ICT AND ECONOMIC GROWTH
– NEW EVIDENCE FROM INTERNATIONAL COMPARISONS –

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Abstract

This paper follows up on previous OECD work for the 2001 and 2002 OECD Ministerial meetings. It was concluded that information and communications technology (ICT) was among the key factors explaining growth differentials in the OECD area in the 1990s, and that ICT had the potential to contribute to more rapid growth in the future. The current paper examines whether ICT is still important now the hype of the new economy is over. It differs from previous OECD work as it considers, firstly, a range of questions that were not explicitly addressed before. For example, why have some OECD countries invested more in ICT than others? What factors help firms in seizing the benefits from ICT? How precisely does ICT affect firm performance? And what policies should governments undertake to help firms benefit from ICT? The paper also differs from previous work as it is based on a broad set of new data and empirical studies. The study incorporates new evidence from official statistics on the use of ICT by firms, which were not available before. It draws on new empirical results with official firm-level statistics that was carried out through an OECD-led team of researchers and statistical offices in 13 OECD countries, thus complementing the sectoral and aggregate analysis undertaken previously. And it draws, to the extent possible, on the latest available data to examine the contribution of ICT to growth performance in recent years.

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Introduction

In 2001, OECD prepared a study for its annual meeting of OECD Ministers that concluded that information and communications technology (ICT) was among the key factors explaining growth differentials in the OECD area in the 1990s. It also concluded that ICT had the potential to contribute to more rapid growth in the future (OECD, 2001a). Both the 2001 and 2002 OECD Ministerial meetings underscored the importance of ICT for growth and requested further work. A specific request for further work on ICT and business performance was also made to the OECD in the autumn of 2001, by the US Secretary of Commerce, Mr. Evans. This paper follows up on these requests. It examines whether ICT is still important now the hype of the new economy is over. The current paper offers a summary of the findings of the OECD work; a more extended version is being prepared for the annual Ministerial meeting of the OECD and will be published in May (OECD, 2003a).

The study differs from previous OECD work as it considers a range of questions that were not explicitly addressed before. For example, why have some OECD countries invested more in ICT than others? What factors help firms in seizing the benefits from ICT? How precisely does ICT affect firm performance? And what policies should governments undertake to help firms benefit from ICT? Many of these questions can not easily be examined with the macro-economic and sectoral data that were used in previous OECD work. Firm-level data are often necessary, since they allow interactions at the firm level to be examined. For example, the role of ICT in helping firms gain market share can only be examined with firm-level data. Studies drawing on such evidence can thus contribute to a better understanding of the interaction between ICT, human capital, organisational change and innovation, and thus to better, evidence-based, policy making.

The report also draws on a range of new data. First, it draws on new empirical analysis with official firm-level statistics that was carried out through an OECD-led team of researchers and statistical offices in 13 OECD countries, thus complementing the sectoral and aggregate analysis.[2] Second, the study incorporates new evidence from official statistics on the use of ICT and e-commerce by firms, which were not available before. Third, it draws, to the extent possible, on the latest available data to examine the contribution of ICT to growth performance in recent years.

The first section of the paper examines the diffusion of ICT across OECD countries, on the basis of official statistics, which may differ substantially from private estimates. The next section provides evidence on the impact of ICT at the macro-economic and sectoral level, updating previous OECD work. The third section provides evidence on the contribution of ICT use to business performance, based on detailed firm-level studies. The final section draws implications from the empirical evidence for policy makers, while a short set of conclusions completes the paper.

The diffusion of ICT in OECD economies

The state of ICT diffusion

The economic impact of ICT is closely linked to the extent to which different ICT technologies have diffused across OECD economies. This is partly because ICT is a network technology; the more people and firms that use the network, the more benefits it generates. While ICT investment has accelerated in

2 . These countries are: Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, United Kingdom and the United States.

most OECD countries over the past decade, the pace of that investment differs widely. ICT investment rose from less than 15% of total non-residential investment in the business sector in the early 1980s, to between 15% and 30% in 2001. In 2001, the share of ICT investment was particularly high in the United States, Sweden and Australia (Figure 1). These shares did not change much in 2001 in the countries for which data are available, although overall and ICT investment declined somewhat in some countries, such as the United States and Canada. This suggests that ICT investment has not been affected disproportionally by the slowdown compared with other types of investment.

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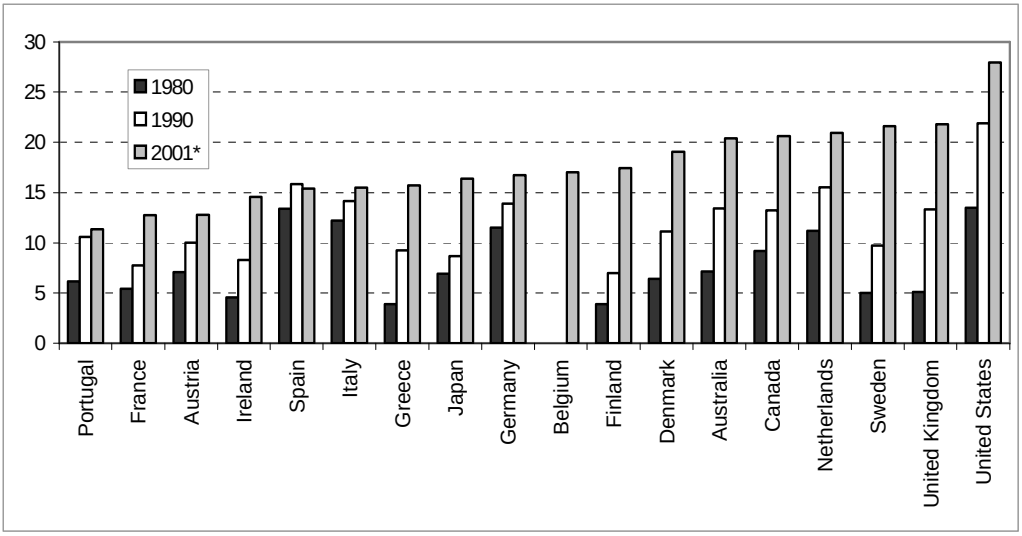
Figure 1: **ICT investment in selected OECD countries**[1]
(As a percentage of non-residential gross fixed capital formation, total economy)



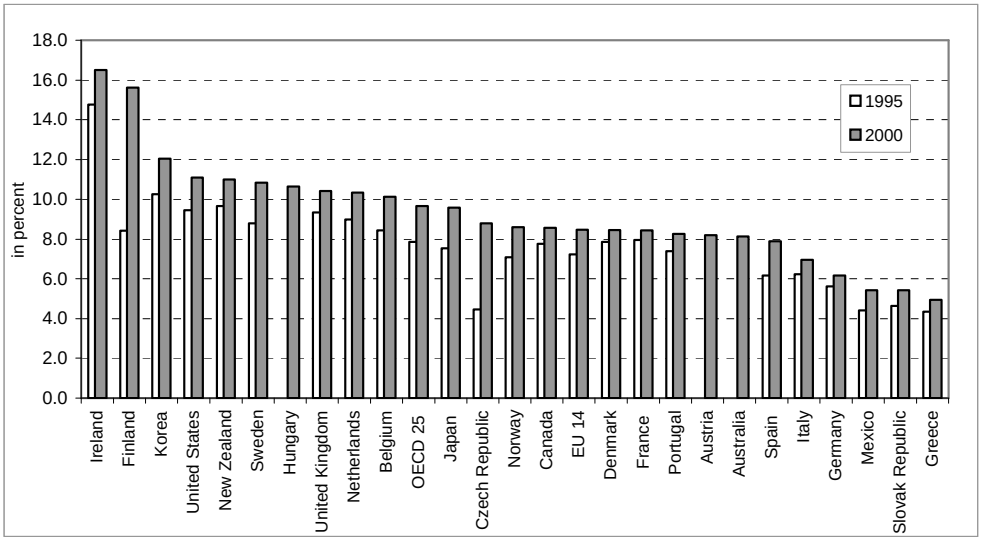
Note: (1) Or latest available year.
Source: OECD, Capital Services Database.

The rapid growth in ICT investment has been fuelled by a rapid decline in the relative prices of computer equipment and the growing scope for the application of ICT (Jorgenson, 2001). The benefits of lower ICT prices have been felt across the OECD, as both firms investing in these technologies and consumers buying ICT have benefited from lower prices. The lower prices of ICT are only one of the drivers of investment, however; firms have also invested in ICT as it offers large potential benefits.

Another determinant of the economic impacts associated with ICT is the size of the ICT sector. Having an ICT-producing sector can be important, since ICT-production has been characterised by rapid technological progress and has been faced with very strong demand. In 2000, value added in the ICT sector represented between 4% and 17% of business sector value added and increased in all OECD-countries for which data are available (Figure 2). Aggregate data also show that about 6-7% of total business employment in the OECD area could be attributed to ICT production.[3] While parts of the ICT sector are currently experiencing a slowdown, these shares are unlikely to change much in the short term.

3 . These estimates are based on the OECD definition of the ICT sector. See OECD (2002*a*).

Figure 2: **Share of the ICT sector in business sector value added, 2000[1]**

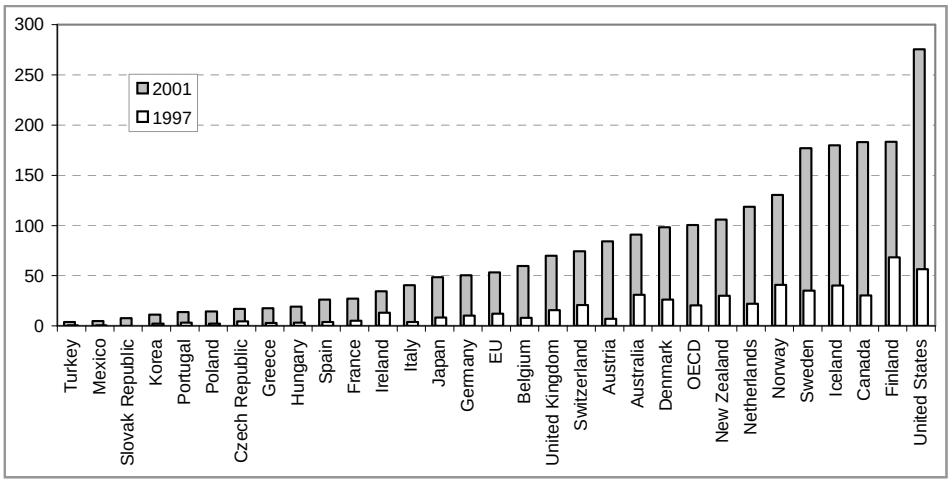


Note: (1) Or latest available year. There are some small differences in the definition of the ICT sector. See source for detail.
Source: OECD (2002*a*), *Measuring the Information Economy*, http://www.oecd.org/sti/measuring-infoeconomy

As was indicated above, strong investment in ICT is related to increased demand for ICT-infrastructure and the services that can be derived from it. Figure 3 gives some empirical evidence for the rapid increase in demand and speed of ICT diffusion within an economy. It shows the number of Internet hosts per 1000 inhabitants and provides thus for an indicator for the size of and the access to ICT infrastructure. Two main patterns emerge: First, the number of Internet hosts increased very rapidly over the past four years. Within the OECD area, the number of Internet hosts per 1000 inhabitants was about five times as high in 2001 as compared with 1997. Second, strong cross-country differences in the use of ICT infrastructure prevail. The United States is ahead and is followed by a second group of strong Internet users, notably some North-European countries and Canada. In contrast, the access to and use of ICT infrastructure, as measured by the number of Internet hosts, is still limited in Turkey, Mexico, Korea, and some East-European countries.

Another indicator of ICT diffusion is the proportion of businesses that use the Internet to purchases and sales (OECD, 2002a). While data are not available for all OECD countries, similar patterns emerge as compared with Internet hosts. The existing evidence shows a large number of firms using the Internet for sales or purchases in the Nordic countries (Denmark, Finland, Norway and Sweden) as well as in Australia, the Netherlands and New Zealand. In contrast, only few firms in Greece, Italy, Portugal and Spain use the Internet for sales or purchases. Monetary estimates of electronic commerce suggest that electronic commerce is growing, albeit slower than originally envisaged. However, it still accounts for a relatively small proportion of overall sales. For the few countries that currently measure this, Internet sales in 2000/2001 ranged between 0.2% and 2% of total sales. In the fourth quarter of 2002, 1.65 per cent of all retail sales in the United States were carried out through computer-mediated networks, up from 1.3 per cent in the fourth quarter of 2001.

Figure 3: **Internet hosts per 1.000 inhabitants, 2001**[1]



Note: (1) See source for data coverage and differences in definitions
Source: OECD (2002*a*), *Measuring the Information Economy*, http://www.oecd.org/sti/measuring-infoeconomy

There are many other indicators that point to the role of ICT in different OECD economies (OECD, 2002*a*). In practice, the different indicators are closely correlated and tend to point to the same countries as having the highest rate of diffusion. These typically are the United States, Canada, New Zealand, Australia, North-European countries such as Denmark, Finland and Sweden, as well as the Netherlands. It is therefore likely that the largest economic impacts of ICT should also be found in these countries.

Factors affecting the diffusion of ICT

Why is the diffusion of ICT so different across OECD countries? Previous OECD work already noted several factors, such as lack of relevant skills, lack of competition, or high costs in certain OECD countries (OECD, 2001*a*). From a firm's perspective, high costs are important, as they affect the possible returns that a firm can extract from their investment. Firms do not only incur costs in acquiring new technologies, but also in making it effective in the workplace, and in using the technologies on a daily basis. Costs related to personnel, telecommunication charges and organisational change are therefore also important. Some cross-country evidence is available on how these factors may have affected diffusion.

A first factor concerns the costs of ICT hardware. Since ICT hardware is traded internationally, prices should not vary too much across countries. The available evidence suggests otherwise, however. Detailed price comparisons of ICT goods show that over much of the 1990s, firms in the United States and Canada enjoyed considerably lower costs of ICT investment goods than firms in European countries and Japan (OECD, 2001*a*). Barriers to trade, such as non-tariff barriers related to standards, import licensing and government procurement, may partly explain the cost differentials (OECD, 2002*b*). The higher price levels in certain OECD countries may also be associated with a lack of competition within countries. International differences in the costs of telecommunication are also considerable.

Cost differentials can not only be observed for ICT hardware and software, but also in the associated costs of communication. For example, by August 2001, the prices of 20 hours of Internet access at peak times were lowest in the United States. The EU average was almost 3 times the US price level, while prices in Japan were almost double those in the United States (Figure 4). It is not only the liberalisation of ICT markets that is important to lower price levels, but primarily the introduction of effective competition.

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Japan liberalised its telecommunications markets quite early, but took long to reap the benefits as an effective regulatory framework took time to be established.

Figure 4 **Countries with low access costs have a greater diffusion of the Internet**

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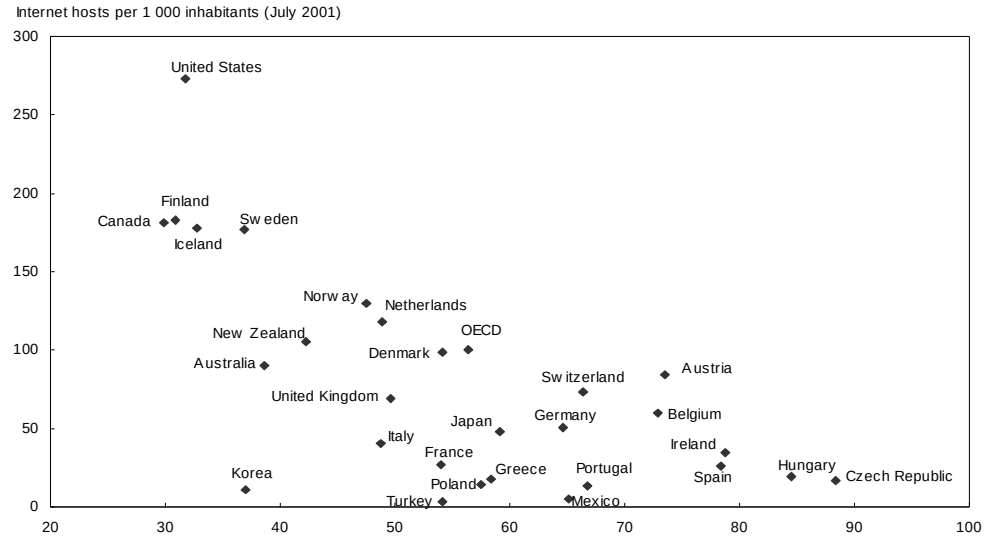
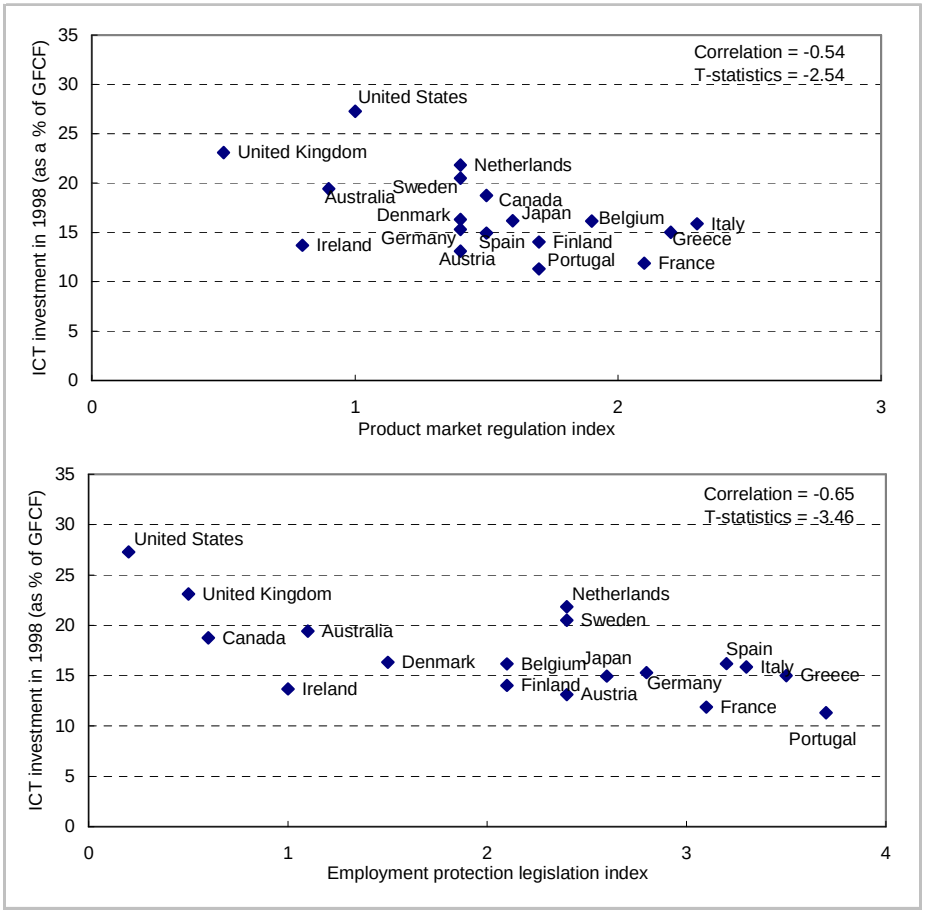


Source: OECD (www.oecd.org/dsti/sti/it/cm) and Telcordia Technologies (www.netsizer.com).

A second factor relates to the complementary investments that need to be made by firms to draw the benefits from ICT. Such complementary investments are, for instance, the need for changes in the organisational structure of firms, as well as for hiring and training staff. These complementary investments are often much more costly than the initial outlays for ICT investment goods. Brynjolfsson and Hitt (2000), for example, suggest that 1 USD of ICT investment may be associated with 9 USD of investment in intangible assets. One main area of additional investment concerns the need for appropriate skills and competencies of workers in order to develop and use ICT effectively. Moreover, due to rapidly changing needs for skills and competencies related to ICT, firms have to adjust hiring and training of staff continuously and in a flexible way. Lack of appropriate human capital may thus also hinder the fast diffusion of ICT.

There is, thirdly, cross-country evidence that regulations in product and labour markets may affect ICT investment (Figure 5). Product market regulations typically limit competition, which is important to spur ICT investment as it forces firms to seek for ways to strengthen performance relative to competitors, and also because it helps lower the costs of ICT. Moreover, product market regulations may limit firms in the ways that they can extract benefits from their use of ICT. For example, they may not be able to extend beyond traditional sectoral boundaries (*e.g.* software firms offering financial services). Labour market regulations also play a role as they have an impact on the organisational changes that may be needed to make ICT work. If firms can not adjust their workforce or organisation, and make ICT effective within the firm, they may decide to limit investment or relocate. These links between regulations and ICT investment have been confirmed through econometric analysis; Gust and Marquez (2002) find that regulations impeding workforce reorganisations and competition between firms hinder investment in ICT. Bartelsman, *et al.* (2002) confirms these findings.

Figure 5: **Countries with strict product and labour market regulations have lower ICT investment**



Source: ICT investment from Figure 1; regulations from Nicoletti, *et al.* 1999.

Previous OECD work has pointed out that the US economy might be able to achieve greater benefits from ICT since it got its fundamentals right before many other OECD countries (OECD, 2001*a*). The combination of sound macroeconomic policies, well-functioning institutions and markets, and a competitive economic environment may be at the core of the US success. A recent study by Gust and Marquez (2002) confirms these results and attributes relatively low investment in ICT in European countries partly to restrictive labour and product market regulations that have prevented firms from getting sufficient returns from their investment. These factors already point to some areas that are relevant for policy. For example, measures to increase competition can help bring down costs, labour market and education policies may help reduce skill shortages, and risk and uncertainty may be tackled by a well-designed regulatory framework.

ICT's impact on growth

What precisely are the impacts that ICT can have on business performance and growth? Three effects can be distinguished. First, as a capital good, investment in ICT contributes to overall capital deepening and

therefore helps raise labour productivity. Second, rapid technological progress in the production of ICT goods and services may contribute to more rapid multifactor productivity (MFP) growth in the ICT-producing sector. And third, greater use of ICT may help firms increase their overall efficiency, and thus raise MFP. Moreover, greater use of ICT may contribute to network effects, such as lower transaction costs, higher productivity of knowledge workers and more rapid innovation, which will improve the overall efficiency of the economy. This section discusses the empirical evidence for these effects on the basis of aggregate and sectoral data; the next section examines the evidence from firm-level studies.

The impact of investment in ICT

Aggregate data suggests that the growth in MFP may be associated with the productivity-enhancing benefits from investment in ICT. Evidence on the role of ICT investment across countries is primarily available from the macro-economic level, *e.g.* from Colecchia and Schreyer (2001) and Van Ark, *et al.* (2002*a*). Both studies show that ICT has been a very dynamic area of investment, due to the steep decline in ICT prices which has encouraged investment in ICT. While ICT investment accelerated in most OECD countries, the pace of that investment and its impact on growth differ considerably across countries (Figure 6). Notably the United States, Australia and Finland experienced a strong increase in productivity growth due to investment in ICT in the second half of the 1990s. Few other countries have thus far experienced similar gains.

Figure 6. **Pick-up in MFP growth and increase in ICT investment**

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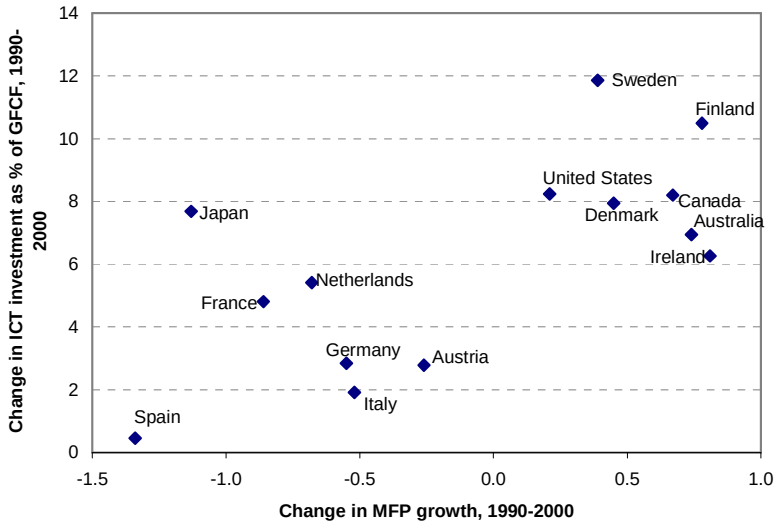

Note: Correlation coefficient: 0.52; T-statistics: 2.30.
Source: ICT investment from OECD (2002*a*), MFP growth from OECD (2003*b*).

Figure 7 provides evidence for the role of growth in ICT-capital for overall GDP growth within a growth-accounting framework. For the countries for which data are available, these estimates show that ICT investment typically accounted for between 0.3 and 0.9 percentage points of growth in GDP per capita over the 1995-2000 period. The United States, Canada and Australia received the largest boost; Germany, France and Italy a much smaller one. However, the contribution of ICT-investment increased considerably

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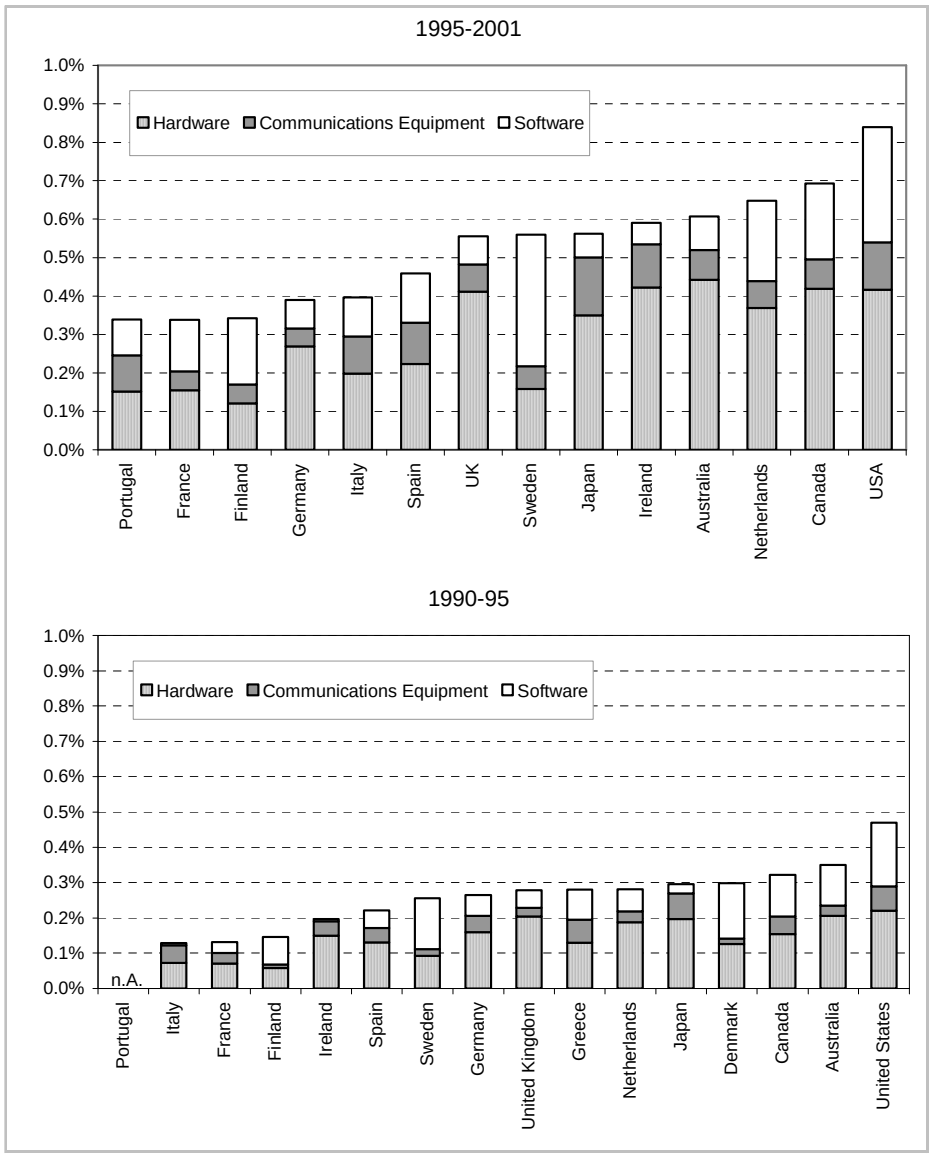
in all countries in the second half of the 1990s as compared with the first half. Throughout the 1990s, growth in ICT-capital services was mainly attributed to growth in hardware. In the more recent years, however, the other components of ICT-capital services have gained importance. This is particulalrly the case for software which accounts now for almost one third of the overall contribution of ICT capital services to GDP growth in OECD countries. With the decline in investment in some countries over 2001-2002, the contribution of ICT investment to growth has fallen somewhat, although it is likely to pick up once the recovery takes hold.

Figure 7: **The contribution of ICT-capital services to GDP growth (this is the new graph)**

Percentage points contribution to annual average GDP growth, total economy



Note: * or latest year available.

Source: OECD, estimates based on Capital Services Database.

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The role of ICT-producing and ICT-using sectors

Evidence on the impact of ICT can also be found from sectoral data, notably in the relative contributions of ICT-producing and ICT-using sectors to overall growth performance. The ICT-producing sector is of particular interest for several countries, as it has been characterised by very high rates of productivity growth. Figure 8 shows that in most OECD countries, the contribution of ICT manufacturing to overall labour productivity growth has risen over the 1990s. This can partly be attributed to more rapid technological progress in the production of certain ICT goods, such as semi-conductors, which has contributed to more rapid price declines and thus to higher growth in real volumes (Jorgenson, 2001).

ICT manufacturing made the largest contributions to aggregate productivity growth in Korea, Finland and Ireland, where close to 1 percentage point of aggregate productivity growth in the 1995-2000 period was due to ICT manufacturing. The contribution of this sector to productivity growth increased in several countries over the 1990s, notably in Finland, Ireland and Sweden. The ICT-producing services sector (telecommunications and computer services) plays a smaller role in aggregate productivity growth, but has also been characterised by rapid progress (Pilat, *et al.* 2002). Also the contribution of the service sector to productivity growth increased in several countries over the 1990s, notably in Finland, Germany and the Netherlands. Some of the growth in ICT services is due to the emergence of the computer services industry. These services are important for ICT use, as firms in these sectors offer key advisory and training services and also help develop appropriate software.

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Figure 8: **The contribution of ICT manufacturing to aggregate labour productivity growth**[1]

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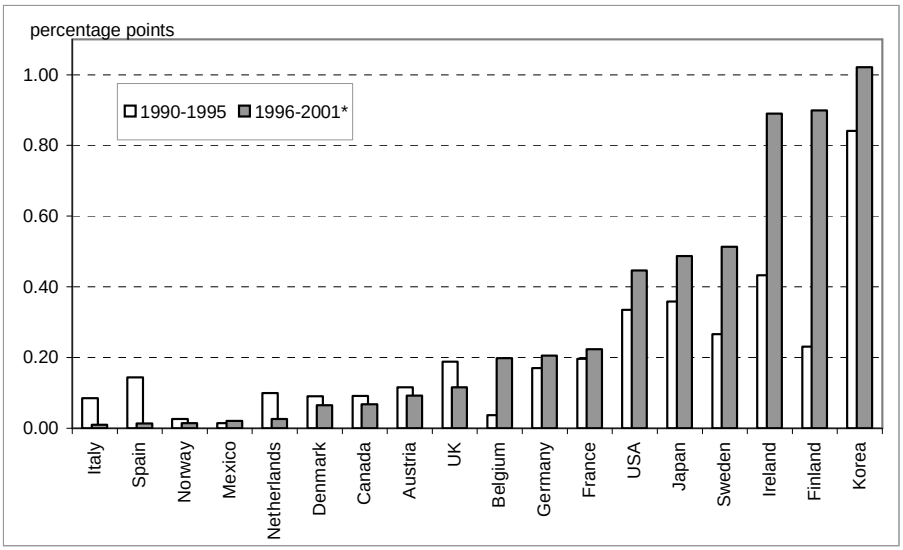

Note (1): 1991-1995 for Germany; 1992-95 for France and Italy; 1993-1995 for Korea; 1996-98 for Sweden, 1996-99 for Korea and Spain; 1996-2000 for Belgium, France, Germany, Ireland, Japan, Mexico, Norway and Switzerland.
Source: Pilat, Lee and Van Ark (2002) and OECD STAN Database.

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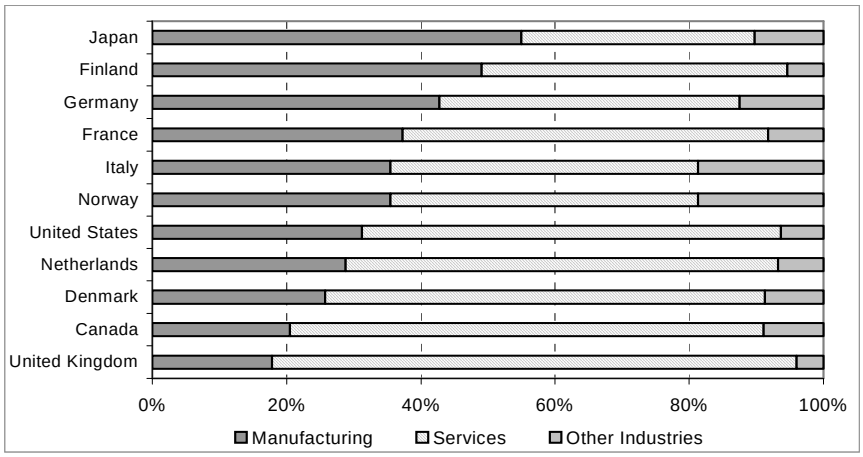
Much of the current interest in the potential impacts of ICT on growth is linked to the potential benefits arising from its use in the production process. If the rise in MFP due to ICT were only a reflection of rapid technological progress in ICT production, there might not be effects of ICT use on MFP in countries that

are not already producers of ICT. For ICT to have benefits on MFP in countries that do not produce ICT goods, the use of ICT would need to be beneficial too.

The empirical evidence points to a relatively strong role of the use of ICT for economicgrwoth. This can be seen by examining productivity growth in industries that are intensive users of ICT (McGuckin and Stiroh, 2001; Pilat, *et al.*, 2002). Analysing the performance of these sectors over time can help point to the role of ICT in aggregate performance. Figure 8 shows that services take on a large part within the ICT-using sector. On average about 56% of all intermediate inputs that are produced by ICT producing manufacturing and service industries flow to the service sector. In United Kingdom and Canada, the service sector accounts even to about 70% of ICT-related intermediate goods and services. Key ICT-using services are wholesale and retail trade, finance and insurance as well as business services. These services together account to about 60 to 70% of the total use of ICT-related intermediate inputs by the service sector. Further empirical evidence for the United States shows that these services are also the industries with the strongest investment in information technology (OECD, 2003a). In market related services such as legal and business services, as well as wholesale trade the information technology account for between 30 and 40% of all stock of equipment and software in 2000.

Figure 9: **Use of ICT-related intermediate goods and services**
Percentage share of intermediate inputs from ICT-producing industries

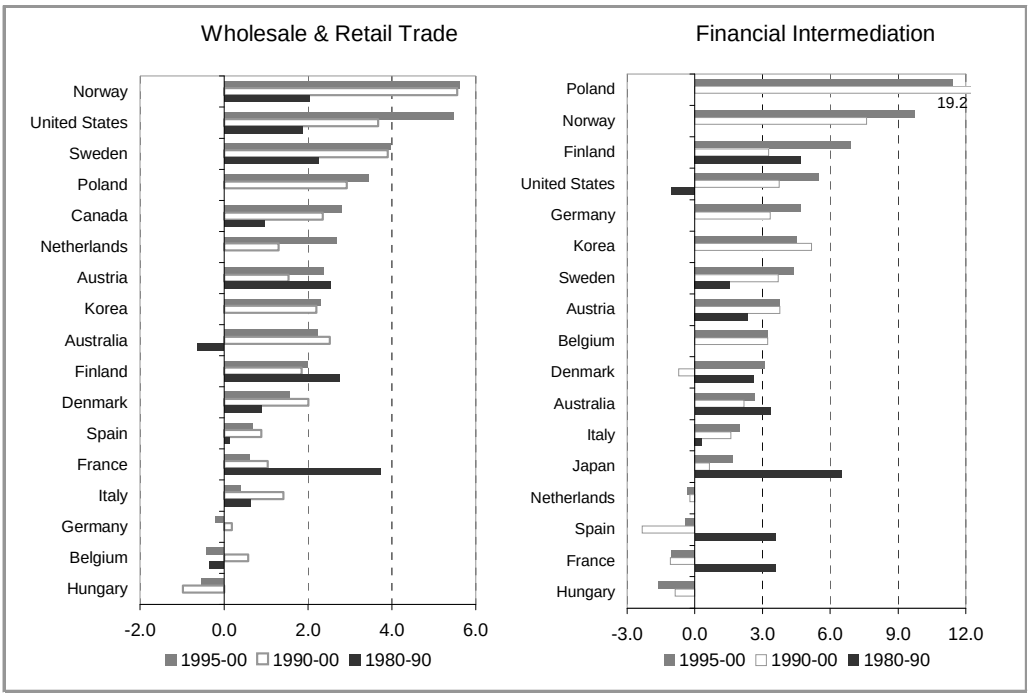


Source: OECD Input-Output Tables, 1995, 1997.

Figures 10 and 11 provide empirical evidence on the role of ICT-using services in aggregate productivity growth. Figure 10 shows relatively strong positive growth rates in labour productivity over the past twenty years in wholesale and retail trade and in financial intermediation services, two key ICT-using services. In particular, the United States, Norway, Finland and Sweden show continuously high productivity growth rates in the 1990s in both or in one of these two service industries. Figure 10 also shows that labour productivity growth in these services increased further in the most recent years. In financial intermediation productivity growth rates amount to an average level of about 4.5 per cent and are thus comparable to some high-growth industries within manufacturing. Relatively strong productivity growth can also be found - albeit to a lesser degree - in wholesale and retail trade. Productivity growth rates in these services are on average about 2.5 per cent across countries, which is equivalent to productivity growth in the economy as a whole.

The high productivity growth rates in these sectors are sometimes attributed to the introduction of cost-reducing technologies such as ICT, which have helped to enhance logistics in wholesale trade and in transport services, and inventory control in retail trade. Empirical studies for the United States stress the considerable part of the pick-up in overall productivity growth that can be attributed to retail trade. US retailing firms such as Walmart used innovative practices, including ICT, to gain market share from competitors (McKinsey, 2001). The larger market share for Walmart and other productive firms raised average productivity and also forced their competitors to improve performance. Among the other ICT-using services, securities accounts also for a large part of the pick-up in US productivity growth. Its strong performance has been attributed to a combination of buoyant financial markets (*i.e.* large trading volumes), effective use of ICT (mainly in automating trading processes) and stronger competition (McKinsey, 2001; Baily, 2002). Studies for Australia (*e.g.* Parham, *et al.*, 2001), suggest that a range of structural reforms have been important in driving the strong uptake of ICT by firms and have enabled these investments to be used in ways that generate productivity gains. This is particularly evident in wholesale and retail trade and in financial intermediation, the main drivers of Australian productivity gains in the 1990s.

Figure 10: **Labour productivity growth in selected key ICT-using industries**
Compound annual growth rates



Source: OECD-STAN Database 2002.

Figure 11 shows the contribution of key ICT-using services (*i.e.* wholesale and retail trade, finance, insurance and business services) to aggregate productivity growth over the 1990s. The graph suggests improvements in the contribution of ICT-using services in Canada and the United Kingdom, and substantial increases in Australia, Ireland, Mexico and the United States. The United States has experienced the strongest improvement in productivity growth in ICT-using services over the 1990s, which may be linked to more rapid productivity growth in wholesale and retail trade, and in financial services, as described above. Strong contributions of ICT-using services to aggregate productivity growth may also

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result from a stong increase in the share of these services in total value added, notably in financial and business services since 1995 (Wölfl, 2003).

Figure 11: **The contribution of ICT-using services to aggregate productivity growth**
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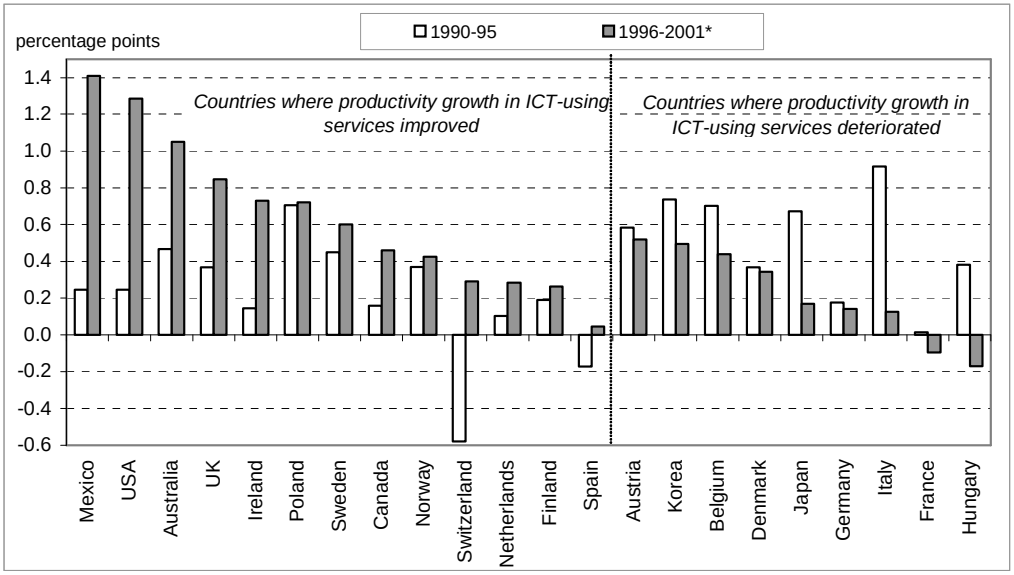


Note: See Figure 8 for period coverage.
Source: Pilat, Lee and Van Ark (2002) and based on OECD STAN Database.

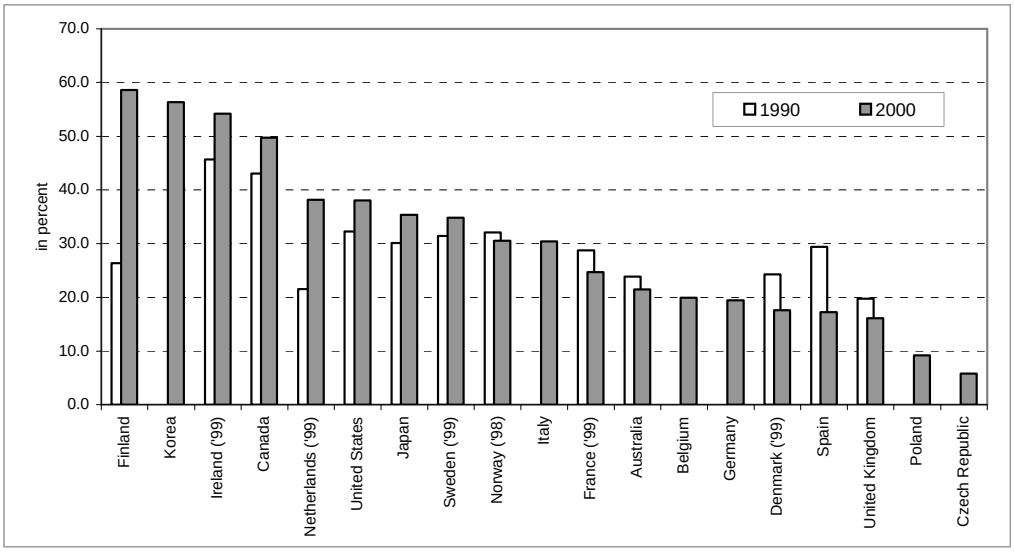
Stronger growth in labour productivity in ICT-producing and ICT-using industries could simply be due to greater use of capital. Estimates of MFP growth adjust for changes in the use of capital and can help show whether ICT-using sectors have indeed improved overall efficiency. Breaking aggregate MFP growth down in its sectoral contributions can also help show whether changes in MFP growth should be attributed to ICT producing sectors, to ICT-using sectors, or to other sectors. MFP estimates at the sectoral level are only available for a limited number of OECD countries, due to the limited availability of estimates of capital stock or capital services (Pilat, *et al.*, 2002). For the United States, several detailed industry studies suggest that MFP in certain services improved over the second half of the 1990s. For example, a recent study by Triplett and Bosworth (2002) estimated that MFP growth in wholesale trade accelerated from 1.1% annually to 2.4% annually from 1987-1995 to 1995-2000. In retail trade, the jump was from 0.4% annually to 3.0%, and in securities the acceleration was from 2.9% to 11.2%. Combined with the relatively large weight of these sectors in the economy, this translates into a considerable contribution to more rapid aggregate MFP growth of these ICT-using services.

An indirect impact via innovation?

Empirical studies show that ICT investment is strongly linked with innovation activities by firms. This suggests that there may be an indirect effect of ICT on economic performance via the improvement of the

innovative capacity of firms and the economy as a whole.[4] An indirect effect may arise from two channels. First, the ICT-sector itself comprises industries with a very high R&D-intensity. Figure 12, for instance, shows that on average about 30% of total R&D expenditure can be attributed to ICT-manufacturing industries. In some countries, notably Finland, Ireland, Korea and Canada, the share of R&D from ICT-manufacturing in total R&D expenditure amounted to 50% or more in 2000. Furthermore, the use of ICT is often linked with a process of co-invention. Users of ICT help make their investments more valuable through own experimentation and invention, *e.g.* by introducing new processes, products and applications. There is empirical evidence that without this process of "co-invention", which often has a slower pace than technological invention, the economic impact of ICT would be more limited. One driver for innovation and productivity growth through ICT can also be seen in the entry of small innovative firms in the ICT-producing and using sector and the increased dynamism that they may induce within the economy. Due to the high costs of R&D and the risks of failure, entry and success of such innovative firms is typically associated with low entry and exit costs in form of a condusive competitive environment, sufficient scope for experimentation and well-functioning financial markets.[5]

Figure 12: **Share of R&D in the ICT manufacturing in total R&D expenditure of the manufacturing sector, August 2002**



Source: OECD (2002a), *Measuring the Information Economy*, http://www.oecd.org/sti/measuring-infoeconomy.

Second, ICT improves the flow of information and technological knowledge. It may thus enhance innovation indirectly through spillover effects and the improved use of knowledge that has been produced by other firms and is embodied in investment and traded goods and services. By reducing transaction costs between and within firms, ICT may facilitate co-operation between firms and may thus improve the access to external knowledge. In addition, fast flow of information through ICT, compatible technologies and the continuous learning and training of staff that comes along with ICT investment may improve the capacity

4 . The link between ICT and innovation has been mainly analysed on the basis of firm-level innovation panels and will thus be more thouroughly dealt with later.

5 . See here also Bartelsman, *et al*. 2002 for further empirical evidence on the role of experimentation for drawing benefits from ICT in the United States.

of a firm to absorb such external knowledge in their own production process. Spillover effects via the international flow of goods and services may also play a role, as ICT investment started earlier, and was stronger, in few technology-leading countries, notably the United States, than in most OECD countries (Colecchia and Schreyer, 2001; Van Ark, *et al*, 2002*a*).

ICT and firm-level performance

The macro evidence may not always be sufficient to draw policy implications, however. Indeed, more elaborate evidence on the impact of ICT use can be drawn from firm-level evidence. ICT use may have several impacts at this level. For example, it may help firms gain market share at the cost of less productive firms, which could raise overall productivity. In addition, the use of ICT may help firms expand their product range, customise the services offered, or respond better to client demand; *i.e.* to innovate. Moreover, ICT may help reduce inefficiency in the use of capital and labour, *e.g.* by reducing inventories. These effects might all lead to higher productivity growth. These, and related, effects have long been difficult to capture in empirical studies, contributing to the so-called "productivity paradox". However, a growing number of firm-level studies provide evidence on such impacts.

The impacts of ICT at the firm level

A number of survey articles summarise the early literature on ICT, productivity and firm performance (e.g. Brynjolfsson and Yang, 1996). Many of these studies tended to find no, or a negative, impact of ICT on productivity. Most of these early studies also primarily focus on labour productivity and the return to computer use, not on MFP or other impacts of ICT on business performance. Moreover, most of these studies used private sources, since official sources were not yet available. Recent work by statistical offices, using large official databases, has provided many new insights in the role of ICT. To help guide this work with firm-level data, OECD worked closely with an expert group, composed of researchers and statisticians from 13 OECD countries. This group worked with the OECD to generate further evidence on the link between ICT and business performance. Their work and that of others is discussed below.

The use of ICT and advanced technologies is positively linked to firm performance

There is evidence from many firm-level studies, and from many OECD countries, that ICT use has a positive impact on firm performance. These impacts can vary. Baldwin and Sabourin (2002), for instance, illustrate a typical finding and shows that Canadian firms that used either one or more ICT technologies had a higher level of productivity than firms that did not use these technologies. Moreover, the gap between technology-using firms and other firms increased between 1988 and 1997, as technology-using firms increased relative productivity compared to non-users. This evidence is confirmed by many other studies, which also point to different impacts of ICT on economic performance. For example, firms using ICT typically pay higher wages. The studies show, however, that the use of ICT does not guarantee success; many of the firms that improved performance thanks to their use of ICT were already experiencing better performance than the average firm. Moreover, the benefits of ICT appear to depend on sector-specific effects and are not found equally in all sectors.

Usunięto: Tthe

There is also evidence that ICT can help firms in the competitive process. For the United States, Doms *et al.* (1995) found that increases in the capital intensity of the product mix and in the use of advanced manufacturing technologies are positively correlated with plant expansion and negatively with plant exit. For Canada, Baldwin and Sabourin (2002) found that a considerable amount of market share is transferred from declining firms to growing firms over a decade. Those technology users that were using communications technologies or that combined technologies from several different technology classes

increased their relative productivity the most. In turn, gains in relative productivity were accompanied by gains in market share.

Computer networks play a key role

Some ICT technologies may be more important to strengthen firm performance than others. Computer networks may be particularly important, as they allow a firm to outsource certain activities, to work closer with customers and suppliers, and to better integrate activities throughout the value chain. This is one main result from Baldwin and Sabourin (2002) for Canada. For the United States, Atrostic and Nguyen (2002) directly linked computer network use (both EDI and Internet) to productivity. They found that average labour productivity is higher in plants with networks and that the impact of networks is positive and significant after controlling for several production factors and plant characteristics. Networks are estimated to increase labour productivity by roughly 5 per cent.

Similar work has been carried out for Japan. Motohashi (2001) found that the impact of direct business operation networks on productivity is much clearer than that of back office supporting systems, such as human resource management and management planning systems. Firms with networks are also found to outsource more production activities. For Germany, Bertschek and Fryges (2002) show that the more firms in an industry that already use B2B, the more likely it is that the firm will also implement B2B.

Firms in the services sector also benefit from ICT

Thanks to improved data, the work with firm-level statistics is also broadening to the services sector. For example, Doms, Jarmin and Klimek (2002) showed that growth in the US retail sector involves the displacement of traditional retailers by sophisticated retailers introducing new technologies and processes, thus confirming the sectoral evidence discussed above. For Germany, Hempell (2002) showed significant productivity effects of ICT in the German service sector. Experience gained from past process innovations helps firms to make ICT investments more productive. ICT investment may thus have contributed to growing productivity differences between firms, and potentially also between countries. For the Netherlands, Broersma and McGuckin (2000) found that computer investments have a positive impact on productivity and that the impact is greater in retail than in wholesale trade.

Factors that affect the impact of ICT

The evidence summarised above suggests that the use of ICT does have impacts on firm performance. However, these effects occur primarily, or only, when accompanied by other changes and investments, including investment in skills and organisational change. This is also confirmed by many empirical studies that suggest that ICT primarily affects firms where skills have been improved and organisational changes have been introduced. The role of these complementary factors was raised by Bresnahan and Greenstein (1996), who argued that users help make investment in technologies, such as ICT, more valuable through their own experimentation and invention. Without this process of "co-invention", which often has a slower pace than technological invention, the economic impact of ICT may be limited. This section looks at some of the factors that affect the uptake of ICT and the main complementary factors for ICT investment.

ICT use is complementary to skills

A substantial number of firm-level studies address the interaction between technology and human capital, and their joint impact on productivity performance. For the United States, Krueger (1993) found that

workers using computers were better paid than those that do not use computers. Doms, *et al.* (1997) found no correlation between technology adoption and wages, however, and concluded that technologically advanced plants pay higher wages both before and after the adoption of new technologies. A more recent study by Luque and Miranda (2000) found that technological change in US manufacturing was skill-biased, however.

For Germany, Falk (2001*a*) found that firms with a higher diffusion of ICT employ a larger fraction of workers with a university degree as well as ICT specialists. A greater penetration of ICT is negatively related to the share of both medium- and low-skilled workers. For France, Entorf and Kramarz (1998) found that computer-based technologies are often used by workers with higher skills. These workers become more productive when they get more experienced in using these technologies. Caroli and Van Reenen (1999) found that French plants that introduce organisational change are more likely to reduce their demand for unskilled workers than those that do not. Shortages in skilled workers may reduce the probability of organisational changes. Greenan, Mairesse and Topiol-Bensaid (2001) examined the late 1980s and early 1990s and found strong positive correlations between indicators of computerisation and research on the one hand, and productivity, average wages and the share of administrative managers on the other hand. They also found negative correlations between these indicators and the share of blue-collar workers.

For the United Kingdom, Haskel and Heden (1999) found that computerisation reduces the demand for manual workers, even when controlling for endogeneity, human capital upgrading and technological opportunities. Caroli and Van Reenen (1999) found evidence that human capital, technology and organisational change are complementary, and that organisational change reduces the demand for unskilled workers.

Studies for Canada also point to the complementarity between technology and skills. For example, Baldwin *et al.* (1995) found that use of advanced technology was associated with a higher level of skill requirements, leading to a higher incidence of training and increased expenditure on education and training. A more recent study (Sabourin, 2001) found that establishments adopting advanced technologies often reported labour shortages of scientists, engineers and technical specialists. However, the most technologically advanced establishments were often able to solve these shortages.

Organisational change is key to making ICT work

Closely linked to human capital is the role of organisational change. Studies typically find that the greatest benefits from ICT are realised when ICT investment is combined with other organisational changes, such as new strategies, new business processes and practices and new organisational structures. Several US studies with official statistics have addressed this link to human capital and organisational change. For example, Black and Lynch (2001) found that the implementation of human resource practices is important for productivity, *e.g.* giving employees greater voice in decision-making, profit-sharing mechanisms and new industrial relations practices. In another study (2000), they found that firms that re-engineer their workplaces to incorporate high-performance practices experience higher productivity and higher wages.

For Germany, Bertschek and Kaiser (2001) found that the introduction of organisational changes raises overall labour productivity. Falk (2001*b*) found that the introduction of ICT and the share of training expenditures are important drivers of organisational changes, such as the introduction of total quality management, lean administration, flatter hierarchies and delegation of authority.

For France, Greenan and Guellec (1998) found that the use of advanced technologies and the skills of the workforce are both positively linked to organisational variables. An organisation that enables

communication within the firm and that innovates at the organisational level seems better able to create the conditions for a successful uptake of advanced technologies. Moreover, these changes also seemed to increase the ability of firms to adjust to changing market conditions through technological innovation and the reduction of inventories.

For the United Kingdom, Caroli and Van Reenen (1999) found that organisational change, technology and skills were complementary. More specifically, it found that organisational change reduced the demand for unskilled workers; and that organisational change has the largest productivity impacts in establishments with larger initial skill endowments. For the Netherlands, Broersma and McGuckin (2000) also found that computer use was linked to the introduction of flexible employment practices, *e.g.* greater use of temporary and part-time workers.

Firm size affects the impact of ICT

A substantial number of studies have looked at the relationship between ICT and firm size. Most studies find that the adoption of advanced technologies, such as ICT, increases with the size of firms and plants. Evidence for the United Kingdom (Clayton, *et al.* 2003) shows that large firms are more likely to use network technologies such as Intranet, Internet or EDI than small firms; they are also more likely to have their own website. However, small firms of between 10 and 49 employees are more likely to use Internet as their only ICT network technology. Large firms are also more likely to use a combination of network technologies. For example, over 38 per cent of all large UK firms use Intranet, EDI and Internet, and also have their own website, as opposed to less than 5 per cent of small firms. Moreover, almost 45 per cent of all large firms already use broadband technologies as opposed to less than 7 per cent of small firms. These differences are linked to the different uses of technology. Large firms may use the technologies to redesign information and communication flows within the firm, and to integrate these flows throughout the production process. Some small firms only use the Internet for marketing purposes.

Ownership, competition and management are important

Firm-level studies also point to the importance of ownership changes and management in the uptake of technology. For example, McGuckin and Nguyen (1995) found that plants with above-average productivity are more likely to change owners and that acquiring firms tended to have above-average productivity. Plants that changed owners generally improved productivity following the change. According to the authors, ownership changes appear associated with the purchase or integration of advanced technologies and better practices into new firms.

Some studies also point to the impact of competition. A study by Baldwin and Diverty (1995*a*) found that foreign-owned plants were more likely to adopt advanced technologies than domestic plants. For Germany, Bertschek and Fryges (2002) found that international competition was an important factor driving a firm's decision to implement B2B electronic commerce.

Management also plays a role. Stolarick (1999) found that low productivity plants may sometimes spend more on IT than high productivity plants, in an effort to compensate for their poor productivity performance. The study suggest that management skill should therefore be taken into account as an additional factor when investigating the IT productivity paradox.

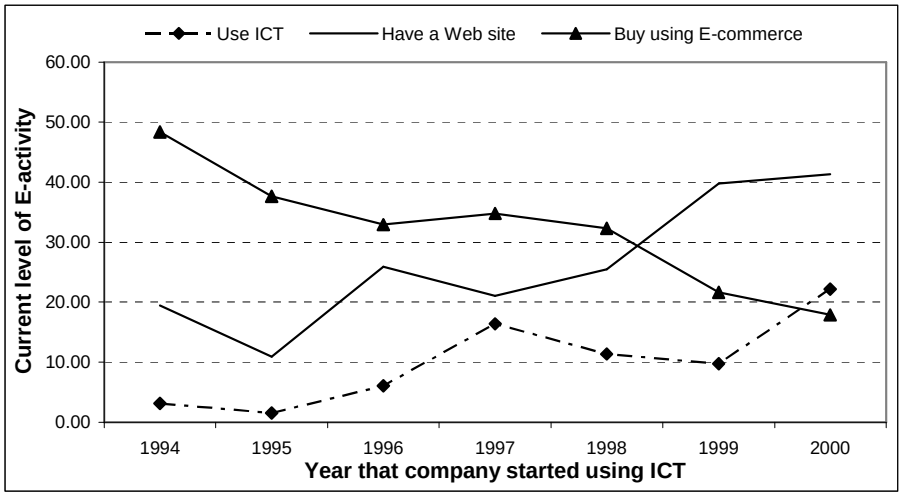
ICT use is closely linked to innovation

Several studies point to an important link between the use of ICT and the ability of a company to adjust to changing demand and to innovate. The clearest example of this link is found in work on Germany, which draws on results from innovation surveys. For example, Licht and Moch (1999) found that information technology has important impacts on the qualitative aspects of service innovation. Hempell (2002) found that firms that have introduced process innovations in the past are particularly successful in using ICT; the output elasticity of ICT capital for these firms is estimated to be about 12 per cent, about four times that of other firms. This suggests that the productive use of ICT is closely linked to innovation in general, and to the re-engineering of processes in particular. Studies in other countries also confirm this link. For example, Greenan and Guellec (1998) found that organisational change and the uptake of advanced technologies seemed to increase the ability of firms to adjust to changing market conditions through technological innovation.

The impacts of ICT use only emerge over time

Given the time it takes to adapt to ICT, it should not be surprising that the benefits of ICT only emerge over time. This can be seen clearly in the relationship between the use of ICT and the year in which firms first adopted ICT. Figure 13 shows evidence for the United Kingdom. It shows that among the firms that had already adopted ICT in or before 1995, close to 50 per cent currently buy using electronic commerce. For firms that only adopted ICT in 2000, less than 20 per cent buy using e-commerce. The UK evidence also suggests that firms move towards more complex forms of electronic activity over time; out of all firms starting to use ICT prior to 1995, only 3 per cent had not moved beyond the straightforward use of ICT. Most had established an Internet site, or bought or sold through e-commerce. Out of the firms adopting ICT in 2000, over 20 per cent had not yet gone beyond the simple use of ICT.

Figure 13: **Relationship between the year of ICT adoption and the current degree of E-activity**
(as a percentage of all firms adopting ICT in specific year, business-weighted)

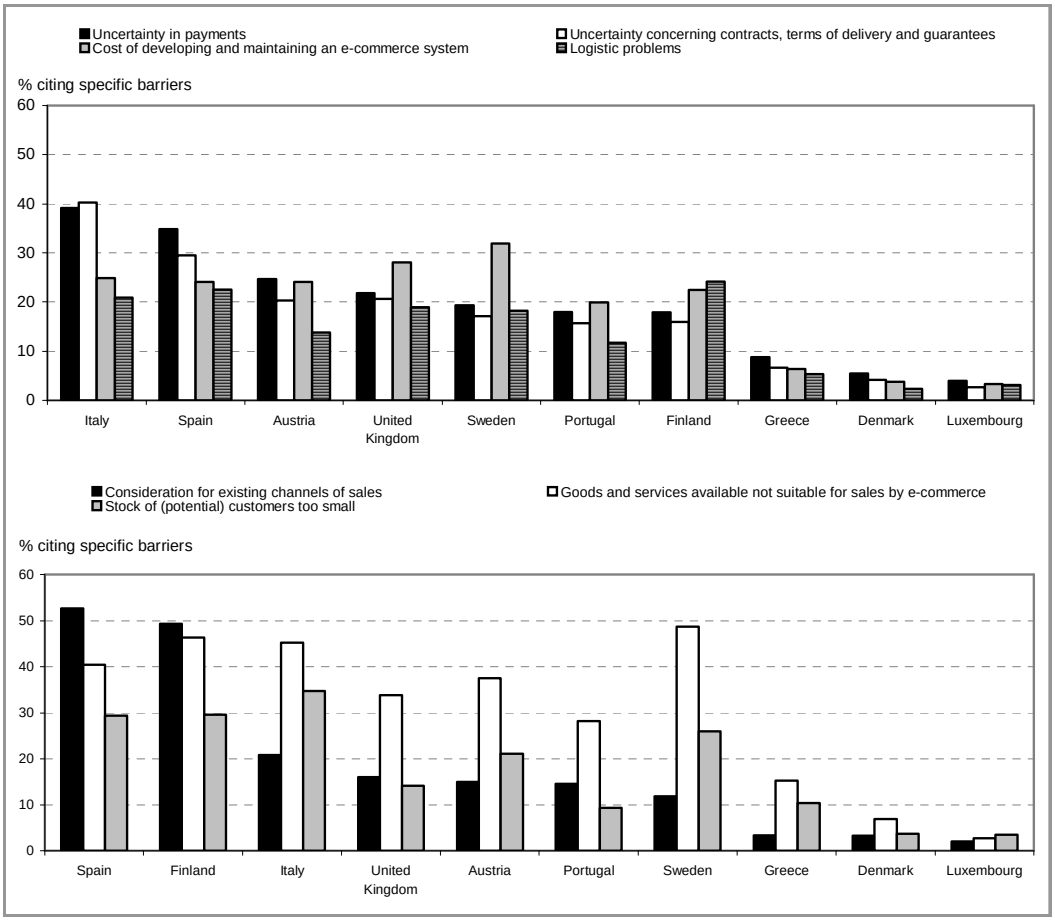


Note: The graph shows the percentage of firms engaged in a specific type of e-activity in 2000, out of all the firms starting to use ICT in that year.
Source: Clayton and Waldron (2003).

Barriers to the uptake of ICT from the firm level perspective

Firm-level surveys are also a useful tool to draw evidence on barriers to the uptake of ICT. Such surveys ask firms and consumers about the barriers they face in using the Internet and electronic commerce. Some interesting patterns emerge (OECD, 2002*a*). As regards Internet access, lack of security and slow or unstable communications were considered the key problems in European countries. Other problems, such as lack of know-how or personnel, high costs of equipment or Internet access, were considered less of a problem. Surveys on the barriers to Internet commerce also provide insights (Figure 14). These suggest that legal uncertainties (uncertainty over payments, contracts, terms of delivery and guarantees) are important in several countries. Business-to-consumer transactions are typically hampered by concerns about security of payment, the possibility of redress in the on-line environment and privacy of personal data. For business-to-business transactions, the security and reliability of systems that can link all customers and suppliers are often considered more important. Cost considerations also remain an important issue for businesses in several countries, while logistic problems were also cited frequently.

Figure 14: **Barriers to Internet commerce faced by businesses, 2000**
Percentage of businesses using a computer with 10 or more employees



Source: OECD (2002*a*), *Measuring the Information Economy*, based on Eurostat, E-commerce Pilot Survey.

Commercial factors were also cited by many businesses as a factor in not taking up Internet commerce, e.g. because Internet commerce might threaten existing sales channels. Existing transaction models or strong links with customers and suppliers along the value chain may discourage businesses from introducing new sales models. In many cases, the goods and services on offer by a particular firm were not considered suitable for Internet commerce, while firms in several countries considered the market too small. Some of these considerations differ by the size and activity of firms; *e.g.* large firms found logistical barriers more important than small firms.

More elaborate analysis of this survey evidence provides further insights in the factors explaining ICT uptake. Using recent data for Switzerland, Hollenstein (2002) finds that the anticipated benefits and costs of adoption, the firm's ability to absorb knowledge from other firms and institutions, experience with related technologies and international competitive pressure are among the main factors explaining ICT adoption, with sectoral differences also playing an important role.

Impact of ICT at the firm level differs across countries

Cross-country studies on the impact of ICT at the firm level are still relatively rare, primarily since many of the original data sources were of an ad-hoc nature and not comparable across countries. In recent years, the growing similarity of official statistics is enabling more comparative work. An example is a recent comparison between the United States and Germany (Haltiwanger, *et al.* 2002), that examines the relationship between labour productivity and measures of the choice of technology, distinguishing between different categories of firms according to their total level of investment and their level of investment in ICT. The study showed that firms in all categories of investment have much stronger productivity growth in the United States than in Germany. Moreover, firms with high ICT investment have stronger productivity growth than firms with low or zero ICT investment . The study also showed that firms in the United States have much greater variation in their productivity performance than firms in Germany. This may be because US firms engage in much more experimentation than their German counterparts; they take greater risks and opt for potentially higher outcomes.

Some policy implications

The OECD growth study provided a number of recommendations on policies to seize the benefits of ICT and foster economic growth (OECD, 2001*a*). This included, *inter alia*, policies to increase competition in telecommunications, to enhance skills and encourage labour mobility, to reduce obstacles to workplace changes, and to build confidence in the use of ICT. The growth study also concluded that ICT is not the only factor explaining growth disparities, and that policies to bolster ICT will not on their own steer countries on to a higher growth path. Strengthening growth performance will thus require a comprehensive and co-ordinated set of actions to create the right conditions for future change and innovation, including policies to strengthen fundamentals, to foster innovation, to invest in human capital and to stimulate firm creation. The present study confirms these conclusions and provides further evidence on the appropriate policies to seize the benefits from ICT.

A. Strengthening competition in ICT goods and services. The first policy implication that can be drawn from the work concerns costs differentials and the need for sufficient competition in ICT goods and services. The available evidence suggests that differences in the costs of investment into the technology continue to play a role in determining investment patterns. Barriers to trade, in particular non-tariff barriers related to standards, import licensing and government procurement, may partly explain these differentials. The higher price levels in other OECD countries may also be associated with a lack of competition within countries. In time, however, international trade and competition should further erode these cross-country

price differences. Policy could help to accelerate this trend, by implementing a more active competition policy and measures to promote market openness, both domestically and internationally.

The investment and diffusion of ICT depend also on the associated costs of communication and use once the hardware is linked to a network. Increased competition in the telecommunications industry, thanks to extensive regulatory reform, has been of particular importance in driving down these costs. Liberalisation, and the competition it has generated, has brought tremendous benefits to OECD countries and users. Prices have declined, and continue to do so in certain market segments. Technological diffusion and new service development have been rapid, and continue to grow. Incumbent telecommunication carriers have adjusted to the new market conditions by increasing efficiency and improving levels of service. A large number of new firms have entered the market, and while some have failed, the number of market players in many OECD countries remains large. But efforts to increase competition and continue with regulatory reform in the telecommunications industry continue to be important to enhance the uptake of ICT. Improving the conditions of access to local communication infrastructures and networks is particularly important, and will require effective policies to unbundle the local loop and establish interconnection frameworks. Such policies will also help enhance access to high-speed communication services.

B. Fostering a business environment for ICT adoption. A competitive environment is more likely to lead a firm to invest in ICT, as a way to strengthen performance and survive, than a more sheltered environment. Moreover, the state of competition influences firms' decisions to implement ICT applications, such as electronic commerce. Many firms do not engage in e-commerce because the market is considered too small, or because their products are not considered suitable for electronic commerce. In other cases, electronic commerce is seen as a rival to existing business models. These concerns can be genuine, but may also reflect a conservative attitude. Existing firms may wish to retain their current business model and avoid the risks associated with new investments and new business models. Start-up firms can help instil greater dynamism, introduce new business models, and invigorate mature industries. Policies to enhance firm creation are key in such markets.

ICT is an enabling technology that has the potential to transform firms. They can use it in smart ways to improve performance, but not all firms will succeed in making the necessary changes that are needed to make the technology work. Competition and creative destruction are key in selecting the successful firms and in making them flourish and grow. If firms that are able to make ICT work succeed and grow, the benefits for the economy as a whole are greater than if poorly-performing firms survive. While many new firms may not survive, start-ups may force incumbent firms to improve performance, and those that survive may contribute to improved productivity and innovation.

Allowing room for experimentation may be important for firms wishing to gain benefits from their investments in ICT (Bartelsman, *et al.* 2002). For instance, new firms in the United States seem to experiment more with business models than those in other OECD countries; they start at a smaller scale than European firms, but grow much more quickly when successful. This may be linked to less aversion to risk in the United States, and may be influenced by its financial system, which provides greater opportunities for risky financing to innovative entrepreneurs. Moreover, low regulatory burdens enable US firms to start at a small scale, experiment, test the market and their business model, and, if successful, expand rapidly. Moreover, if they do not succeed, the costs of failure are relatively limited. In contrast, firms in many other OECD countries are faced with high entry and exit costs. In a period of rapid technological change, greater scope for experimentation may enable new ideas and innovation to emerge more rapidly, leading to faster technology diffusion.

Investment in ICT relies on complementary investments that need to be made by firms to draw the benefits from ICT, e.g. in changing the organisation of functions and tasks, or in training staff. These complementary investments are often much more costly than the initial outlays for ICT investment goods.

Adapting the organisation of functions and tasks to ICT can be particularly costly to firms, as it often meets with resistance within the firm, and may be limited by legal constraints. Social partners and government can work together to ensure that a virtuous circle of human resource upgrading, organisational change, ICT and productivity is set in motion. This depends on workers being given a sufficient "voice" in the firm. A closer contact between management and employees can help build a high-skill, high-trust enterprise climate that facilitates change.

Also matching the skills of workers to the new technology requires considerable investment. For ICT to be developed and used effectively, and network externalities to materialise, the right skills and competencies must be in place. Having a good supply of qualified personnel helps, but education policies, important as they are, need to be supplemented with actions to foster life-long learning. The OECD growth report pointed to a range of policy conclusions in this area, which continue to be important for countries wishing to draw the benefits from ICT. Such policies are aimed at enhancing basic literacy in ICT, at building high-level ICT skills, at lifelong learning in ICT, and at enhancing the managerial and networking skills needed for the effective use of ICT. Moreover, a certain degree of labour mobility is needed to seize the new opportunities associated with ICT, which may require changes to regulations in some countries.

Another implication relates to management. Firm-level studies typically find that firms that get most out of their investment in ICT are those firms that were already performing well in terms of gains in productivity and market shares. These firms improved performance by investing in ICT, by innovating and by adapting their organisation and workforce.[6] In contrast, many firms that invested much in ICT received no returns at all, as they were attempting to compensate for poor overall performance. This reinforces the view that ICT is no panacea, and also points to a role for management. While governments can not directly influence management decisions, it can help create framework conditions for good management. Frameworks for good corporate governance play a role in this respect.

Policies to seize the benefits from ICT rely on fundamental economic and social stability to succeed. All of the policy areas discussed in this paper are interlinked and depend on each other. But those countries that have managed to seize the benefits from ICT were able to do so because they had been getting their fundamentals right. They owed their economic success to sound macroeconomic policies, well-functioning institutions and markets, and an orientation to build a more open and competitive economic environment. Studies for Australia, one of the key examples of ICT-driven growth, emphasise the interaction between structural reform and the uptake of ICT (Parham, *et al*. 2001). By contrast, in those countries whose growth performances appeared to lag, some of the fundamentals were perhaps missing or were at best so weak as to make it difficult to harness the new dynamism, such as not having the right institutional set-up for new business creation.

C Boosting security and trust. Businesses, governments, consumers and key infrastructures increasingly rely on the use of information networks, which are often interconnected at the global level. This raises new issues for security as these electronic networks need to be stable and ready for safe, secure and reliable use under all conditions. Legal uncertainties (uncertainty over payments, contracts, terms of delivery and guarantees) remain a barrier to electronic commerce. Likewise, business-to-consumer transactions are hampered by concerns about security of payments, opportunities for redress, and the privacy of personal data.

Much work is currently underway to address these concerns. Authentication and certification mechanisms are being developed to help identify users and safeguard business transactions. To counter computer

6. The management literature provides extensive discussions on how firms can make ICT work in their particular environment. These issues are not discussed here, as government policy has little role in influencing these corporate processes.

viruses, hacking and other threats, OECD has drawn up new and comprehensive security guidelines that are currently awaiting implementation by OECD countries. The OECD privacy and consumer protection guidelines are also an important step towards an international consensus on core protections. Continued efforts to implement these guidelines are key and will require that governments, business and civil society work together.

Some of the slowness to do business (personal or otherwise) via the Internet is to do with attitudes. Governments can help to change these by using ICT applications themselves. Tendering public services, providing digital public services, collecting taxes or procuring goods and services online can help increase government efficiency and enhance access to public services, while having the additional benefit of building public confidence and strengthening demand.

D. Unleashing growth in the services sector. The growing importance of ICT also affects policies for the services sector. Service industries such as wholesale and retail trade, financial and business services are among the most important adopters of ICT. It is in these "old economy" sectors, not in the telecommunications sector or the dot-com sector that the long-term impacts of ICT use should become most important. Evidence shows that only in few countries, notably the United States and Australia, ICT has already enabled productivity growth in some of these industries. This suggests that policies must take better account of the needs and characteristics of the services sector if they are to promote growth. For example, competition in many services sectors remains limited due to heavy regulatory burdens, reducing pressures to strengthen performance. Further reform of regulatory structures is needed to promote competition and innovation and to reduce barriers and administrative rules for new entrants and start-ups in those services. International competition is also important for the uptake of ICT, but services are typically less exposed to international competition yet. This will require the reduction of trade and foreign investment barriers in services, which can also promote the diffusion of innovative ideas and concepts across countries. Evidence from firm-level studies that foreign firms are often the first to adopt new technologies confirms that such international competition is essential.

E. Harnessing the potential of innovation and technology diffusion. ICT is closely linked to the ability of firms to innovate, i.e. introduce new products and services, new business processes, and new applications. For example, ICT has helped speed up the innovation process and reduced cycle times, resulting in a closer link between business strategies and performance. Moreover, ICT has fostered greater integration and networking in the economy, as it has facilitated outsourcing and improved co-operation beyond the firm, with suppliers, customers and competitors. The roles of innovation and ICT in recent growth performance are thus closely related. Some of the recent changes in the innovation process could not have occurred without ICT. Conversely, some of the impact of ICT might not have been felt in the absence of changes in the innovation process, e.g. stronger links between scientific research and innovation (OECD, 2001*a*). This implies that policies to harness the potential of innovation and technology diffusion, as outlined in the OECD growth study, are of great importance in seizing the benefits of ICT. Moreover, such policies help foster the kind of innovative environment in which new growth opportunities will flourish.

Concluding remarks

Despite the slowdown in the economy and parts of the ICT sector, ICT has emerged over the past decade as a key technology with the potential to transform economic and social activity. It has already led to more rapid growth in countries where appropriate policies to reap the benefits from ICT have been put in place. All OECD governments can do more to exploit this technology, by fostering a business environment that encourages its diffusion and use and by building confidence and trust. However, policies to bolster ICT will not on their own lead to stronger economic performance. Indeed, economic performance is not the result of a single policy or institutional arrangement, but a comprehensive and co-ordinated set of actions

to create the right conditions for future change and innovation. Policies to strengthen economic and social fundamentals are thus of over-riding importance in drawing the benefits from ICT.

REFERENCES

ATROSTIC, B.K. and S. NGUYEN (2002), "Computer Networks and U.S. Manufacturing Plant Productivity: New Evidence from the CNUS Data", *CES Working Paper 02-01*, Center for Economic Studies, Washington D.C.

BAILY, M.N. (2002), "The New Economy: Post Mortem or Second Wind", *Journal of Economic Perspectives*, Vol. 16, No. 2, Spring 2002, pp. 3-22.

BALDWIN, J.R. and B. DIVERTY (1995), "Advanced Technology Use in Canadian Manufacturing Establishments", *Working Paper No. 85*, Microeconomics Analysis Division, Statistics Canada, Ottawa.

BALDWIN, J.R., T. GRAY, and J. JOHNSON (1995), "Technology Use, Training and Plant-Specific Knowledge in Manufacturing Establishments", *Working Paper No. 86*, Microeconomics Analysis Division, Statistics Canada, Ottawa.

BALDWIN, J.R. and D. SABOURIN (2002), "Impact of the Adoption of Advanced Information and Communication Technologies on Firm Performance in the Canadian Manufacturing Sector", *STI Working Paper 2002/1*, OECD, Paris.

BARTELSMAN, E. A. BASSANINI, J. HALTIWANGER, R. JARMIN, S. SCARPETTA and T. SCHANK (2002), "The spread of ICT and productivity growth - is Europe really lagging behind in the new economy?", Fondazione Rodolfo DeBenedetti, *mimeo*.

BERTSCHEK, I. and U. KAISER (2001), "Productivity Effects of Organizational Change: Microeconometric Evidence", *ZEW Discussion Paper No. 01-32*, ZEW, Mannheim.

BERTSCHEK, I. and H. FRYGES (2002), "The Adoption of Business-to-Business E-Commerce: Empirical Evidence for German Companies", *ZEW Discussion Paper No. 02-05*, ZEW, Mannheim.

BLACK, S.E. and L.M. LYNCH (2000), "What's driving the new economy: The benefits of workplace innovation", *NBER Working Paper Series*, No. 7479, January.

BLACK, S.E. and L.M. LYNCH (2001), "How to compete: the impact of workplace practices and information technology on productivity", *The Review of Economics and Statistics*, August, Vol. 83, No. 3, pp. 434-445.

BRESNAHAN, T.F. and S. GREENSTEIN (1996), "Technical Progress and Co-Invention in Computing and the Use of Computers", *Brookings Papers on Economic Activity: Microeconomics*, pp. 1-77.

BROERSMA, L. and R.H. McGUCKIN (2000), "The Impact of Computers on Productivity in the Trade Sector: Explorations with Dutch Microdata", *Research Memorandum GD-45*, Groningen Growth and Development Centre, June.

BRYNJOLFSSON, E. and L.M. HITT (2000), "Beyond Computation: Information Technology, Organizational Transformation and Business Performance", *Journal of Economic Perspectives* 14, pp. 23-48.

BRYNJOLFSSON, E. and S. YANG (1996), "Information Technology and Productivity: A Review of the Literature", *mimeo*, http://ecommerce.mit.edu/erik/.

CAROLI, E. and J. VAN REENEN (1999), "Organization, Skills and Technology: Evidence from a Panel of British and French Establishments", *IFS Working Paper Series W99/23*, Institute of Fiscal Studies, August.

CLAYTON, T. and K. WALDRON (2003), "E-Commerce Adoption and Business Impact, A Progress Report", *Economic Trends*, forthcoming.

COLECCHIA, A. and P. SCHREYER (2001), "The Impact of Information Communications Technology on Output Growth", *STI Working Paper 2001/7*, OECD, Paris.

DOMS, M., T. DUNNE, and M.J. ROBERTS (1995), "The Role of Technology Use in the Survival and Growth of Manufacturing Plants", *International Journal of Industrial Organization* 13, No. 4, December, pp. 523-542.

DOMS, M., T. DUNNE and K.R. TROSKE (1997), "Workers, Wages and Technology", *Quarterly Journal of Economics* 112, No. 1, pp. 253-290.

DOMS, M., R. JARMIN and S. KLIMEK (2002), "IT Investment and Firm Performance in U.S. Retail Trade", *CES Working Paper 02-14*, Center for Economic Studies, Washington D.C.

ENTORF, H. and F. KRAMARZ (1998), "The Impact of New Technologies on Wages: Lessons from Matching Panels on Employees and on their Firms", *Economic Innovation and New Technology*, Vol. 5, pp. 165-197.

FALK, M. (2001*a*), "Diffusion of Information Technology, Internet Use and the Demand for Heterogeneous Labor", *ZEW Discussion Paper No. 01-48*, ZEW, Mannheim.

FALK, M. (2001*b*), "Organizational Change, New Information and Communication Technologies and the Demand for Labor in Services", *ZEW Discussion Paper No. 01-25*, ZEW, Mannheim.

GREENAN, N. and D. GUELLEC (1998), "Firm Organization, Technology and Performance: An Empirical Study", *Economics of Innovation and New Technology*, Vol. 6, No. 4, pp. 313-347.

GREENAN, N., J. MAIRESSE and A. TOPIOL-BENSAID (2001), "Information Technology and Research and Development Impacts on Productivity and Skills: Looking for Correlations on French Firm Level Data", *NBER Working Paper 8075*, Cambridge, MA.

GUST, C. and J. MARQUEZ (2002), "International Comparisons of Productivity Growth: The Role of Information Technology and Regulatory Practices", *International Finance Discussion Papers*, No. 727, Federal Reserve Board, May.

HALTIWANGER, J., R. JARMIN and T. SCHANK (2002), "Productivity, Investment in ICT and Market Experimentation: Micro Evidence from Germany and the United States.", paper presented at OECD workshop on ICT and Business Performance, December.

HASKEL, J. and Y. HEDEN (1999), "Computers and the Demand for Skilled Labour: Industry- and Establishment-Level Panel Evidence for the UK", *The Economic Journal*, 109, C68-C79, March.

HEMPELL, T. (2002), "Does Experience Matter? Productivity Effects of ICT in the German Service Sector", *ZEW Discussion Paper No. 02-43*, Centre for European Economic Research, Mannheim.

HOLLENSTEIN, H. (2002), "The decision to adoption information and communication technologies (ICT): Explanation and policy conclusions", paper presented at OECD workshop on ICT and Business Performance, Institute for Business Cycle Research (KOF), Zurich, December.

JORGENSON D.W. (2001), "Information Technology and the U.S. Economy", *American Economic Review*, Vol. 91, No. 1, pp. 1-32.

KRUEGER, A.B. (1993), "How computers have changed the wage structure: Evidence from microdata, 1984-1989", *The Quarterly Journal of Economics*, February, pp. 33-60.

LICHT, G. and D. MOCH (1999), "Innovation and Information Technology in Services", *Canadian Journal of Economics*, Vol. 32, No. 2, April.

McGUCKIN, R.H. and S.V. NGUYEN (1995), "On Productivity and Plant Ownership Change: New Evidence from the LRD", *Rand Journal of Economics* 26, No. 2, pp. 257-276.

McGUCKIN, R.H. and K.J. STIROH (2001), "Do Computers Make Output Harder to Measure", *Journal of Technology Transfer*, Vol. 26, pp. 295-321.

McKINSEY (2001), *US Productivity Growth 1995-2000: Understanding the Contribution of Information Technology relative to Other Factors*, McKinsey Global Institute, Washington, D.C., October.

MOTOHASHI, K. (2001), "Economic Analysis of Information Network Use: Organisational and Productivity Impacts on Japanese Firms", Research and Statistics Department, METI, *mimeo*.

NICOLETTI, G., S. SCARPETTA and O. BOYLAUD (1999), "Summary indicators of product market regulation with an extension to employment protection legislation", *OECD Economics Department Working Paper No. 226*, Paris.

OECD (2001), *The New Economy: Beyond the Hype*, Paris.

OECD (2002*a*), *Measuring the Information Economy 2002*.

OECD (2002*b*), *Non-tariff Barriers in the ICT Sector: A Survey*, OECD, Paris, September.

OECD (2003a), *Seizing the Benefits from ICT – an International Comparison of the Impacts of ICT on Economic Performance*, Paris, forthcoming.

OECD (2003b), *The Sources of Economic Growth in OECD Countries*, Paris.

PARHAM, D., P. ROBERTS and H. SUN (2001), *Information Technology and Australia's Productivity Surge*, Staff Research Paper, Productivity Commission, AusInfo, Canberra.

PILAT, D., F. LEE and B. VAN ARK (2002), "Production and use of ICT: A sectoral perspective on productivity growth in the OECD area", *OECD Economic Studies*, No. 35, Paris, forthcoming.

SABOURIN, D. (2001), "Skill Shortages and Advanced Technology Adoption", *Working Paper No. 175*, Microeconomics Analysis Division, Statistics Canada, Ottawa.

STOLARICK, K.M. (1999), "Are Some Firms Better at IT? Differing Relationships between Productivity and IT Spending", *CES WP-99-13*, Center for Economic Studies, Washington D.C.

TRIPLETT, J.E. and B.B. BOSWORTH (2002), "Baumol's disease" has been cured: IT and multifactor productivity in U.S. services industries", paper prepared for Brookings workshop on services industry productivity, Brookings Institution, Washington, D.C., September.

VAN ARK, B., J. MELKA, N. MULDER, M. TIMMER and G. YPMA (2002), "ICT investment and growth accounts for the European Union, 1980-2000", paper prepared for DG ECFIN, European Commission, Brussels, September, http://www.eco.rug.nl/ggdc/homeggdc.html

WÖLFL, A. (2003), Productivity growth in service industries – an assessment of recent patterns and the role of measurement, forthcoming as *DSTI-Working Paper*, OECD, Paris.