impact on many industries in an economy. Their key characteristics are:

- pervasiveness (used as inputs by many downstream industries),
- technological dynamism (inherent potential for technical improvements), and
- innovation complementarities with other forms of advancement (meaning that the productivity of R&D in downstream industries increases as a consequence of innovation in the GPT).

Thus, as GPTs improve, they spread throughout the economy, bringing about overall productivity gains.

ICT exhibits many of the characteristics seen in GPTs

Guerrieri and Padoan (2007) argue that ICT can be seen as a GPT, since computers and related equipment are used in most sectors of the economy. ICT has also displayed a substantial level of technological dynamism spurring not only radical improvement in computational capacity (following Moore's Law that computing power tends to double every two years), but also a successive wave of new technologies (ranging from the semiconductor to the Internet). Moreover, ICT has facilitated new ways of organising firms, including the decentralisation of decision-making, team production, etc. In the process, ICT has clearly exhibited innovation complementarities with other forms of technological progress.

The ICT innovation wave

ICT is also considered by some economic and technology historians as the current 'wave' in a series of innovation waves (such as those associated with the steam engine, electricity and mass production) that have occurred since the start of the Industrial Revolution. These waves, many of which have been based on developments in science and technology, have tended to last for about 50 to 60 years and to overlap with one another.

The ICT innovation wave encompasses successive innovations with quickening rates of adoption. For example, the uptake of broadband has been much more rapid than the uptake of the first personal computer systems[2]. In general, the adoption of each individual innovation tends to follow the well-known S-curve pattern (where the early adopters select the technology first, followed by the majority, until the technology or innovation is common).

Economic transformations evolve as an innovation wave diffuses

As a new wave of innovation diffuses through the marketplace, the nature of economic transformations tends to evolve. For instance, the initial transformation generally affects the foundations of the economy or its infrastructure. As these infrastructure technologies become widespread, they establish the environment for new applications to take hold. In the final stages, new services that use the new applications emerge.

2. The PC reached a 25 per cent penetration rate in the United States in 15 years, mobile telephones in 13, the World Wide Web in seven, and broadband within six.

While very significant changes caused by new ICT (such as the Internet, wireless technologies, fibre optic communications) are already apparent, to date they have primarily all been related to information and communications infrastructure. The positive disruptive influences of ICT are expected to go beyond these two categories of use in the next phase[3].

Likely future advances in ICT

The technological futures literature suggests that the main advances in ICT in the next 20 years will be in ubiquitous computing and communications pervading into all facets of economic life. In particular, greater use will be made of computerised controllers, electronic sensors and electro-mechanical actuators in manufacturing, mining, construction, agricultural and transport equipment. This will increase machine 'intelligence' and multi-functionality and reduce labour requirements. Other emerging productivity enhancing technologies include radio frequency identification devices (RFID). These have the potential to raise productivity in many areas of storage, distribution, trade and health care (DCITA 2007).

ICT networks and applications will be seamlessly converged

Likewise, many futurists believe that, by 2020, information and communication networks and applications will be seamlessly converged, and that computing power will be a ubiquitous part of the fabric of daily life. Data from commonplace physical objects, which will be equipped with sensor nodes and network connected, will be generated every minute of every day. The challenges that are likely to be overcome by ICT to 2020 include software agents, cognitive technologies, semantic Web, computational sciences/predictive simulation, software engineering, standardised operating systems and standardised transport infrastructure.

ICT investment and production in Australia

As noted in Parham (2002), investment in ICT became a sizeable proportion of total investment in Australia from the mid-1980s. The growth of investment has been very strong since, especially in the 1990s, when investment in hardware grew by 35 per cent a year and software investment grew by 20 per cent a year in real terms.

Australia is a user rather than a producer of ICT

By the 1990s, Australia had become a high user of ICT by international standards. In 1999, Australia ranked fourth among OECD countries in expenditure on ICT as a proportion of GDP (ahead of the US). This ranking has since fallen as other countries such as Korea have caught up with and surpassed Australia in the adoption of the latest ICT (including very high speed broadband).

Australia ranks at the low end of OECD countries in terms of the size of its ICT equipment production industries, importing most of its ICT equipment.

KEY FINDINGS

- Productivity is a measure of the physical output produced from the use of a given quantity of inputs. It is a measure of how effectively and efficiently an individual or a firm can turn a set of inputs into a product or service.
- Partial productivity measures include labour productivity (the ratio of output to labour input) and capital productivity.
- Multi-factor productivity represents the residual portion of output growth that cannot be explained by increases in inputs such as labour and capital.
- At the national level, productivity matters because it ultimately determines a country's standard of living. Much of the variation in per capita income among countries can be explained by productivity differences.
- At the level of the firm or business, productivity matters because it is a key driver of profitability and business growth. At the individual level, increases in productivity usually translate into higher incomes, which make possible greater consumption of goods and services.
- ICT denotes a wide range of services, applications and technologies, using various types of equipment and software, often running over telecommunication networks.
- ICT can be considered a General Purpose Technology (GPT). GPTs are characterised by pervasiveness, technological dynamism and innovation complementarities.
- The ICT innovation wave encompasses successive innovations with quickening rates of adoption. The main advances in ICT over the next two decades are expected to be in ubiquitous computing and communications that will pervade all facets of economic life.
- Australia was one of the leading adopters of new ICT in the 1990s but has since been overtaken by other OECD countries. Australia produces very little ICT equipment.

3. www.nrc-cnrc.gc.ca/aboutUs/ren/nrc-foresight_21_e.html

3. ICT AND PRODUCTIVITY – MACROECONOMIC EVIDENCE

As explained previously, differences in productivity between countries can be very large and they explain a significant proportion of international differences in living standards (as measured by income per person). This chapter examines productivity variations over time between Australia and other developed countries that are members of the Organisation for Economic Co-operation and Development (OECD). This is followed by a review of the evidence on the impact of ICT on productivity at the national macroeconomic level.

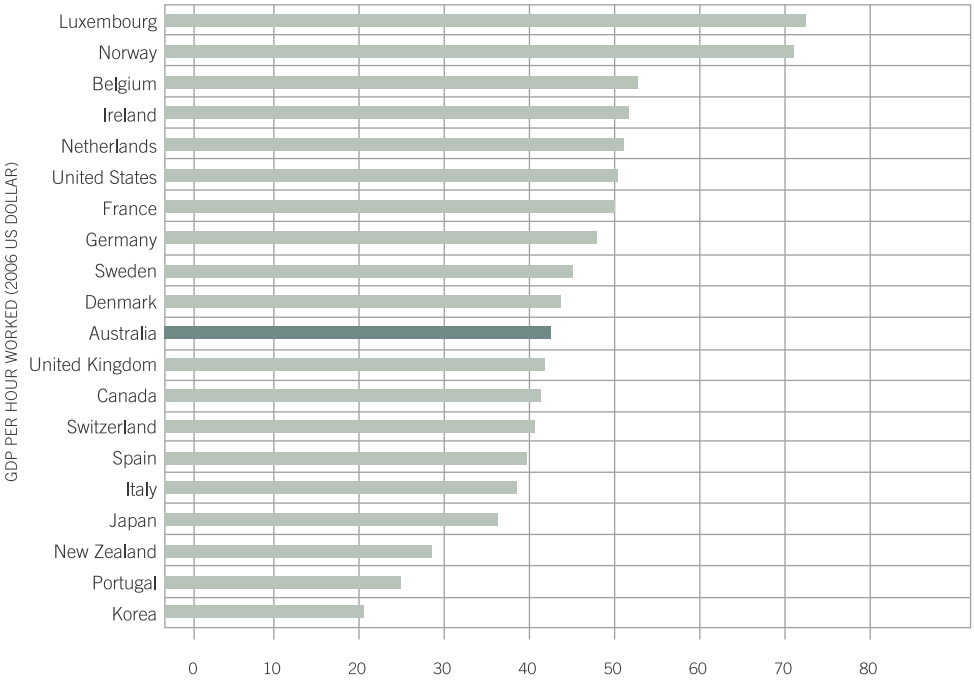
3.1 INTERNATIONAL COMPARISONS OF PRODUCTIVITY

Current labour productivity levels

Australia's productivity performance is average in the OECD

The level of labour productivity in various OECD countries, measured by output or GDP per hour worked, is shown in Figure 2.

Figure 2 GDP per hour worked, US dollar, 2006



Data source: OECD (see www.oecd.org/topicstatsportal/0,3398,en_2825_30453906_1_1_1_1_1,00.html)

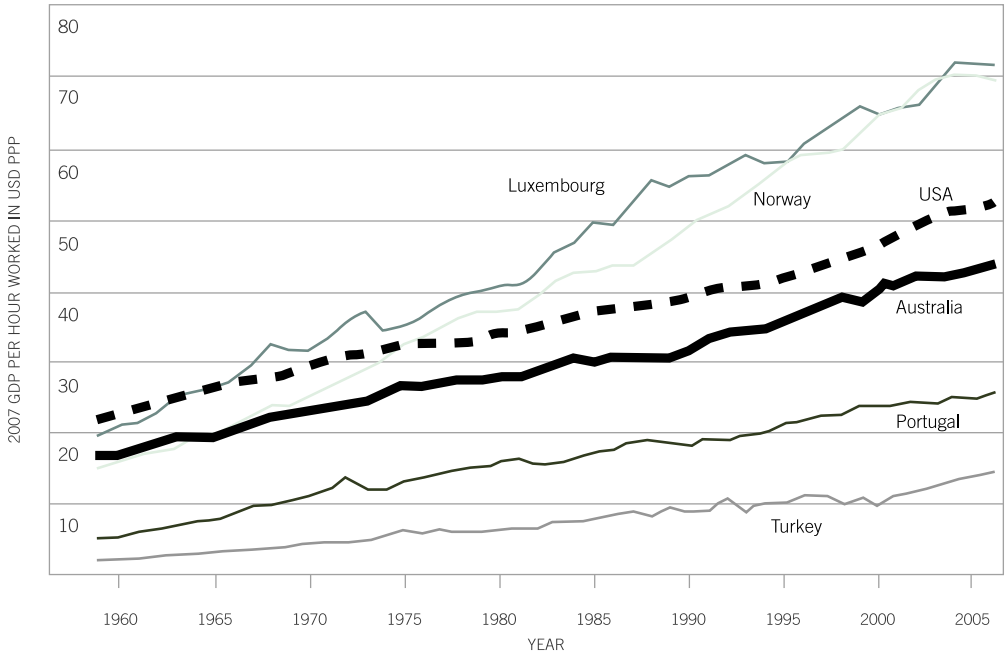
Australia's level of labour productivity is lower than that of some northern European countries such as Luxembourg, Norway and Belgium, but higher than that of Japan, New Zealand and Korea. The relatively high labour productivity levels of European countries such as France and Germany are partly attributable to a relatively short working week. This means that their labour productivity levels do not necessarily translate into high per capita income and consumption levels.

Productivity levels over time

The Australia-US productivity gap has been persistent

The post-World War II labour productivity performances of selected OECD countries relative to that of the US are shown in Figure 3. Countries such as Norway (among other Western European countries) began the post-war era with lower labour productivity levels than the US, caught up with it around 1980, and then overtook it. On the other hand, the aggregate labour productivity gap between Australia and the US has persisted over a long period of time. The Australia-US productivity gap at the industry level will be discussed in Chapter 4.

Figure 3 Labour productivity in OECD countries (2007 GDP per hour worked in USD PPP)



Data source: The Conference Board and GGDC (Total Economy Database, October 2008)

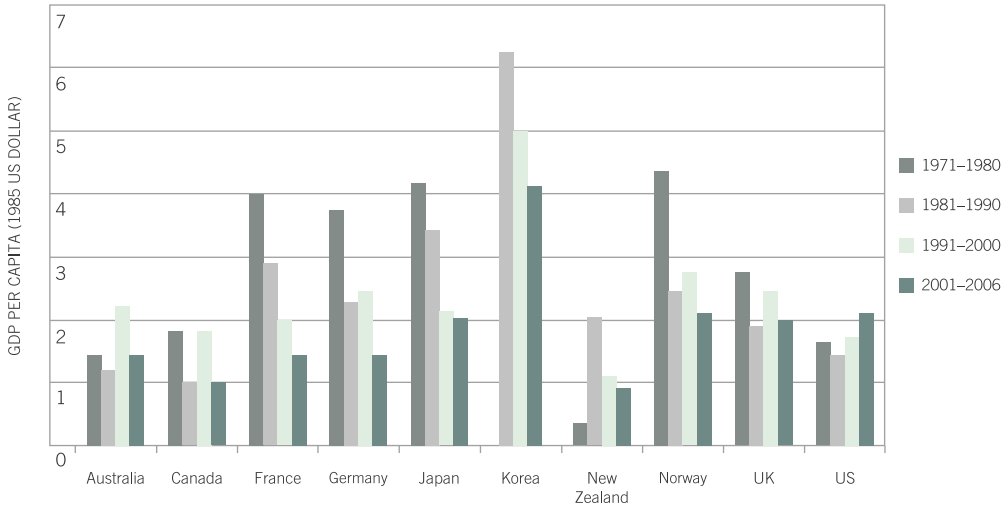
Multi-factor productivity growth rates

The average growth in multi-factor productivity of various OECD countries in each decade between 1971 and 2006 are compared in Figure 4. Countries such as France, Germany, Japan and Norway experienced very rapid MFP growth in the 1970s, while Korea experienced a dramatic productivity growth spurt in the 1980s. Many of these countries experienced significant declines in their MFP growth rates in subsequent decades.

MFP growth in Australia has been relatively stable

By comparison, Australia, the UK and the US experienced relatively stable MFP growth rates over the last three and a half decades, even though Australian and UK productivity growth since 2001 has been somewhat slower than that in the 1990s. This is the reverse of the US experience, possibly due to structural shifts in some industries. However, the annual MFP growth rate in Australia has generally lagged behind that of the UK and the US.

Figure 4 Average annual MFP growth rate in selected OECD countries, 1971–2006



Data source: OECD (see www.oecd.org/topicstatsportal/0,3398,en_2825_30453906_1_1_1_1_1,00.html)

3.2 MACROECONOMIC EVIDENCE OF THE IMPACT OF ICT ON PRODUCTIVITY

In the past two decades, analytical interest in the links between ICT and productivity growth has risen considerably. Many studies of these links have employed a growth accounting framework, based on national accounts approaches to productivity estimation. As explained in Parham (2002), this framework provides three avenues for ICT to influence labour productivity:

Three ways that ICT can influence labour productivity

- **Increases in capital deepening** – Labour productivity can rise due to higher capital use per unit of labour as firms invest in more ICT. This mechanism accords no special qualities to ICT – as it has become cheaper, firms have substituted ICT for labour and other forms of capital, as could happen for many other inputs.
- **Productivity gains in ICT production** – Producers' ability to manufacture much more powerful ICT equipment, with little increase in inputs, can generate substantial MFP gains. If these gains are of sufficient magnitude and production is on a sufficiently large scale, they can show up as contributions to aggregate MFP growth and labour productivity. (However, as noted previously, Australia is not a significant producer of ICT.)
- **Productivity gains in ICT-using industries** – This is the most controversial source of ICT-related productivity gains, requiring that usage of ICT generates MFP gains. Some economists point to MFP gains from such sources as increasing returns from ICT use and spillovers from network economies.

We examine, in turn, US and European and then Asian and Australian evidence on the impact of ICT on the macroeconomy.

US and European evidence

Four key findings have emerged from the US and European macroeconomic literature on ICT and productivity[4]:

1. The Solow Paradox, the observation by the famous economist Robert Solow in 1987 that ICT can be found everywhere except in the productivity statistics, arose because ICT was at that time a small part of the capital stock.
2. Productivity growth has accelerated in the US since 1995.
3. This US productivity acceleration appears to be linked to ICT.
4. There has been no acceleration of productivity growth in the EU, mainly due to the performance of the ICT-using sectors.

ICT's productivity impact on the US macroeconomy became evident in the 1990s

Some of the earliest macroeconomic studies arose from the need to understand the Solow Paradox (Solow 1985). Oliner and Sichel (1994) carefully analysed US Government data to show that this paradox could be explained by the fact that computers could not make a large contribution to aggregate productivity growth in the 1970s and 1980s because they constituted a very small proportion of aggregate US capital stock (about 2 per cent in 1993). Since then the importance of ICT in the capital stock has increased significantly.

Basu et al. (2004) estimate that the share of ICT in US value added in 2000 in the private non-farm economy was 5.5 per cent (1.6 per cent computer hardware, 2.3 per cent software and 1.6 per cent communication). Although it remains a relatively small share of total value added, ICT makes a substantial contribution to productivity growth because of its fast growth and high rate of depreciation.

As with MFP growth, US labour productivity growth has increased in the last decade. This has continued despite the high tech crash and the September 11 terrorist attacks, and reversed a period of slow US productivity growth that set in after the Oil Shocks of the mid-1970s. Many authors point to ICT as having an important role in this acceleration.

Oliner and Sichel (2000, 2002) find that ICT made an important contribution to the observed acceleration in US productivity. Dividing the economy into ICT-producing and ICT-using sectors (such as retail, wholesale and finance), they found that ICT made important contributions to productivity in both sectors.

What has driven these ICT-led increases in productivity? One answer is that there has been rapid technological progress in the ICT-producing sectors. In particular, the technology cycle for semi-conductors appears to have sped up after 1994, leading to a very rapid fall in quality-adjusted prices for ICT goods (Jorgenson 2001).

Rapidly falling ICT prices have been an underlying factor in productivity growth

This technological progress was reflected in MFP growth in the ICT-producing sectors and ICT capital deepening in other sectors. Since the user cost of ICT capital had fallen, there had been substitution into ICT capital and away from other factors of production. Both elements contributed to productivity growth, but the underlying factor has been rapidly falling ICT prices (Jorgenson 2001).

In a UK macroeconomic study, Oulton (2002) finds that ICT's contribution to UK GDP growth increased from 13.5 per cent in 1979–89 to 20.7 per cent in 1989–98. ICT contributed 55 per cent of capital deepening in the UK during 1989–98 and 90 per cent from 1994–98. ICT capital deepening accounted for 25 per cent of labour productivity growth over 1989–98 and 48 per cent over 1994–98.

4. Draca et. al (2006), pp.28–29

While Jorgenson (2005) finds that the surge in ICT capital investment is found across G7 countries, declining contributions of non-ICT capital offset the effect of the ICT surge in France and Germany (as well as Japan).

Asian and Australian evidence

Jorgenson and Motohashi (2005) compare sources of economic growth in Japan and the United States between 1975 and 2003, focusing on the role of ICT. Their data show that the share of the Japanese GDP devoted to investment in computers, telecommunications equipment, and software rose sharply after 1995. The contribution of MFP growth from the ICT-producing sector in Japan also increased, while the contributions of labour input and productivity growth from the non-ICT sector lagged far behind the US.

The authors' projection of potential economic growth in Japan for the next decade is substantially below that in the United States, mainly due to slower growth of labour input. Their projections of labour productivity growth in the two economies are much more similar.

In Australia, a study conducted by Barker, Fuss, Tooth and Waverman from the Centre for Law and Economics at the ANU, using cross-country data at the national level, found that ICT investment and spillovers were major drivers of productivity growth in Australia and other OECD countries in recent years (Barker et al. 2006). The study used a national productivity database for OECD countries compiled by the Groningen Centre in the Netherlands.

Barker et al. show that more intensive use of ICT capital in the United States and its diffusion explained around 44 per cent of the Australian-US productivity gap in 2000, and about 28 per cent in 2003. The results of this study are consistent with a growing body of overseas econometric research, which suggests that ICT has been a major driver of productivity growth in developed countries in recent years.

ICT has increased Australian labour productivity through capital deepening

In an earlier study, Parham et al. (2001) found that ICT made strong capital deepening contributions to acceleration in labour productivity in Australia (around 0.3 to 0.4 of a percentage point), as it did in the US. However, much or all of the increased use of ICT (per hour worked) in the 1990s had been offset by slower growth in the use of other forms of capital. There was therefore little increase in the overall rate of capital deepening in Australia in the 1990s. The acceleration of labour productivity in Australia in the 1990s was entirely attributable to faster MFP growth.

Parham et al. believe that non-ICT factors contributed the bulk of the acceleration in Australian productivity growth in that decade. They maintain that part of the acceleration was due to international catch-up and to microeconomic policy reforms. Creating a more competitive, open and flexible environment encouraged and enabled Australian business to move toward established best practice.

ICT investment is worth more to users than the prices paid

In a follow-up study to their earlier industry-level study, Diewert and Lawrence (2006) estimated that, at the national level, Australian ICT investment is worth around 40 per cent more to users than the prices paid. They explain the undervaluation of ICT inputs by a combination of factors including market disequilibrium due to rapidly falling ICT prices, innovation related externalities and intangible investment in human capital and organisational change associated with ICT investment.

Diewert and Lawrence (2006) also find that Australia's productivity performance over the last 40 years has been significantly underestimated, and that 85 to 90 per cent of Australia's MFP growth is accounted for by technological progress rather than increasing returns to scale in production.

KEY FINDINGS

- Australia's current labour productivity level is, at best, middle of the range among OECD countries.
- Australian productivity accelerated in the 1990s but growth has slowed again since then.
- The impact of ICT on productivity at the macroeconomic level only became apparent from the 1990s onwards as ICT equipment was a relatively small proportion of the total capital stock in the preceding period.
- Recent US studies have mostly found a significant impact of ICT on aggregate productivity. A key underlying factor has been falling ICT prices.
- Most Australian studies have found a significant relationship between ICT investment and productivity growth.
- Non-ICT factors, such as microeconomic policy reforms, have also contributed to productivity growth, particularly in the 1990s.
- An important Australian study has found that ICT investment is worth significantly more to users than the prices paid, and that Australia's productivity performance over the last 40 years may have been underestimated.

4. ICT AND INDUSTRY PRODUCTIVITY

This chapter presents Australian and international evidence on the relationship between ICT and productivity at the industry or sectoral level. We begin by comparing the productivity of Australian industries against their United States counterparts.

4.1 AUSTRALIAN INDUSTRY-LEVEL PRODUCTIVITY: COMPARISON WITH THE US

As noted by the Productivity Commission, the United States can still be taken to be the world's productivity leader and the international benchmark in an aggregate 'technological sense' (Dolman et al. 2007). While some European countries now have higher levels of productivity, this reflects industry mix (such as the prominence of oil production in the case of Norway) as well as policy and institutional distortions in labour markets that have not brought about overall gains in average living standards.

Australia has generally failed to catch up to the US in terms of productivity

The Productivity Commission found that Australia's efforts to match the US aggregate level of productivity since the 1950s have generally been weak. One positive but transient improvement in Australia's relative position came in the 1970s, but it was associated with a US productivity growth slowdown and some unsustained influences in Australia (such as real wage inflation holding down labour utilisation and boosting productivity). Another sharp rise came in the 1990s, when Australian productivity growth accelerated sooner and faster than in the United States. However, there remains a sizeable gap between Australian and US productivity levels.

The Australia-US productivity gap varies by industry

The aggregate productivity comparison masks a diversity of experience at the industry level. While industry data is of poorer quality, some Australian industry sectors (such as mining, construction and transport) appear to have performed at the productivity frontier and have participated in frontier shifts along with US industries (see Table 1 over the page). However, large gaps remain in other areas such as manufacturing, wholesale trade, retail trade, utilities (electricity, gas and water), communications and finance. These gaps may conceivably be reduced through greater and smarter use and adoption of ICT.

4.2 AUSTRALIAN EVIDENCE OF ICT'S IMPACT ON INDUSTRY PRODUCTIVITY

In the past decade the Australian Government, through the Department of Communication, Information Technology and the Arts (DCITA) (now the Department of Broadband, Communications and the Digital Economy (DBCDE)), commissioned a series of studies on ICT and productivity in Australia.

Table 1 Catch-up in Australian productivity levels: 1979 to 2003

Industry	Growth rate in the US (% p.a.)	Australia's growth relative to the US (% points p.a.)	Australian labour productivity (% of US level per year)		
			1979	1998	2003
Agriculture, Forestry and Fishing	3.7	-0.8	94	69	78
Mining	2.7	0.3	186	203	199
Manufacturing	3.7	-1.3	83	71	60
Electricity, Gas and Water	3.5	1.1	41	71	53
Construction	-0.8	2.2	74	111	124
Trade	2.6	-0.1	62	60	60
Wholesale	4.3	-1.0	55	33	43
Retail	2.5	0.2	60	73	63
Accommodation, Cafes and Restaurants	0.3	0.1	85	84	87
Transport and Communications	2.5	-0.6	98	95	85
Transport and Storage	2.3	-2.5	179	95	98
Communications	2.9	3.0	41	114	83
Financial and Business Services	0.4	-0.5	97	90	85
Finance and Insurance	2.6	0.3	62	73	67
Property and Business Services	-0.5	-1.1	120	96	93
Public Services	-0.2	0.9	100	124	124
Other Services	1.4	-0.6	83	71	72
Whole Economy	**1.6**	**0.1**	**84**	**89**	**87**

Data source: Dolman et al. (2007), calculations based on GGDC (60-Industry Database, September 2006)

Two DCITA reports examined productivity growth in manufacturing and some service industries over the 17 years from 1984–85 to 2001–02 (NOIE 2004 and DCITA 2005a). These industries jointly cover about 53 per cent of Australia's GDP.

As noted in DCITA (2007), the two reports used a different approach to earlier studies by the Productivity Commission and others to examine the contribution of ICT to Australian productivity growth. In particular, they investigated the role of technology and ICT in the unexplained residual or MFP, which is a major component of labour productivity.

ICT has impacted labour productivity through its effect on MFP growth

The two reports showed that ICT influences labour productivity growth via its effect on MFP growth through technological changes, capital investment in ICT and the effect of falling ICT prices on the constant price valuation of ICT capital. In service industries, between 35 and 65 per cent of MFP growth is estimated to have been driven by technological factors (which are primarily ICT related). In manufacturing, the range was between 45 and 75 per cent.

Table 2 shows estimates for the various contributions to labour productivity growth in service industries and manufacturing. The main non-technological factors driving MFP growth are institutional factors such as micro-economic reform and the rising education level of the workforce.

Table 2 Drivers of labour productivity growth: 1984–85 to 2001–02

Labour productivity growth attributed to	Annual contribution (%)	Share (%)
Service industries		
Increased capital spending per worker	1.02	46
Falling ICT prices	0.45	20
MFP growth due to technical change	0.27–0.50	12–22
MFP growth due to institutional change	0.50–0.27	22–12
Annual labour productivity growth	2.24	100
Manufacturing		
Increased capital spending per worker	0.75	34
Falling ICT prices	0.28	13
MFP growth due to technical change	0.51–0.85	24–39
MFP growth due to institutional change	0.62–0.28	29–13
Annual labour productivity growth	2.16	100

Data source: NOIE (2004) and DCITA (2005a)

Productivity growth has been strong in Australian industries that use ICT intensively

The DCITA-commissioned studies were carried out at the industry level. They indicate that productivity growth (both total labour productivity and MFP) was particularly strong in industries that are heavy users of ICT equipment and software. In services, these sectors include telecommunications, finance, wholesale trade and electricity. In manufacturing, ICT intensive industries include electronics, medical and scientific instruments, petrochemicals, basic metals and motor vehicles. The many new applications of ICT introduced as a result of rapidly falling ICT hardware prices have been the primary reason for the strong impact of ICT on productivity growth.

Another DCITA-commissioned study, Diewert and Lawrence (2005), estimated productivity growth at the sectoral level. The authors used advanced quantitative economic techniques to explore whether the assumptions used in modelling might bias econometric estimates for a rapidly developing input such as ICT. They found that traditional growth accounting is likely to understate the MFP benefit from ICT use. For sectors with sufficiently robust data, they found that ICT investment is worth more to producers than the market price, after adjusting for quality (a finding confirmed in their national-level 2006 study). They suggest that underestimations might occur because, in the long run, users benefit more from ICT capital than its cost. However, their findings were not conclusive because of inconsistencies in the ABS productivity database at the sectoral level.

4.3 OVERSEAS EVIDENCE

Overseas evidence at the industry level has been mixed

While early US industry studies – such as Berndt and Morrison (1995), which used data on manufacturing industries between 1968 and 1986 – found no statistically significant relationship between ICT and productivity, some industry-level studies using more recent data have found significant returns to ICT capital. For example, Stiroh (2004) found positive returns over the 1987–2000 period in a study of 58 industries. The study considered ICT capital as a whole, and for individual sub-components (computers and telecom). In a study of the ICT industries, Chun and Nadiri (2002) found that product innovation was responsible for 30 per cent of MFP growth in the US computer industry, process innovation was responsible for 50 per cent, and scale economies for 20 per cent.

Draca et al. (2006) argue that the absence of effects found in earlier studies may be due less to the time period and more to the combination of noisier data and ICT being a much smaller proportion of total capital.

Other studies have found the relationship between ICT and productivity at the industry level to be insignificant or unstable across time and across countries. For example, Basu et al. (2004), using US Government data on manufacturing and services from 1977 to 2000, found ICT capital growth to be negatively correlated with US MFP growth in the late 1990s. Data on ICT investment was composed of four broad classes of assets: computers and related equipment, software, communications equipment and other information processing equipment.

BOX 1 DERIVATION OF US AND EUROPEAN INDUSTRY-LEVEL ICT DATA

US Government industry-level data on ICT spending are derived from a top-down approach. First, gross investments in ICT for the US economy are computed starting from micro data – produced mainly by the Census Bureau – on computer shipments. Exports, intermediate, household and government purchases are subtracted from the total, while imports are added. Second, industry totals on overall investments are built from micro data on establishments for the Economic Census and Annual Capital Expenditure Survey. To obtain a time series on ICT by industry, the industry and asset totals are combined and distributed across the different industries using an occupational-employment-by-industry matrix.

Measuring nominal ICT flows is but the first in a series of adjustments required to obtain proper ICT capital. One other such adjustment is the creation of appropriate deflators to convert nominal into real flows. This is particularly important for ICT assets as they have experienced dramatic price and quality changes over the years. Another adjustment is the creation of appropriate depreciation techniques to account for the rate of decline in the economic value of different investment vintages.

European industry data on ICT assets generally lag behind that of the US. Often, they combine official statistics on ICT flows at industry level for EU economies with US methodologies (such as for depreciation patterns) to produce broadly comparable ICT stocks from the late 1970s.

Data source: Draca et al. (2006)

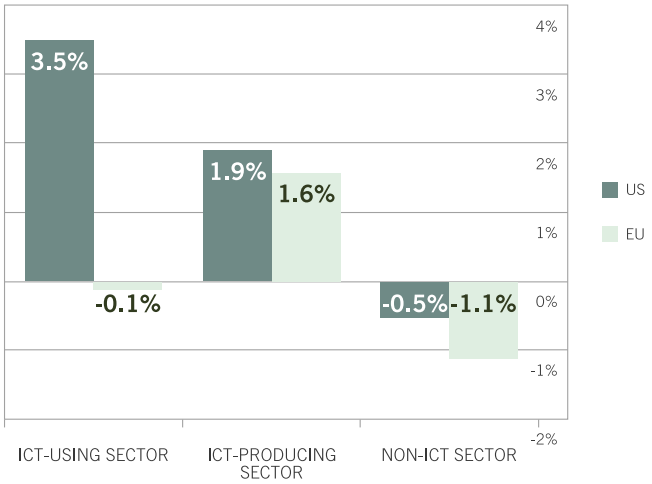
On the other hand, the same authors found that ICT capital services were correlated with MFP in the UK. This was based on a Bank of England dataset of 34 industries between 1979 and 2000. This UK finding was corroborated by Oulton and Srinivasan (2003). In France, Crepon and Heckel found that ICT increased productivity by 0.7 per cent a year between 1987 and 1998 (0.4 per cent from ICT production, and 0.3 per cent from capital deepening).

Acceleration in US productivity growth has been strongest in ICT-using sectors

O'Mahoney and van Ark (2003) compared the accelerations in US and European productivity growth between 1990 and 2002. In the US, the acceleration was strongest in the ICT-using sectors (those that use ICT extensively, such as retail, wholesale and finance), up from 1.2 per cent per annum in the early 1990s to 4.7 per cent per annum after 1995. There has also been a smaller acceleration in the ICT-producing sectors (up by 1.9 percentage points). Outside these sectors, there was a deceleration in annual productivity growth of about half a percentage point (see Figure 5).

Figure 5 US and European acceleration in productivity growth

CHANGE IN ANNUAL GROWTH IN OUTPUT PER HOUR FROM 1990–95 TO 1996–2001



Data source: O'Mahoney and van Ark (2003)

In the European Union there was also productivity acceleration in the European ICT-producing sectors, and a deceleration in the non-ICT sectors (those that do not use ICT intensively). However, unlike the US, there has been no acceleration of productivity in the ICT-using sectors. This is somewhat surprising given the relatively small price variation in ICT across the world.

There is no consensus on why US and European productivity experiences differ

While there has been considerable discussion over this productivity difference between the US and Europe, no consensus has yet emerged. It may well be that, in the absence of ICT, European productivity growth may have been much lower than has been observed. Some authors such as Blanchard (2004) claim it is simply a matter of time before Europe resumes the catching up process, while others point to more long-term structural problems in Europe such as over-regulated labour and product markets (Gust and Marquez 2004).

Basu et al. (2004) examine the differences between the US and UK specifically. Unlike the US, but like other European countries, the UK did not experience a productivity acceleration in 1995–2000 relative to 1990–1995. While the authors had difficulty accounting for the US-UK difference, they argued that the UK is likely to catch up because of its later investment in organisational capital to complement ICT investments[5].

Many industry-level studies are affected by the problems of aggregate industry data and the problem that ICT is included on both sides of the estimating equations. Attention has shifted to micro-level (such as firm-level) studies in view of the concerns about aggregation and other statistical biases.

KEY FINDINGS

- Australia's efforts to match the level of productivity in the United States (still considered to be world's productivity leader in an aggregate 'technological sense') since the 1950s have generally been weak.
- Some Australian industry sectors (such as mining, construction and transport) have performed at the productivity frontier.
- However, sizeable gaps remain in other areas such as manufacturing, wholesale trade, retail trade, utilities, communications and finance. New ICT may help close these gaps.
- Australian studies have shown that ICT influences labour productivity growth via its effect on MFP growth through technological changes, capital investment in ICT and the effect of falling ICT prices.
- In Australian service industries, 33–65 per cent of MFP growth has been driven by technology factors (which are primarily ICT-related). The range in manufacturing industries was 45–75 per cent.
- It has been shown that ICT investment, after adjusting for quality, is worth around 40 per cent more to users than the prices paid.
- Some recent industry-level US studies have found significant returns to investment in ICT capital, as have studies in the UK and France.
- The US has experienced productivity accelerations in both ICT-producing and ICT-using sectors since the 1990s.
- There has also been acceleration in the productivity of European ICT-producing sectors, although not in European ICT-using sectors.
- Many industry-level studies are affected by data problems and statistical biases. Attention has therefore shifted to micro-level (e.g. firm-level) studies.

5. Organisational capital includes unique systems and processes employed in the investment, production and sales activities of an enterprise, along with the incentives and compensation systems governing its human resources.

5. ICT AND FIRM/ENTERPRISE PRODUCTIVITY

This chapter looks at the results of Australian and international studies on the linkages between ICT and firm- or enterprise-level productivity.

As noted in Draca et al. (2006), using micro, firm-level data rather than industry data allows the well-documented firm-level variations in productivity and investment patterns to be taken into account. This is particularly relevant in the context of ICT assets, as ICT is frequently found to have a differential impact on firm-level productivity according to characteristics such as organisational structures and skills. These characteristics are likely to differ even across firms within the same industry.

5.1 IMPACT OF ICT ON SMES

SMEs may benefit especially from ICT

While ICT is likely to benefit firms of all sizes, they may be important particularly for Small and Medium-sized Enterprises (SMEs). As noted in OECD (2008), ICT and broadband-enabled trade-in services allows SMEs to buy services they previously could not afford, for example, using remote security surveillance rather than hiring a security guard on the premises, ICT services rather than an ICT technician, and similar examples for legal services, accounting, advertising, etc.

Other examples include managed services provided by broadband providers, such as Voice over Internet Protocol (VoIP) services, IP Virtual Private Networks (VPNs), website hosting, managed email accounts, Internet security (business network security features such as virus and spam protection and firewalls), data storage, archiving and back-up, desktop management, software as a service (also known as managed software, on-demand software and application service provision), Web conferencing, surveillance, monitoring and closed circuit TV.

On the sales side, ICT also enables SMEs to market and sell their goods and services to a broader (and potentially international) market. They may do so through their own websites or via Internet business-to-consumer (B2C) auction sites such as eBay and business-to-business (B2B) auction sites. SMEs may achieve efficiency and productivity gains by leveraging the production scale economies resulting from an expanded customer base.

5.2 AUSTRALIAN EVIDENCE

According to the Productivity Commission's *Annual Report 2007–08*, communication technology provides important platforms for innovation by firms. It enables many of the intangible investments such as databases, information systems, organisational capital and delivery systems that support an organisation's on-going innovation activity. The timely provision of efficient communications infrastructure thus plays a key role in supporting innovation activity and Australia's productivity performance (PC 2008).

CEOs believe the Internet impacts positively on firm productivity

A recent survey by Deloitte of 526 Chief Executive Officers (representing companies with sales revenue of more than $82 billion and employing more than 210,000 people) for the Australian Industry Group indicated that the Internet has had a positive impact on the efficiency and productivity of 93 per cent of companies (AIG 2008). The survey indicated that in 15 sectors out of 18 more than 90 per cent of firms see the Internet as having a positive impact on productivity. The sectors reporting the highest rates of positive impact were transport and utilities; finance; insurance and property; transport equipment; and wood products and furniture. The survey also indicated that larger firms and firms located in metropolitan areas were more likely to report positive productivity benefits from the Internet.

In an econometric study, Gretton, Gali and Parham (2004), using the Australian Business Longitudinal Study Panel of Australian firms of various sizes for three years (1988–89, 1993–94 and 1998–99), found that ICT has a positive impact on productivity in most specifications, although the effect was statistically significant in only two specifications.

Among the research publications on productivity commissioned by DCITA (now DBCDE) and its predecessor (NOIE, the National Office for the Information Economy) are three reports which examine the nature of good business strategies in the adoption and development of ICT.

The first report, *Productivity and organisational transformation: optimising investment in ICT*, by Ovum, examines the experiences of 18 Australian organisations in various sectors that were seeking to extract maximum benefits from their ICT investments (NOIE 2003).

ICT investments require appropriate policies and supportive environments

The report suggests that investment in ICT requires consistent organisation and ICT strategies, effective internal and external communication, and careful assessment of risk. The report emphasises that ICT is only an enabler, a necessary but not sufficient condition for productivity growth and transformational improvements. The desired outcomes may not necessarily occur unless organisations have appropriate policies and supportive environments in place.

The second DCITA report, *Achieving value from ICT: key management strategies* by Opticon/Australian National University, is based on responses from 1,050 Australian firms and organisations to a telephone survey, supplemented by 50 in-depth interviews (DCITA 2005b).

This study identified four types of benefits of ICT on firm performance:

- informational benefits by way of more and better information,
- strategic benefits such as creating a competitive advantage,
- transactional benefits in reducing transaction costs, and
- transformational benefits associated with positive organisational change.

While there was little difference in the amount of benefit obtained in each category, ICT provided informational benefits most frequently and transactional benefits least often.

The value of ICT depends on ICT-awareness, openness to organisational change, and persistence

The report identified three conditions that influence the value realised from ICT:

- **Being ICT aware.** This includes elements such as good understanding by management of the benefits to be gained from ICT and their ability to carry out an effective ICT implementation strategy.
- **Being open to organisational transformation.** Organisational transformation must be recognised as a necessary accompaniment to ICT implementation.
- **Being persistent and patient in realising ICT benefits.** Because the successful use of ICT involves a continuous cycle of learning and change, there is often a time lag between the initial investment in ICT and the time when the full benefits from the investment are realised.

The study suggested that achieving business value from ICT is largely within an organisation's control, regardless of the size of the organisation or the industrial sector. The key requirement is 'ICT investment impetus' derived from 'ICT aware' management, with a good understanding of the possible benefits that investment in ICT can bring about and the manner in which the realisation of transformational benefits can occur over time. The study revealed that organisations that treated ICT as a serious management issue would achieve better value from ICT.

ICT is often produced in non-ICT firms

A third report commissioned by DCITA was entitled *Digital factories: the hidden revolution in Australian manufacturing*. Howard and Partners interviewed managers of manufacturing firms to examine the impact of ICT on their productivity growth (DCITA 2005c). They found that, while not part of the ICT sector, there is considerable ICT production 'hidden' in these firms. These companies are designing, developing and enhancing ICT applications that are incorporated into non-ICT products or services and internal business processes. The report highlights the importance of ICT components embedded into machinery and equipment, and the difficulties in classifying hybrid applications involving ICT.

In addition, the report found that the skills of managers in understanding the potential benefits from ICT and appropriate methods of applying it are strategically important in ensuring the commercial success of ICT-related applications.

5.3 EVIDENCE FROM NORTH AMERICA

Most US firm-level studies reveal a positive link between ICT and productivity

According to Draca et al. (2006), the main findings from firm-level studies of the link between ICT and productivity are:

- Most studies reveal a positive and significant association of ICT with productivity.
- The magnitude of the relationship is often fairly large.
- The size of the relationship between ICT and productivity may be due to organisational capital.
- There is a very wide range of estimates of impact of ICT on productivity using firm-level data.

Studies that find a positive relationship between ICT and MFP include Wilson (2004), who also found that ICT capital complements non-ICT capital and that different types of capital are substitutable within their technology class.

Atrostic and Nguyen (2005) find that labour productivity is between 3.7 per cent and 7.2 per cent higher for establishments using computer networks compared with those that do not. This finding is confirmed in Atrostic and Nguyen (2006), which also disentangles some of the diverging effects of different types of network use. In particular, online supply chain activities, such as inventory control, order tracking, transportation and logistics management are consistently found to be positively linked to productivity[6].

ICT's impact on productivity may be related to organisational capital

The explanation (found in some studies using firm-level data) that the strong relationship between ICT and productivity is due to organisational capital, has been supported by Bresnahan et al. (2002). They find that skills and organisational capital are significant determinants of ICT demand, and that interactions between ICT and skills and between ICT and organisational capital are significant determinants of productivity. These findings were echoed by Brynjolfsson et al. (2002), who also found that key organisational characteristics were correlated with ICT capital but not physical capital.

However, Caroli and Van Reenen (2001) and Black and Lynch (2001, 2004) do not find support for interactions between ICT and organisation, although they use less sophisticated measures of ICT capital. Bloom et al. (2005) find some support for the organisational capital hypothesis – they find much higher returns for ICT in US multinationals compared to non-multinationals than between statistically similar UK establishments.

In Canada, Turcotte and Rennison (2004) use a 1999 workplace and employee survey developed by Statistics Canada and Human Resource Development Canada to show that computer use, university education and computer skills development are associated with higher productivity. They find evidence that computer skills training can augment the qualifications of lower-skilled workers and make firms equally well-off in terms of the productivity gain associated with technology use.

Estimates of the impact of ICT on firm productivity vary widely

The wide range of estimates of the impact of ICT on productivity at the firm level is reviewed in the Stiroh (2004) meta-study. These estimates range from over 25 per cent to minus 6 per cent. While this wide variation is partly due to methodological differences, it is also strongly suggestive of differences between countries, industries and types of firms. This is corroborated by Bloom's (2005) findings of systematic differences in returns to ICT by ownership type and industry. Specifically, they find that US firms receive a higher return from ICT and that this return is driven by sectors that use ICT intensively.

Hempell (2005) finds that ICT has a positive relationship with productivity for a sample of Dutch firms and German firms in distribution and business services. Matteucci et al. (2005), in a study of German, Italian and UK firms between 1995 and 2000, find a significant effect of ICT on productivity in manufacturing but not in services.

6. Furthermore, productivity impacts tend to be higher in newer plants. However, positive productivity effects are not identified for online processes related to production, sales and human resources.

5.4 EVIDENCE FROM EUROPE

ICT has been shown to impact productivity in French, German, Dutch, Italian and UK firms

Bloom et al. (2005) find a significant impact of ICT on productivity in a sample of 7,000 British establishments between 1995 and 2004. The data suggests that the effect is greater for US multinationals operating in the UK than non-US multinationals or domestic firms. This 'US effect' is particularly strong in ICT-intensive industries.

US firms in the UK were able to get significantly more productivity out of their ICT than other multinational (and domestic British) firms, even in the context of a UK environment. This suggests that part of the ICT-related productivity gains in the US may be due to the management or organisational capital of firms rather than simply the 'natural advantages' (geographical, institutional or otherwise) of the US environment.

Forth and Mason (2003) also finds a generally positive impact of ICT on productivity among UK firms participating in an international benchmarking survey.

Haltiwanger et al. (2003) compare the productivity outcomes for similar ICT-intensive firms in Germany and the United States. They find that ICT-intensive US firms exhibit greater productivity dispersion, particularly amongst younger businesses. The German data is drawn from a manufacturing sector panel.

Greenan and Mairesse (1996) report a positive and stable relationship between ICT and productivity among French firms from 1987 to 1993. However, Greenan et al. (2001) find that the ICT effect is not significant in a sample of French manufacturing and services firms when individual firm characteristics are taken into account.

KEY FINDINGS

- ICT may have different impacts on firms' productivity depending upon characteristics such as organisational structures and skill sets.
- ICT (particularly broadband-enabled trade-in services) are important for SMEs, enabling them to buy services they previously could not afford, such as remote security surveillance in place of a security guard.
- Australian studies have found significant productivity impacts from ICT at the firm level. ICT confers informational, strategic, transactional and transformational benefits.
- Investment in ICT requires consistent organisational and ICT strategies, effective internal and external communication, and careful risk assessment.
- ICT is an enabler, a necessary but not sufficient condition for productivity growth and transformational improvements. Productivity growth also depends on a firm's ability to adopt organisational changes that improve its capacity and capability to effectively address its business environment.
- The value a firm derives from ICT is influenced by factors such as ICT-awareness, openness to organisational transformation, as well as persistence and patience in realising ICT benefits.
- Most US firm-level studies of the link between ICT and productivity reveal a positive and significant relationship. The magnitude of the effect may be dependent on the organisational capital of the firm.
- On balance, European studies have demonstrated a statistically significant relationship between ICT and productivity.

6. ICT AS A DRIVER OF INDIVIDUAL AND WORKGROUP PRODUCTIVITY

Finally, in this chapter we examine the impact of ICT on productivity at the most basic level. Specifically, we analyse ICT's role as a driver of individual and workgroup productivity. Evidence on the link between ICT and productivity at this level is usually gathered from surveys of individuals and businesses. Most of these studies have been conducted outside Australia.

6.1 ICT AND INDIVIDUAL PRODUCTIVITY

In a Finnish study, Maliranta and Rouvinen (2004) found that a computer with only processing and storage capabilities boosts labour productivity by 9 per cent, portability by 32 per cent, wireline connectivity by 14 per cent and wireless connectivity by 6 per cent. As this study was carried out using data for 2001 when wireless connectivity was still in its infancy, the productivity impact finding for that technology is likely to be lower since the benefits could be expected to increase significantly as the use of wireless devices and mobile broadband intensifies.

The productivity impact of ICT may depend on worker type

While ICT is likely to boost the productivity levels of most workers, the type of ICT required by a worker and their productivity impacts are likely to vary considerably according to his/her occupation and the nature of his/her job. In Australia, Telstra has segmented workers into six different types according to their ICT needs[7]:

- Mobile Workers
- Roaming Professionals
- Decision Makers
- Trade Workers and Service Providers
- Information Processors
- Office Knowledge Workers.

The ICT requirements of each type of worker, along with their likely occupations and industries, are summarised in Table 3 (opposite). More micro-level research needs to be undertaken to quantify the impact of particular types of ICT on each type of worker in different industry and workgroup situations. Such research will enable businesses to make better decisions regarding ICT investment in order to achieve significant productivity gains that represent the greatest return on investment.

7. This was based on 2,250 telephone interviews with a cross-section of Australian workers.

Table 3 Worker type segmentation according to ICT needs

Worker type	Location	ICT usage and requirement	Industries	Occupations
Mobile Workers	Not office-based	Basic ICT requirements Fixed line telephony, mobile telephony, some in-car	Primary Industry, Health Care, Community Services	Trade, Machinery, Personal Service
Roaming Professionals	Not office-based	Intermediate ICT requirements Basic email, fixed line, desktop, laptop, mobile (in-car)	Education and Training	Professionals, Technicians, Police
Decision Makers	Office-based, multiple trips	Advanced ICT requirements High bandwidth/ security, desktop, fixed line, mobile, PDA, audio/video conferencing	Across all industries	Managers, Professionals
Trade Workers & Service Providers	Not office-based, on site	Basic ICT requirements Fixed line	Wholesale, Accommodation, Food Service Industries	Trade, Machinery, Labour, Sales, Farm Workers
Information Processors	Office-based	Intermediate ICT requirements Data entry focussed, fixed line, desktop	Rental/Hire, Real Estate, Finance and Insurance Industries	Sales (Point of Sale), Clerical/ Administrative
Office Knowledge Workers	Office-based	Advanced ICT requirements High bandwidth/ security, fixed line, desktop some laptop, audio/ video conferencing	Across all industries	Clerical/ Administrative, Professional

Data source: Telstra

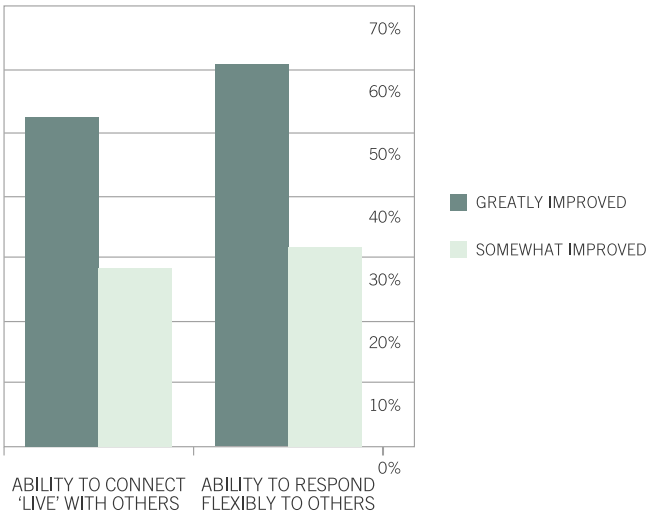
Electronic communication methods

The Economist Intelligence Unit, in a survey in late 2004, queried 1,500 computer users around the world about their use of electronic workplace communications tools[8]. Respondents were largely from business services (such as advertising and accounting), information technology, banking and finance, education and telecommunications.

Electronic communications allow individuals to connect "live" with others quickly

Survey respondents were asked how electronic communications methods, such as email, telephone, instant messaging, and mobile phones etc, affected various aspects of their workplace. According to the survey, 53 per cent of respondents felt that such communication methods greatly improved the ability to connect quickly 'live' with others, while another 29 per cent felt that these communications methods improved this somewhat (see Figure 6).

Figure 6 Impact of electronic communication tools



Data source: EIU

Similarly, 61 per cent felt that these communication methods greatly improved their flexibility to respond to others, while another 32 per cent felt that these communication methods improved this somewhat.

When asked to describe the change in their overall productivity as a direct result of automated communications methods, 81 per cent of respondents believed that these communication methods made communicating with people inside their company 'more productive' (48 per cent) or 'very productive' (33 per cent). A similar proportion of respondents also believed that these communication methods made communicating with people outside their company 'more productive' (47 per cent) or 'very productive' (34 per cent).

Mobile phones

Mobile phones can increase worker flexibility, efficiency and productivity

Mobile phones have become pervasive in people's personal non-work life and professional life. They allow people to make better use of their time spent travelling and waiting, keeping in touch with friends and family, or performing a range of work-related tasks. Thus, in addition to being a communications tool, a mobile phone can increase worker flexibility, efficiency and productivity.

A US survey has shown that 26 per cent of mobile phone owners said they could not live without their mobile phone, 45 per cent said they would miss it, but could do without it, and 29 per cent said they could live without it (Rainie and Keeter 2006).

8. About 30 per cent of the respondents were from western and eastern Europe, 26 per cent from North America, and 26 per cent from Asia and Australasia.

BOX 2 CASE STUDY 1 – IMPACT OF ICT ON THE PRODUCTIVITY OF NURSES

Royal District Nursing Service provide a broad range of nursing services to clients in the community and in their homes in the greater Melbourne area in Victoria. They employ over 1,300 staff providing over 1.6 million visits to over 32,000 people annually. The service is highly mobile and has over 500 nurses on the road per day.

The implementation of Telstra Next G™ network mobile data services to support the client management system means that the nurses can access schedules, view secure electronic client records, and update information on the road.

The system means that nurses can collect their schedules and then report back without having to visit the RDNS site – saving an estimated one hour per nurse per day in travel time, which is then put back into extra clinical time. The nurses are now able to undertake a significant number of extra patient visits per year, and the organisation has been better able to manage travel time and costs.

Data source: Telstra and Royal District Nursing Service

Mobile telephony enhances business productivity by enabling employees to remain up-to-date with project news and developments while away from the office or on the move.

A UK study by the Centre for Economics and Business Research commissioned by the telecommunications firm O2, estimated that about 16 per cent of ICT-led growth in the UK from the early 1980s has been due to advances in communications (CEBR 2005). Assuming that mobile telephony's share of communications equipment-led productivity benefits is equal to mobiles' share of communication spending (which was 42 per cent in 2004), CEBR estimated that mobiles saved about 320 million working hours in the UK in 2005.

Furthermore, assuming that mobile telephony's share of MFP is the same as its share in capital deepening (2.6 per cent in 2004) then this increases the number of hours saved by UK workers by another 140 million.

'Mobile workers' benefit most in time savings from mobile telephony

The amount of time saved by mobile telephony is particularly pronounced for 'mobile workers', who are primarily blue-collar workers without a permanent business location. These workers use their phones for:

- maintaining closer contact with colleagues,
- planning their schedule on the move,
- catching up with developments back at their base,
- making vital calls to customers or suppliers, and
- calling clients and suppliers to build and reinforce business networks.

BOX 3 CASE STUDY 2 – PRODUCTIVITY IMPACT OF ICT ON TECHNICIANS

To improve the productivity of Telstra's 7,000 Communications Technicians, Telstra installed a new technician support system. The system is an integrated job dispatch system that utilises Next G™ network mobile technology, WiFi and Global Positioning System (GPS) technology to direct resources based on geography, technician skill set and availability. The system also provides maps and directions to the next job for each technician.

Allocation of jobs to technicians based on their geographical location has significantly improved responsiveness, reduced travel time and led to significant productivity gains. In 2007, Telstra calculated a gain in productivity of 13.3 per cent across its Communications Technicians workforce and a 5.6 per cent reduction in the number of kilometres travelled per job through the integration of GPS into its job dispatch system. The new system is also supporting Telstra's business customers' productivity by improving the efficiency of Telstra service delivery to its customers.

Data source: Telstra

Mobile telephony increased UK labour productivity by almost 1% p.a.

All in all, CEBR estimated that mobile telephony increased labour productivity in by almost one per cent per annum (which is approximately half of total labour productivity growth in the UK). Translated into working time, having access to mobile phones enabled UK workers to work for around 20 minutes less each week to achieve the same output. These productivity gains were estimated to have increased UK GDP by £8.9 billion in 2004, assuming that workers used the extra 20 minutes for additional work.

Smartphones

As email use grows, the ability to respond to email while away from the office enabled by mobile devices such as smartphones and PDAs makes employees more time efficient and better at utilising gaps in their daily work schedules.

In a study undertaken by Ipsos-Reid, BlackBerry smartphones were found to enable the average user to convert 54 minutes of downtime into productive time each workday, which equates to 196 hours per user per year in recovered downtime (IR 2004). The study was conducted with 490 ICT managers responsible for managing BlackBerry handhelds in their firms and 210 BlackBerry end-users.

BlackBerry increases team efficiency by 29%, according to ICT managers

In the study, the average BlackBerry user reported that having access to this ICT technology increased the efficiency of the teams they work with by 29 per cent, which equated to over US$21,000 per user per year based on international employee productivity data. In addition to their own personal productivity, the BlackBerry also allows mobile staff to keep work moving for others while they are out of the office.

BOX 4 CASE STUDY 3 – PRODUCTIVITY IMPACT OF SMARTPHONES IN TRANSPORTATION

Robert Transport, the second largest transportation company in Quebec, Canada, found that the introduction of the BlackBerry in 2002 improved the efficiency of the company's operations by enabling a more efficient and up-to-date billing system, improved communications with drivers, and online tracking systems to check delivery status. This resulted in a productivity gain for dispatch teams of two hours per day.

Data source: BlackBerry

Wireless devices can also have a considerable impact on the productivity in transportation, delivery and courier services. Mobile broadband devices can help drivers to identify optimal routes, in terms of delivery points, distance, traffic congestion etc., and increase the number of deliveries that can be made in any one day. Mobile devices, when used in conjunction with RFID technologies, can also be used to download information about stocks in different sales/delivery points while on the road so that these can also be managed more efficiently (OECD 2008).

Broadband

The Internet has altered the economics of information production

The Internet as a new creative outlet has altered the economics of information production and led to the increasing democratisation of media production and changes in the nature of communication and social relationships. Changes in the way users produce, distribute, access and re-use information, knowledge and entertainment potentially give rise to increased user autonomy, increased participation and increased diversity (OECD 2008). Users can only fully exploit the potential of Internet via high-speed broadband connections.

Access to broadband enables more flexible work practices

Access to broadband enables more flexible work practices, hours and location, which may contribute to easing congestion and pollution challenges faced by large cities. It also provides an incentive for women and older workers to stay in employment by enabling them to work remotely, thus reducing hiring and training costs for employers.

Broadband generates further benefits to consumers by reducing search and information costs and giving greater access to information, making price comparisons easier, raising competition and creating downward pressure on prices. More generally, broadband changes the role of individuals in production, facilitating user-driven innovation and the development of user-created content.

BOX 5 CASE STUDY 4 – IMPACT OF MOBILE BROADBAND ON HEALTHCARE

BreastScreen Victoria is part of the free national breast screening program. It screens around 200,000 women per year through 39 dedicated screening sites and two Mobile Screening Services that move around regional Victoria. The Mobile Screening Services cover more than 20 communities every two years and screen up to 42 women a day.

The Mobile Screening Services were recently wireless broadband-enabled. One Mobile Screening Service was also provided with digital mammography technology as part of BreastScreen Victoria's Rural Broadband Digital Mammography Project. This has improved both the quality and speed in the delivery of digital mammogram files being transferred.

High speed connectivity was required because the file size of a digital breast screen image is between 30 and 50 megabytes. As a result of the ICT upgrade, these images can now be sent directly as a digital file to an assessment clinic over the network, rather than via courier. As a consequence, ordering of additional images (if necessary) can be done immediately rather than over the course of weeks and across repeat visits – improving efficiencies for clients as well as radiographers in the Mobile Screening Service. For example, for some clients, a 10-hour round trip to visit a fixed screening site could be reduced to a half-hour visit to a Mobile Screening Service.

Data source: BreastScreen Victoria

Access to broadband creates many opportunities

Broadband creates new ways for companies to exploit the creativity and innovativeness of their workforce. Blogs, wikis, podcasting, tagging technologies, and lessons of community and social networking sites are increasingly seen as important tools to improve the productivity of employees.

6.2 ICT AND WORKGROUP PRODUCTIVITY

ICT that has enabled gains in workgroup productivity include Web 2.0 collaboration tools and tools that facilitate teleworking.

Web 2.0 collaboration tools

Around the world, companies are leveraging Web 2.0 collaboration tools, such as social networking sites and wikis (which allow for the collective editing and modifying of on-line content), to redefine the way sales representatives share insights and lessons learned in the field. Organisations believe that increased levels of knowledge sharing create a work environment where sales representatives have access to all information required to close a deal, thereby increasing overall sales productivity.

The need for improved knowledge sharing is a key driver in the adoption of Web 2.0 tools

According to research by the Aberdeen Group, 73 per cent of companies that use internal-facing Web 2.0 technologies within sales cite the need to improve knowledge sharing within the organisation as the top pressure causing them to focus resources on Web 2.0 collaboration tools (Aberdeen 2008). This need is due, in part, to a competitive marketplace where customers can easily gather and share feedback concerning a company's products or services in online forums and other social media exchanges. It has become necessary for sales representatives to gather and process information on consumer sentiment quickly and disperse the information throughout the enterprise efficiently.

According to this study, the top strategic actions to improve enterprise-wide knowledge sharing are to reduce the amount of time employees spend searching for relevant information and to establish a forum for employees to post and/or share lessons learned from the field.

By allowing sales representatives to edit and modify content, wikis enable organisations to create forums where employees can go to have their questions answered in a timely fashion.

In the same study, 57 per cent of survey respondents said that social networking sites have a significant amount of influence over consumers. Not surprisingly, 32 per cent of companies that use Web 2.0 collaboration technologies to improve sales productivity also use social networking sites to track customers' views of their products.

One way in which social networking sites are being utilised within sales processes is prospect mapping. By integrating existing contacts from social networking sites into their Customer Relationship Management (CRM) solution, sales representatives can discover the quickest and easiest 'path' to reach a potential customer. Knowing which contacts are in touch with key decision makers allows sales representatives to request introductions or reach out directly to these decision makers.

Teleworking

Teleworking is a growing phenomenon that is highly ICT-dependent

Teleworking refers to working from a distance although it has many forms and labels, including remote access, remote work, mobile work, e-work, telecommuting, working from home and more. Teleworking is a significant and growing phenomenon that is highly ICT-dependent. This trend is expected to continue in line with further rapid technological development that increases broadband diffusion and bandwidth.

A 2005 US survey found that about one-third of all workers telework from an average of 3.4 locations (home, clients or customers, plane/car, outdoors, etc.). Of these 45 million workers, 25 million reported working from home at least once a month and 22 million at least once a week (ITAC 2005).

Broadband is a vital factor in telework as it allows workers not only remotely connect to their employers and clients, and have access to and store information, but also to do this in a timely way. Increasing bandwidth increases the possibilities, for example through tele- and video-conferencing.

The benefits of teleworking for employers include improved staff morale and retention, space saving, reduction in absenteeism, reduced utility costs, and improved service response to customer needs. Benefits for individuals include reduced commuting time and cost savings, improved health, improved work-life balance, and increased flexibility.

Telecommuting options increase the employability of groups such as mothers and fathers with young children.

In addition, some telework strategies have the capacity to deliver remote learning options and potential work opportunities in remote communities. Telework provides a framework within which individuals in rural areas no longer have to leave their community to seek or perform paid work. This can potentially lead to a more productive and efficient utilisation of human resources in these communities.

According to the Telework Australia website, managers have reported that their teleworking employees are between 8 and 40 per cent more productive.

There is widespread evidence on the productivity benefits of teleworking

Evidence of the productivity benefits of teleworking include:

- An Australian study of small to medium sized enterprises by Sensis in 2005 which found that 17 per cent of employers experienced improved productivity while 24 per cent of teleworkers reported higher productivity.
- In the US, over 70 per cent of teleworkers in a Southern New England Telephone Company initiative claimed that they were significantly more productive.
- A British Telecom Study reported by the Gartner Group indicated that the average teleworker works 11 per cent more hours than an office counterpart (due partly to commute time savings); they also found that reduced costs for office space and other overhead items save employers an additional amount equal to 17 per cent of annual salary costs.
- According to the C Grantham Institute for Study of Distributed Work, a firm can obtain $2 of improved productivity for every $1 spent on equipment.

Other government and corporate examples of productivity improvements obtained from teleworking are shown in Table 4.

In addition to the productivity benefits for individuals, workgroups and firms, teleworking can also generate environmental benefits. For example, it reduces the carbon footprint of individual workers through minimising daily commuting.

ICT also has the potential to generate environmental benefits

Similarly, ICT such as broadband can also promote environmental sustainability. As noted previously, mobile broadband devices can help delivery and other transport drivers identify optimal routes in terms of delivery points, distance, traffic congestion, etc., thereby reducing fuel consumption and greenhouse gas emissions.

Table 4 Productivity impact of teleworking

Organisation	Staff type	Productivity improvement
Government		
City of Los Angeles	Teleworkers	12.5%
City of San Diego	Teleworkers	34–40%
Corporate		
Blue Cross/Blue Shield and Travellers Insurance (insurance)	Teleworkers	20%
J C Penny (retail)	Teleworking catalogue order processing staff	25%
Storage Technology Corp (ICT)	Teleworkers	144%
Hewlett Packard (ICT)	Teleworking call centre staff	20%
Bell Atlantic Corporation (telecommunications)	Employees teleworking	60%

Data source: Telework Australia

KEY FINDINGS

- While ICT is likely to boost the productivity levels of most workers, the type of ICT required by a worker and their productivity impacts are likely to vary considerably according to job characteristics.
- Electronic communication methods (such as email, telephone, instant messaging, mobile phone) have enabled individual workers to quickly connect with others. ICT also makes communicating with people both inside and outside the company more timely and thus more productive.
- Mobile phones allow people to make better use of the time they spend travelling and waiting, keeping in touch with colleagues, friends and family, or performing a range of work-related tasks.
- Mobile phones increase worker flexibility, efficiency and productivity. This enhances business productivity by enabling employees to remain up-to-date with project news and developments while away from the office.
- Broadband enables more flexible work practices, hours and location, which can increase productivity and contribute to easing congestion and pollution challenges faced by large cities.
- Broadband access also benefits consumers by reducing search and information costs and giving greater access to information, making price comparisons easier, facilitating competition and creating downward pressure on prices.
- More generally, broadband changes the role of individuals in production, facilitating user-driven innovation and the development of user-created content.
- ICT also enhances workgroup productivity via Web 2.0 collaboration tools (such as social networking sites and wikis that allow collective editing and modifying of on-line content) and by facilitating teleworking.
- Global studies on teleworking have found that both teleworkers and their employers report substantial productivity gains (due partly to savings in commuting time which has been enabled by home access to ICT).

7. CONCLUSIONS

This paper has examined the impact of ICT on productivity at the macroeconomic, industry/sectoral, firm/enterprise, workgroup and individual levels. The preponderance of empirical evidence suggests that investment in ICT has brought about significant productivity benefits at these various levels in many different countries.

FUTURE OUTLOOK ON THE LINK BETWEEN ICT AND PRODUCTIVITY

In the Productivity Commission's *Annual Report 2007–08*, it noted that proximate productivity drivers including ICT investment have remained broadly supportive of productivity growth.

Will ICT continue to support productivity growth?

According to the Productivity Commission, there are reasons to be optimistic that ICT will continue to drive productivity improvements in the near term (Dolman et al. 2007). Past experience with general purpose technologies, such as electrification, shows the process of deploying and exploiting them is quite prolonged due to the need for complementary technological and organisational innovations (Abramovitz and David 2001). In particular, there remains room for further exploitation of existing information technologies, such as expanding the role of the Internet in retail trade and in the supply chain.

Other experts, such as those at the National Research Council of Canada, also expect the ICT innovation wave to continue to have considerable transformative influence out to 2020 and beyond, particularly with the application of automated processes and tasks, computational sciences, predictive simulation, software engineering, and standardised operating systems and transport infrastructure. The next wave of innovation, expected to be biotechnology, will have considerable impact in the areas of gene function, and molecular, cell and system biology. However, it will also likely converge with information and communications technology, thus increasing the potential for more significant impacts.

Falling prices and new applications will drive ICT uptake

Another reason for expecting ICT to contribute to further productivity gains is that ICT remains only a small share of the capital stock (Jovanovic and Rousseau 2005) and rapidly falling prices should continue to support its take-up. Perhaps most importantly, competitive pressures to develop innovative new business models that draw on ICT developments remain in place.

NEED FOR MORE MICRO-LEVEL RESEARCH AND THE DEVELOPMENT OF A MICRO-LEVEL PRODUCTIVITY INDEX IN AUSTRALIA

There remains scope for significant productivity improvements in Australia

While investment in ICT has boosted the productivity of workers, Australian firms, industries and the national economy, productivity levels in Australia are still below those of countries on the productivity frontier. There remains room for improvement and catch-up through increased and smarter adoption of the latest ICT innovations by businesses and organisations, particularly in areas such as manufacturing, wholesale trade, retail trade, utilities, communications and finance. Such business decisions must be based upon quality data and sound information on the link between specific ICT investments and potential gains in productivity and profitability.

But there is need for more data on productivity at the micro level

While there have been a significant number of Australian studies on the impact of ICT on productivity at the macroeconomic and industry levels (many of which have been commissioned by the Australian Government), there have been relatively few Australian studies of the relationship at the individual and workgroup levels.

Similarly, while there is good data on Australian productivity at the national level and while the ABS has produced experimental estimates of productivity at the industry level, there has been an absence of Australian micro-productivity measures at the individual, workgroup, and firm levels. Where they do exist, they are inconsistently applied and understood and hence their mapping to macro-measures is not always apparent.

A productivity index could provide some of that data

The real impact of ICT on business productivity analysed via a bottom-up approach thus requires careful consideration and possibly a common or unified methodology. A simplified cross-industry tool or index would assist Australian businesses and governments in making sound ICT investment decisions that would likely result in further improved productivity outcomes.

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