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The impact of ICT on Productivity and Growth

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Differences in productivity growth between Europe and the US

Since the mid 1990s, the patterns of productivity growth between Europe and the United States have been diverging. Slower labour productivity in Europe reverses a long-term path toward convergence. Van Ark *et al.* (2008) divide Europe growth performance relative to the United States into three periods:

- 1950-1973: productivity growth in Europe follows a traditional catching up pattern sustained by strong investment and supporting institutions. This process came to an end by the mid 1970s.

- 1973-1995: productivity growth in both Europe and the United States began to slow down. However, average annual labour productivity growth in the EU-15 was still twice as fast as in the United States and the productivity gap was very narrow by 1995.

- 1995 onwards: the U.S. productivity growth accelerated while the rate of productivity growth in Europe fell. By 2004, GDP per hour worked in the EU was about 10 percentage points below the U.S. level.

The causes of the strong U.S. productivity resurgence have been extensively discussed. A growing body of research points out that the U.S. acceleration in productivity growth reflects underlying technology acceleration. The findings of this research stream, along with considerable anecdotal and microeconomic evidence, suggest that Information and Communication Technologies (ICTs) have played a substantial role.

In the mid 1990s, a burst of productivity in the industries producing ICT equipment (computer hardware, software and telecommunications) led to falling relative prices of ICTs, increasing investments in ICT assets and capital-deepening across the whole economy (Jorgenson, Ho and Stiroh, 2008).

With some delay, arguably due to the changes in production processes and organizational practices necessary to adjust to the new technology, industries using ICTs intensively also experienced a surge in multifactor productivity (MFP), particularly in market services (Triplett and Bosworth, 2006). In the United States the MFP uptake in the late 1990s was supported by the industries using ICTs rather than by those producing it.

Although European economies experienced the same fall in the prices of ICTs and an increase in the returns from ICT investment, in Europe the diffusion of ICTs has been much slower since the mid 1990s. A number of studies have tried to explain the reasons for this pattern.

Benefiting from ICTs requires substantial complementary investments in learning, reorganisation and the like, so that the payoff in terms of measured output may take long to materialise. Investment in ICTs may be associated with contemporary lower MFP growth as resources are diverted to reorganisation and learning. Basu *et al.* (2003) find that industries with higher ICT capital growth rates in the 1980s also had higher MFP growth rates in the late 1990s, whereas ICT capital growth in the late 1990s was negatively correlated with contemporaneous MFP growth, when controlling for lagged effect.

The successful implementation of ICTs requires reorganisation of the firm around the new technology - fees paid to consultants, management time and expenditures in training (Yang and Brynjolffson, 2001 and Brynjolffson, Hitt and Yang, 2002). Evidence from micro panel studies also suggests that U.S. firms have a greater organisational capital than European firms (Bloom *et al.*, 2007).

As most literature attributes the European slow-down in productivity growth to the lag in ICT adoption by the ICT-using sector, factors related to national regulations may play a role in explaining the slow reorganisation of European firms around the new technology. Gust and Marquez (2004) and Van Reenen *et al.* (2010) provide evidence that labour market and product market regulations explain a significant part of the differences between U.S. and European productivity. They also suggest that policies should promote product market competition, faster adjustment in labour market and openness to trade.

The rise in productivity growth in the U.S. lasted through the middle of 2004, but it has slowed down in more recent years. While the contribution of ICTs to productivity growth remain large as compared to the relative importance of ICTs production in the U.S. economy, after 2000 productivity growth has significantly slowed down in both the ICT producing and the ICT using industries. Given that the increase in MFP after 2000 is mainly driven by sectors that are intensive in ICT usage, continued fall in ICT prices is likely to be an important factor for sustained MFP growth over time.

Growth accounting: From the Solow Paradox to the ICT-driven Productivity Resurgence

Early studies on the impact of ICTs on productivity resulted largely inconclusive. The well-known Solow's paradox (2005) for which "computers are visible everywhere except in productivity statistics" summarizes the state of art in the early 90s. The lack of correlation between ICT investment and productivity growth was mostly due to incorrect measurement of ICT capital prices and quality.

Significant improvements in the measurement of ICT capital (OECD, 2001, 2009) have opened the way to a new stream of analysis on the productivity effects of ICTs. While, the work carried out by the OECD to internationally harmonise ICT prices (Wyckoff 1995, Schreyer 2000 and Colecchia and Schreyer 2002) allowed controlling for differences in methodologies among countries.

Most macroeconomic and industry studies are based on the growth accounting framework, where the contribution of each input to production is assumed to be proportional to the corresponding share in total input costs. Increases in production above the inputs' contribution are ascribed to growth in multifactor productivity (MFP), i.e.: technological progress not embodied in production inputs.

Jorgenson and Stiroh (2000) apply the Jorgenson's *production possibility frontier* (1967) to explain the increase in productivity growth in the U.S. after 1995. They find that computer hardware played an increasing role as a source of economic growth and that average labour productivity grew much faster between 1995-1999 due to capital-deepening as a direct consequence of the fall in ICT prices and the increase in MFP.

Oliner and Sichel (2000, 2002) reach similar results, based on a Solow-like growth accounting model. They find that the contribution of ICT capital increased between the periods 1974-1995 and 1996-1999 and that MFP growth also increased by 40% in the period 1996-1999.

Colecchia and Schreyer (2002) extend the approach followed by Jorgenson and Stiroh (2000) and Oliner and Sichel (2000) to nine OECD countries up to the year 2000. They found that in the preceding two decades ICT contributed between 0.2 and 0.5 percentage points per year to economic growth, depending on the country. During the second half of the 1990s, this contribution rose to 0.3 to 0.9 percentage points per year. They showed that the United States had not been alone in benefiting from the positive effects of ICT capital investment on economic growth and in experiencing an acceleration of these effects. However, effects have clearly been largest in the United States followed by Australia, Finland and Canada. Of the nine countries considered Germany, Italy, France and Japan registered the lowest contribution of ICT to economic growth.

Oulton (2002) applies a modified growth accounting approach to the UK, using U.S. producer price indices adjusted for exchange rates to deflate the value of ICT investments. He finds that ICT contribution to GDP growth increased from 13.5% in 1979-89 to 20.7% in 1989-98. ICTs contributed 55% of capital deepening during the period 1989-98 and 90% in the period 1994-98.

Using data on ICT investments from the tax declarations of 300 000 French firms, Crepon and Heckel (2002) evaluate the contribution of ICTs to the growth of value added via two channels: the accumulation of IT capital across all industries and the MFP gains in ICT-producing industries. They find that, over the period 1987-1998, ICTs accounted for 0.7 percentage points of the yearly value added growth, 0.3 points from capital deepening and 0.4 points from MFP growth in ICT-producing industries. This amounts to over one-fourth of the yearly value added growth (2.6%).

Improving the measurement of ICT capital is also at the core of the work led by Van Ark *et al.* (2002a) to explain the different impact of ICTs on productivity between the U.S. and Europe. Using data on manufacturing and service industries from 1980 to 2000, they find that the pattern of ICT diffusion in Europe has not been much different from that in the U.S., beginning with a rapid increase in office and computing equipment, followed by a surge in communication equipment, and backed up by increased investment in software. However, EU countries started from much lower stocks of ICT capital so that both the intensity of ICT and its contribution to productivity growth have been lagging behind the U.S.

The slowdown in productivity growth in the EU contrasts sharply with the rapid acceleration in productivity growth in the U.S. after 1995. Van Ark *et al.* (2002b) show that this slowdown has affected all sectors of the economy and, in particular, services. However, intensive ICT-using services in Europe have kept up their productivity growth. This evidence suggests that ICT is not the only factor explaining differences in productivity growth between Europe and the U.S.

A detailed account of the sources of labour productivity in the service industry is made by Inklaar, Timmer and Van Ark (2008) using the EU KLEMS database. The focus on market services is particularly useful, not only because the U.S. experience shows that they can be a substantial source of growth, but also because services are amongst the most intensive users of new technologies and skilled labour. The EU KLEMS database makes possible to measure and analyse the role of high skilled labour and investment in ICT capital for labour productivity growth at a detailed industry level. The study shows that growth differences in market services closely mirror aggregate growth differences across countries. ICTs and highly skilled workers contribute substantially to labour productivity growth in market services in all European countries and in the U.S. Most of the cross-country growth differences are not due to differences in the pace of investment in ICTs or human capital, but to differences in efficiency gains in the service sector. However, as in Stiroh (2004), the authors did not find any evidence of externalities to the use of ICTs and university educated workers which might explain differences in MFP.

If ICT capital deepening and MFP growth in ICT-producing sectors measure the direct growth contribution of the use and the production of ICTs, microeconomic studies emphasize the complexity of the link from technology to productivity. To leverage ICT investment successfully, firms must typically make large complementary investments and innovate in areas such as business organisation, workplace practices, human capital and intangible capital. Important progresses have been made in incorporating these variables into a macro growth accounting framework by Corrado *et al.* (2006). They find that the growth rates of output and output per worker increase at a noticeably faster rate when intangibles are included then under the baseline case in which intangible capital is ignored and capital deepening becomes the unambiguously dominant source of labour productivity growth. More broadly, the factors typically associated with the growth of the knowledge economy take up a greater importance when intangibles are included.

Is the resurgence of U.S. productivity growth sustainable?

Information technology emerged as the driving force behind the acceleration of U.S. labour productivity growth in the mid-1990s. The rise in productivity growth lasted through 2004 but it slowed down considerably afterwards: 1.3% a year from 2004 to 2007, similar to the rates registered in the 1970s and 1980s.

Jorgenson (2008) argues that the sources of productivity growth have changed over the last decade. From 1995 up to the dot-com crash in 2000, economy-wide productivity growth was driven by the dynamics of productivity in the ICT-producing sector and the massive investments in the ICT-using sector. Since 2000, the main driver has been MFP growth in those industries that are the most intensive users of ICTs. As a result of this shift, the fall in ICT prices has become even more important for a sustained MFP growth over time.

Jorgenson (2008) distinguishes three scenarios. In the optimistic one, ICT prices would keep falling at a rate of 30% per year from 2010 on, which would allow for a continuation of the productivity growth. In the base scenario, the 1995-2010 would be a one-off acceleration, ICT prices would fall at a "normal" pace of 15% per year after 2010 and productivity growth would return to the pre-1995 rates of 2.4% per year. In this scenario, Europe would benefit from the lagged effects of ICT investment and could converge to the U.S. productivity level by 2020. In the pessimistic scenario, ICT prices would fall by only 5% per year after 2010, U.S. productivity growth would fall below the 1973-1995 levels while Europe would still have the possibility to catch up. However, after 2020 productivity in both the U.S. and the EU would grow at historically low rates.

What is growth accounting not taking into account?

There are several well-known issues with the growth accounting approach. First, growth accounting describes but it does not explain. There is no attempt to claim that there is any causal relationship between changes in input, such as ICT capital, and productivity. It is simply assumed in growth accounting that the shares of ICT capital measure its contribution, and no attempt is actually made to estimate the strength of the relationship from the data.

Second, the assumptions underlying the growth accounting are strong and generally not tested. It is assumed, for instance, that all markets are perfectly competitive and that production in every sector is characterised by constant returns to scale. Labour and capital are assumed to be completely mobile, an assumption that implies a single wage rate for labour across all sectors and a single rental rate for each type of capital. Within this competitive market structure, firms are assumed to set their investment and hiring decisions to maximise profits. Moreover, when firms purchase new capital or hire more workers they are assumed not to incur in any adjustment cost not to experience any temporary decrease in output while these new inputs are integrated into the production routine. Also growth accounting does not allow to model for cyclical changes in intensities with which firms use their capital and labour.

Finally, if there are externalities related to production factors, they will be included in the residual (MFP), and the contribution of these factors will be underestimated.

Further analytical findings at the macro level

Econometric estimation of the production function provides an alternative approach to growth accounting. Though different econometric techniques are suitable to this purpose, the most widely used remain the OLS, which do not account for unobserved heterogeneity (factors correlated with productivity that are not measured) and endogeneity (input factors such as ICT are chosen by firms and are not exogenous). Some studies use estimation methods that are better suited for dealing with these problems, such as the General Method of Moments (GMM) and the Olley-Pakes method.

Gust and Marquez (2004) use aggregate data for thirteen industrialised countries from 1993 to 2000 to explain why ICT diffusion positively impacts productivity growth only in the United States. They model labour productivity growth as a function of ICTs and other controls (like employment to population ratio and countries fixed effects). They find that ICT production and, to a lesser extent, ICT expenditures are associated with higher productivity growth. They also point out that regulation plays a predominant role in influencing the speed of diffusion of information technologies. Burdensome regulations have impinged on firms' incentives to adopt new technologies in several countries, slowing down the rate of adoption of ICTs. A wide variety of regulatory regimes across countries, ranging from product market regulations, which may result into lower market competition, to business regulation, which may raise the entry costs of new firms, to labour market regulations, which may reduce the ability of firms to adjust their workforce in a flexible manner.

Nicoletti and Scarpetta (2003) show that lower entry barriers stimulate MFP growth in the manufacturing sector in OECD countries. Whether their results also apply to services, it remains an interesting question as market services are intensive ICT users and among the most highly regulated industries today (Conway and Nicoletti, 2006). Inklaar *et al.* (2008) look at the impact of regulatory barriers to entry in services, but they find only limited evidence in support of this hypothesis. MFP growth in post and telecommunications benefited substantially from entry liberalisation during the 1990s. This supports the view that deregulation fosters productivity, but similar evidence has not been found for other industries. The analysis, however, does not reject the notion that a decline in entry barriers in services may unlock the productivity growth potential of other market services.

While ICTs have been a major source of innovation over the last few decades, most of the measured MFP acceleration has taken place outside of the production of ICT goods. This pattern is consistent with the view of ICTs as a "general purpose technology" (GPT): an innovation in one sector, ICTs, causes unexpected waves of ICT-related invention and investment in sectors that seem far away.

The hypothesis of ICTs as a GPT suggests that measured MFP should rise in ICT-using sectors - due to the accumulation of intangible capital, change in organisation and spillovers - but only with some lags. In fact, contemporaneous investments in ICT may even be associated with lower MFP as resources are diverted to reorganization and learning.

Basu *et al.* (2003) and Basu and Fernald (2007) tested these predictions of the GPT hypothesis using BLS data on capital input by industry. They found that the impact of ICT investments on MFP growth has a lagged effect while ICT capital growth in the late 1990s turned out to be negatively correlated with contemporaneous MFP growth. They also find that industries that had high ICT capital growth rates in the 1980's or early 1990s also had high MFP growth rates in the late 1990s.

These findings seem consistent to the interpretation that the European firms have been slower to reorganise and adjust to ICTs and that tighter labour and product market regulation is not helping this reorganizational process (Gust and Marquez, 2004).

O'Mahony and Vecchi (2005) use a dataset of U.S. and UK non-agricultural market industries to estimate the impact of ICT capital on output growth. As traditional industry panel data analysis fails to find a positive contribution, they employ a dynamic panel data approach in order to account for heterogeneity across industries. Pooled estimates show a positive and significant return of ICT capital on output growth. ICT investment produces excess returns as compared to the prediction from growth accounting. Individual countries estimates imply a larger long-run impact in the U.S. than in the U.K.

Some macroeconomic studies focus on specific ICT infrastructures such as telecommunication or broadband infrastructure and find positive and significant impacts on growth. Czernich *et al.* (2009) test the effect of broadband infrastructure on economic growth using an annual panel of 25 OECD countries in 1996-2007. In order to control for the endogeneity of the broadband penetration, they specify a technology diffusion model in which the ceilings of the broadband diffusion curve across countries are determined by the size of the pre-existing traditional networks. The results show a positive effect of broadband diffusion on economic growth, suggesting that a 1 percentage-point increase in the broadband penetration rate results into a 0.09-0.15 percentage-point increase in annual per-capita growth.

Koutroumpis (2009) analyses the effect of broadband infrastructure on GDP growth in OECD countries between 2002 and 2007. To control for the bidirectional relationship between infrastructure and growth, he uses a simultaneous equation model that endogenises supply, demand and output. His results suggest that 1 percentage-point increase in the penetration rate increases GDP growth by an average of 0.025 percentage-points. In addition, there is evidence of increasing returns to broadband telecommunication investment, consistent with the persistence of network effects. The critical mass in broadband infrastructure investment is estimated to be at 30 per cent of broadband penetration, which effectively translate into half of the population having access to broadband connection.

Using a similar methodology, Roller and Waverman (2001) investigate the relationship between investment in telecommunication infrastructure and economic performance in 21 OECD countries over the period 1971-1990. Controlling for simultaneity and country-specific fixed effects, they find a causal relationship between telecommunication infrastructure and aggregate output. Their results suggest that 1 percentage-point increase in telecommunication penetration rate (main telephone lines per capita) increases aggregate output growth by an average 0.045 percentage points.

In an interesting meta-study, Stiroh (2004) compares the methods, data and results of a set of 20 studies. He finds out that the estimated ICT elasticity to output differs among studies due to the econometric method, the sample period or the level of aggregation. Studies reporting excess returns to ICT investments are characterised by the omission of important variables - such as improved workplace practices and firm reengineering - related to ICT deployment. When controlling for unobserved heterogeneity via fixed effects, the ICT coefficient falls substantially. The GMM estimation, which accounts for unobserved heterogeneity and simultaneity, suggests that ICT matter but excess returns are replaced by normal returns.

Further research is needed to understand these contradictory effects. While macroeconomic analyses of the productivity effects of ICT treat labour as homogeneous, considering the role of different occupations and qualification levels would provide a more complete picture of the productivity potentials of ICTs.

The contribution of firm level studies

Firm-level studies help to disentangle what is hidden in multifactor productivity (Draca *et al.*, 2006). Most firm-level studies show a positive and significant association between ICTs and productivity growth. In addition, the magnitude of the ICT coefficients is larger than it might be expected from the standard neoclassical assumptions underlying the growth accounting framework. This finding suggests the existence of positive spillovers from ICT investments.

A plausible explanation of why positive spillovers are apparent at the firm-level but not in more aggregated estimates, is that they reflect the increase in the market shares of more productive firms. If two firms invest equally in ICTs but they differ in their capability to introduce complementary organisational changes, the productivity increase associated to their ICT investments will also differ. As a result, the increase in productivity at the industry level will be lower than at the firm level. Eventually lagging firms will either exit the market or catch-up with the leaders due to competitive pressure, but this process inevitably takes time. In the meantime, country or industry performances would reflect the performances of both lagging and leading firms.

Micro studies also permit to account for improvements in output quality, such as faster delivery and customisation of products, which are among the most characteristic effects of ICT investments. The problem of unmeasured quality changes in aggregate statistics is especially important in the case of unmeasurable services (trade, finance, insurance etc.) where ICT investment has grown more rapidly. As a consequence, the contribution of ICT to real output growth inferred from aggregate data is likely to be underestimated. On the contrary, firm-level studies suffer less from measurement bias because micro data permit to account for differences in output quality among firms and through time. Controlling for these differences is likely to result into higher estimates of the output elasticity to ICT investment.

Most of the studies on the impact of ICT carried out at the firm level employ a production function framework to estimate the elasticity of output with respect to ICT capital. The quantitative results of these studies, however, vary considerably. Apart from differences in the definition of ICT capital stocks and sample design, much of this variation may be due to differences in the econometric techniques and model specifications.

Brynjolffson and Hitt (2003) apply standard growth accounting and productivity measurement approaches to examine the relationship between computer spending and growth in output and MFP in 527 large U.S. firms. They estimate that the contribution of computerization to productivity and output growth in the short term (1-year difference) is roughly equal to the cost of computers. However, the ICT contribution is up to five times greater over longer periods (5 to 7-year differences). This suggests that, in order to generate productivity gains, ICTs require investments in complementary assets, such as organisational capital, over a prolonged period of time.

Bloom, Sadun and Van Reenen (2005) compare productivity growth among U.S. multinational, non-U.S. multinational and domestic firms based in the UK. Their results point out that the way U.S. firms are managed or organised enables better exploitation of ICTs. This finding supports the view that faster productivity growth in the US is mainly due to organisational capital.

Bresnahan, Brynjolffson and Hitt (2002) investigate the hypothesis that the combination of three related innovations - information technology, complementary workplace reorganization and new products and services – resulted into skill-biased technical change and affected labor demand in the United States. Using detailed firm-level data, they find evidence of complementarities among all three types of innovation in factor demand and productivity regressions. In addition, firms that adopt these innovations tend to use more skilled labor. The effects of IT on labor demand are greater when IT is combined with the particular organizational investments that they identify, highlighting the importance of IT-enabled organizational change.

Hempell and Zwick (2007) regress measures of organisational flexibility on ICTs and control variables and point to flexibility as an important link between ICTs and firm performance. They argue that ICTs enable flexibility in labour organisation while flexibility enhances innovative capacity. Flexibility increases the workers' mobility between activities and tasks, empowers workers with greater responsibility in decision-making and provides them with a greater variety of activities (team work, autonomous workgroups and flat hierarchies). Flexibility also increases the scope for outsourcing or contracting-out jobs to specialised suppliers, which can produce at lower costs and/or higher quality through economies of scale and learning effects.

The increasing complexity and widening scope of ICT applications have increased the necessity for external know-how. Firms contract ICT consulting and source out ICT maintenance and support in order to use these technologies more efficiently. Abramovsky and Griffith (2006) use a large and representative dataset of UK establishments to investigate how ICT investments affect outsourcing and offshoring services. They find that more ICT-intensive firms purchase a greater amount of services on the market and they are more likely to purchase offshore than less ICT-intensive firms.

Bartel, Lach and Sicherman (2005) provide evidence that an increase in the pace of technological change increases outsourcing because it allows firms to use services based on leading edge technologies without the costs of adoption of these new technology. Furthermore, they find a positive correlation between a firm's ICT capital and the share of ICT-based services outsourced.

Ohnemus (2009) analyses a comprehensive panel survey of German manufacturing and service firms between 2000 and 2007. He compares different estimation techniques (pooled OLS estimation, fixed effects vector decomposition approach, Olley and Pakes approach and system GMM estimation) in order to control for unobserved firm heterogeneity, measurement errors in the variables and simultaneity of inputs and outputs. All specifications show a positive impact of business process outsourcing on firm-level productivity.

Cerquera and Klein (2008) argue that the benefits of ICTs are not equally distributed among adopting firms. As some firms reap those benefits sooner and better than others, the adoption of ICT represents a source of firm heterogeneity that might generate competitive advantages, affect firm strategies and/or influence aggregate productivity growth. Based on the ZEW ICT Survey in Germany, their paper shows that ICTs have a robust, positive impact on firm heterogeneity. This result is shown to be robust to different empirical strategies. In addition, ICT-induced heterogeneity has a significant and positive, albeit small, impact on the incentives to innovate, particularly on the decision to invest in R&D personnel.

While most studies refer to ICTs as a homogeneous aggregated input, some recent contributions have been looking at different ICT applications (e.g. e-commerce, enterprise resource planning, supply chain management, customer relationship management, etc.) and their specific effect on productivity.

Bertschek *et al.* (2006) provide evidence of a simultaneous relationship between labour productivity and the adoption of Business to Business e-commerce (B2B) in a dataset of 1460 German firms. Firms deciding to use B2B e-commerce employ their input factors more efficiently than non-B2B users. Conversely, firms seem to refrain from engaging in B2B because they expect the cost of B2B adoption not to be sufficiently compensated by productivity gains.

Engelstätter (2009) studies a number of ICT applications to enterprise systems such as Enterprise Resource Planning (ERP), Supply Chain Management (SCM) and Customer Relationship

Management (CRM). The analysis, based on a production function, focuses on the productivity impact of the adoption of more than one enterprise system at a given time. The data refer to German enterprises of different industry branches from the manufacturing and service sector. The results confirm the expected positive effect of the enterprise systems on labour productivity and show a complementary relationship between SCM and CRM, especially if the necessary ICT infrastructure is provided through the ERP system. Therefore, the use of the three enterprise systems together seems to deliver the largest productivity gains.

A recent report on the economic impact of ICTs by Van Reenen *et al.* (2010) analyses the AMATECH database, which combines company-level data from BVD'Amadeus, Harte Hanks'data on ICT and the EPO data on patents and their citations. Through microeconomic production functions and technology adoption equations, the authors provide evidence that returns to ICT capital are above normal in European firms. They also find that intangible complementary assets significantly affect the impact of ICT. These assets include organisational capital, in particular firm decentralisation and management practices. Investment in highly qualified personnel and employees with ICT skills is another important condition for the full exploitation of the ICT potential. In addition, the report points out that labour market and product market regulation affect productivity negatively and explain a major part of the differences between U.S. and European productivity.

What are the implications for the policies?

The economic literature shows that ICTs are an important driver of productivity and growth. However, countries, industries and firms continue to show great differences both in the intensity of ICT use and in their capability to reap the productivity gains from ICTs.

Low intensity of ICT capital and use may call for policy measures – such as direct subsidies or tax incentives - to support the diffusion of ICTs among firms. However, the evidence of ICT productivity spillovers, which would justify these policies, remains weak (Van Reenen *et al.*, 2010). Contrary to this argument, there is increasing evidence that ICTs act as an enabler of innovation, increasing the capabilities of firms to introduce new products, new processes, new organisation and new marketing methods (OECD, 2010).

A complementary policy approach, which is currently taken in a significant number of countries, focuses on the development of backbones ICT infrastructures, eg: broadband. Some of the studies reviewed in this paper detect significant network spillovers for which the increase in productivity from broadband usage depends on the number of users. The existence of network spillovers deserves further research but, if confirmed, it would provide a sound justification for ICT infrastructure policies.

A third area for policy intervention focuses not on the diffusion of ICTs but on the productivity gains associated to ICT use. Indeed, most studies suggest that complementary production factors (management practices and organisational structures) as well as regulations of labour and product markets explain a good deal of the observed differences among countries.

Therefore, policies aimed at fostering investment in complementary assets would raise the return to ICT investment and encourage their faster diffusion. Similarly, policies aimed at increasing competition, raising human capital, lowering barriers to trade and foreign investment, removing distortion in the tax system and increasing labour market flexibility would help Europe to employ ICTs more efficiently and to resume the catching-up process with the U.S.

While there is increasing consensus in the ICT policy and academic community about this approach, its main drawback is that its implementation goes well beyond the field of ICT policies. Market regulations, tax systems, trade tariffs may be hampering ICT-driven productivity growth but they serve other policy purposes. In order to gain support for change in regulations and institutions, one needs compelling evidence that the costs from these changes are more than offset by the benefits delivered by ICTs. This is clearly a piece of evidence that is highly needed but not an easy one to deliver.

Finally, also in areas where ICT policies converge with other policy objectives - such as investment in human capital, increasing competition, etc. – their implementation requires a high degree of coordination among different ministries and institutions. While this is an issue of governance that goes beyond the scope of the present analysis, more evidence is necessary to measure the complementarities/externalities between ICT policies and the policy areas.

The severe budgetary constraints faced by many governments as a consequence of the financial crisis makes the evaluation of ICTs policies even more important. The massive investments in broadband infrastructures included in the stimulus packages in the aftermath of the crisis show that most countries regard ICTs as one of the keys to emerging from the economic downturn and putting economies back on a path of sustainable growth. However, as policy programs are going under close scrutiny in the search for budgetary cuts, it becomes of foremost importance to provide a rational for ICT policies based on their impact on productivity and growth.

Issues for discussions

- Over the last two decades Information and Communication Technologies (ICTs) have been a main source of growth in value added and productivity. However, countries, industries and firms show large differences in their capability to exploit the potential of ICTs. Are ICT-driven productivity differences across countries and sectors temporary or permanent? Are the productivity effects of ICTs likely to converge across countries and across industries?

- Growth accounting shows that the contribution of ICTs to MFP growth has decreased in all industrialized countries after 2004. Is the observed decrease a sign that the "ICT wave" is approaching to an end, as it was the case for other general purpose technologies in the past, e.g. electricity? Or is the decreasing contribution of ICTs to MFP the result of our limited capability to measure intangible assets? To what extent is MFP an "artefact" of the hypotheses – perfect competition, separable production function, etc. - underlying the growth accounting approach?

- Firm-level estimates of the output elasticity to ICT capital are typically larger than what is postulated by growth accounting. This suggests the existence of positive spillovers from ICT investments. Their size, however, varies significantly depending on the estimation methods and the model specifications. As spillovers provide a sound rational for ICT policies, it is important to have a reliable estimate of their size. Are some techniques or models preferable to others? Is it possible to assess the strengths and weaknesses of different approaches?

- Micro-level studies help to disentangle the factors hidden in the MFP estimates but provide only a partial picture of the overall effects of ICTs on the economy. How can we better connect the macro and the micro analysis as to identify the main channels through which the diffusion of ICT affects aggregate productivity and economic growth?

- A majority of studies on the impact of ICTs are based on U.S. data, mainly due to data availability and accessibility. Some significant progress has been made in Europe in recent years, e.g.: the EUKLEMS and the AMATECH databases. Some EU projects (COINVEST, INDICSER) have also tried to develop comparable data on intangibles. What further progress can we make in the production of ICT statistical data? What are the statistical priorities to evaluate the economic impact of ICTs?

- ICTs are universally regarded as a key source of growth but the severe budgetary constraints inherited by many countries after the crisis put the effectiveness ICT policies under scrutiny. Can we provide a sound evaluation of the returns from public investments in ICT infrastructures, e.g.: broadband? Is there a justification for public support to ICT investments other than R&D? Can we provide compelling evidence that the costs from relaxing regulation in product and labour markets would be more than offset by the benefits from further diffusion of ICTs?

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