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Contribution of information and communication technologies (ICT) to growth

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The contribution of information and communication technologies (ICT) to economic growth has stabilised since the early 2000s in industrialised countries. To date the euro area has benefited less from this than the United States. Appropriate policies would enable the euro area to catch up.

This Rue de la Banque *compares changes in the contribution of ICT to economic growth in the United States, the euro area, and the United Kingdom over the 1970-2013 period. After a long period of sustained growth, ICT diffusion as a factor of production has stabilised since the early 2000s, at levels that are significantly higher in the United States than in the euro area, while the United Kingdom is in a position in between these two areas.*

Ample empirical literature has been dedicated to the analysis of the diffusion and the contribution of information and communication technologies (ICT) to economic growth (see Cette *et al.*, 2015). These analyses show that ICT diffusion and its contribution to productivity growth increased steadily up until mid-2000s, and that both are higher in the United States than in any of the other advanced countries. Furthermore, Cette and Lopez (2012) demonstrate that ICT diffusion as a factor of production in the advanced countries stabilizes in early 2000s and displays divergent gaps with a strong advance in the case of the United States. Byrne *et al.* (2013) show that the contribution of ICT to productivity growth falls sharply in the United States from the mid-2000s, before the inception of the current crisis.

ICT contributes to productivity growth through three channels: i) the use of ICT as a factor of production in which these technologies characterise both a growing use and strong, continuous advances in performance; ii) the production of ICT of which the significance has increased over the past few decades with very high advances in productivity; iii) externalities. Our analysis looks only at the first one.

The methodology adopted to assess the contribution of ICT capital to labour productivity growth is the one used for the growth accounting approach. It is detailed in Cette *et al.* (2015).

The diffusion of ICT

The ICT capital coefficient, which relates ICT capital to GDP, characterises the diffusion of ICT in this study. This indicator can be constructed in value or in volume terms where the ICT to GDP price ratio links these two measures together.

Following a balanced growth path, once ICT diffusion reaches maturity, we expect stability in the ICT capital coefficient in value terms as well as in the other products

NB: We wish to thank Dirk Pilat, Belen Zinni and Anita Woelf of the OECD for having provided us with the ICT investment data.

that make up capital. This stability is associated with a prolonged, if not permanent, change in volume if the investment price relative to the GDP price is not stable. For decades in the past, the relative price of ICT has constantly dropped and has significantly contributed to a fall in the relative price of total investment. The fall in the relative price of ICT started slowing in the mid-2000s before the beginning of the current crisis. The slowdown, which has given rise to a major debate which is still inconclusive in economic literature, is the subject of various interpretations (see Cette, 2014, for a summary). One largely developed by Gordon (2012, 2013) discusses how the slowdown can result from a gradual exhaustion of Moore's Law caused by technological advances in semiconductor chips due to continuous improvements in transistors. In addition to these advances, measurement difficulties in national accounts and performance improvements can also completely or partially explain this decelerating phenomenon (see Byrne *et al.*, 2013).

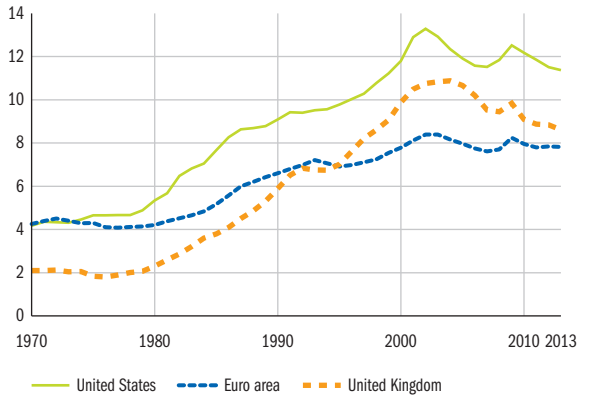
After a rather stable decade in the 1970s, the ICT capital coefficient in value terms rises throughout the two successive decades in the United States, the euro area, and the United Kingdom (see Chart 1). This rise implies a growth in diffusion which is linked to an increase in the use of these productive technologies. The ICT coefficient reaches a maximum in the early 2000s and then tends to stabilise in the euro area, decrease slightly in the United States and decline more markedly in the United Kingdom. The peak at the beginning of the 2000s reflects an increased investment effort associated with the fear of Y2K.

The ICT capital coefficient at current prices stabilises at different levels with ICT diffusion settling at a higher level in the United States than in the euro area, and at an intermediary level in the United Kingdom. The lag of ICT diffusion is considerable. At the end of the period, the ICT capital coefficient in value terms of the United States is 30% higher than that of the euro area. Various authors in economic literature, such as van Ark *et al.* (2008), Timmer *et al.* (2011), and Cette and Lopez (2012), have already underlined this hierarchy of ICT diffusion, the highest being that of the United States.

Numerous studies provide explanations for these differences in ICT diffusion. Various factors underlying this hierarchy include the level of education among the population of working age, as well as labour and product market rigidities. An efficient use of ICT requires a higher degree of skilled labour than other technologies and a firm reorganisation which can be constrained by strict labour market regulations. Moreover, the slightest competitive pressure induced by certain product market regulations has the ability to reduce the incentive to exploit the most efficient production techniques. A large number of empirical analyses, like those of Aghion *et al.* (2009), Guerrieri *et al.* (2011), and Cette and Lopez (2012) who use country-level panel data or Cette *et al.* (2013) who use sector-level panel data, confirm the importance of the explanatory factors using an econometric approach. More precisely, the United States boasts the highest level of ICT diffusion thanks to a higher level of education among the population of working age and market rigidities below those in the euro area and the United Kingdom.

C1 ICT capital coefficient at current prices (ratio of ICT capital stock to GDP at current prices – the whole economy)

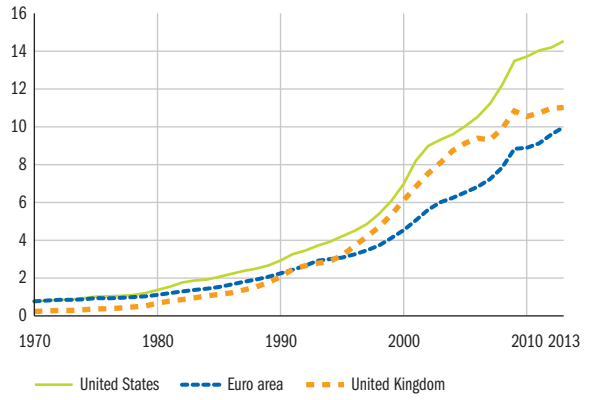
(in %)



Source: Authors' calculations.

C2 ICT capital coefficient at constant prices (ratio of ICT capital stock to GDP at constant prices – the whole economy)

(in %)



Source: Authors' calculations.

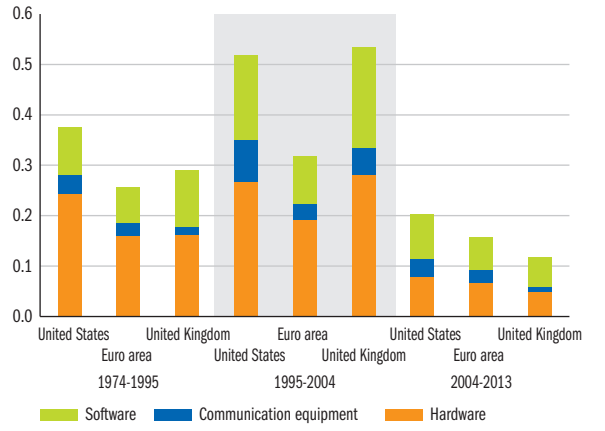
The ICT capital coefficient in volume terms increases continuously over the entire series in the United States, the euro area, and the United Kingdom (see Chart 2). This indicator follows the same hierarchy of ICT diffusion as the preceding indicator at current prices. At the end of the period, ICT diffusion is the highest in the United States and the lowest in the euro area, the United Kingdom being in an intermediary position.

Contribution of ICT capital to labor productivity growth

We only consider the contribution of ICT capital as a factor of production. We assess the ICT contribution to labour productivity growth via an increase in the ICT capital intensity for the three periods starting after the first oil shock: 1975-1995, 1995-2004 and 2004-2013. The assessment distinguishes the contributions of the three ICT products: hardware, software, and communication equipment.

The 1995-2004 period represents the highest contribution of ICT to hourly labour productivity growth (see Chart 3). Economic literature frequently underlines the substantial increase in the contribution of ICT starting in the mid-1990s (for example, see Jorgenson, 2001, Jorgenson *et al.*, 2006, or Byrne *et al.*, 2013, for the United States; and Cette *et al.*, 2009, van Ark *et al.*, 2008, or Timmer *et al.*, 2011, for different advanced countries). The increase is linked to the acceleration of ICT capital in volume terms which is linked to ICT capital in value terms and to the relative price of GDP with respect to ICT.

C3 Contribution of ICT capital intensity to hourly labour productivity growth
(in points per year)



Source: Authors' calculations.

From 2004 onwards, the contribution of ICT decreases in the United States (see Byrne *et al.* (2013), and also in the euro area and the United Kingdom, where the contribution of ICT falls below the contribution during the 1975-1995 period. The momentous decline is explained by a slowdown in the volume of ICT capital, itself linked to the value of ICT capital already mentioned and the relative price of GDP compared to ICT. It also reflects a gradual exhaustion of improvements in ICT performance. This issue, as developed by Gordon (2012, 2013), is not agreed upon unanimously (see Cette, 2014, for a literature review on the issue). Finally, we note that over the three periods, the "communication equipment" component of the contribution is clearly below the other two: "hardware" and "software". The observed hierarchy is in line with what is seen in the previous economic literature (see the references previously mentioned).

Conclusive Remarks

These results provoke two questions. The first relates to the exhaustion of advances in ICT performance, which could allude to the ebb in one of the sources of advancement in productivity that has occurred over the past few decades. As a consequence, this would decrease medium and long term potential growth for the main advanced economies. The second question relates to the lag in ICT diffusion as a factor of production from which the euro area, and the United Kingdom suffer in comparison to the United States. The existing economic literature shows that the lag can be explained, in particular for the euro area, by a lower average level of education among the working population and, to a greater extent, by anticompetitive regulations and labour and product market rigidities. This means that ambitious structural reforms could contribute to reducing this gap, enabling the euro area to benefit from significant advances in productivity inferred by a stronger diffusion of ICT. In the current period characterised by lifeless growth in the euro area, this finding strongly contends for an implementation of such ambitious reforms.

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Appendix

Data and methodology

The proposed analysis concerns the entire economy of each country (not just the business sector). The ICT investment data are supplied by the OECD for each of the three ICT products typically distinguished in economic literature (hardware, software, and communication equipment) for six countries of the G7 (United States, Germany, France, United Kingdom, Italy and Canada) and four other European countries (Spain, the Netherlands, Belgium, and Finland). Aggregating the data of Germany, France, Italy, Spain, the Netherlands, Belgium and Finland, which represent roughly 84% of the GDP of the euro area in 2012, enables us to rebuild, after various corrections and backcastings, a series of data concerning this area for the 1950-2013 period.

The capital stock in volume and value terms is constructed for each of the three ICT products using the perpetual inventory method[1] while assuming a constant annual depreciation rate of 30% for hardware and software and 15% for communication equipment. The total ICT capital stock is recreated, in value and volume, by aggregating the capital stock of each product.

GDP at current prices and its deflator are essentially provided by Eurostat and the OECD. The investment price indices are built, for each country and ICT product, from the United States' national accounts data (BEA), their price indices fully integrating technological advances in ICT performance via hedonic methods. For the other countries, the relative price ratio of investment in each of the ICT products to GDP is assumed to be the same as that of the United States. This methodology was proposed by Schreyer (2000).

1 *For each of the three ICT products indexed by* j, *the capital stock (in value or volume) at the end of year* t, $K_{j,t}$, *is constructed using the relation:* $K_{j,t} = I_{j,t} + (1-\delta_j) K_{j,t-1}$ *where* $I_{j,t}$ *corresponds to investment in product* j *during the year* t, *and* δ_j *refers to the constant annual depreciation rate specific to product* j.

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