# Annex 6 - The impact of ICT on hourly labour productivity

## 1. Introduction

In the US, before 2001, the parallel increase in investment in Information and Communications Technology (ICT henceforth) and in Total Factor Productivity (TFP) suggested the existence of a strong relationship between both of them. Afterwards, following the burst of the technological bubble, ICT investment was scaled back substantially, whereas TFP kept increasing, calling for a reconsideration of the link between both variables.

In Europe, the attention has been focused on the sluggishness of ICT investment with respect to the US and on modest productivity gains between 1995 and 2001 (Van Ark *et alii*, 2003).

Another important and much debated issue is the source of productivity gains. According to some authors, such as Gordon (2003), these are mostly concentrated in the sectors producing durable goods. Other studies, on the contrary, claim a spill-over of productivity gains into sectors using ICT, namely retail services and finance (Bosworth et Triplett, 2003; Jorgenson *et alii*, 2002).

These results are obtained using the same data on investment and highlight how difficult it is to measure growth, hourly labour productivity and their sources. The problems are even bigger for international comparisons, as national statistical offices use different estimations to compute production, investment and hours worked.

Growth accounting provides a framework to analyse the evolution of productivity. Methodological choices and the type of series used allow for the different results obtained by the studies quoted above. We employ this framework for France, the UK, Germany and the US.

Section 2 illustrates the sources of hourly productivity at the macroeconomic level. We highlight the methodological differences with respect to other studies, and especially those about the US.

Section 3 shows the results for the sectors producing and using ICT. Sectoral evaluations are to date not very numerous[1]. Methodological issues are even more excrutiating at the sectoral level, making international comparisons tricky. The sectoral analysis is, however, interesting as allows to delineate the ICT contribution to productivity and assess the scope of productivity gains spill-over to the ICT using sector.

Our results are consistent with previous findings and show important TFP gains in ICT producing sectors. Our sectoral results for the US are broadly consistent with those of Bosworth and Triplett (2003), and indicate significant productivity gains in trade and finance. The UK findings are quite equivalent to those of the US. On the contrary for France, these gains are found to be negative in ICT using industries.

## 2. Contributions to hourly labour productivity growth

ICT, viewed as all-purpose technologies, are associated with a third industrial revolution in most of the recent literature, as it increases growth potential and brings about productivity gains improving the quality of life. However, some scholars (Gordon, 2003) are quite sceptical about the capability of ICT to generate innovations big enough to trigger a true technological change. The debate is based on the analysis of the US, where a quick acceleration in productivity growth has been associated with a strong ICT contribution during the second half of the 90s.

Different estimations have been carried out using a standard growth accounting framework, based on the Solow model. Three factors contribute to hourly productivity growth: capital deepening (the ratio between capital services and hours worked), labour quality (labour services divided by hours worked) and TFP (see annex 3).

### 2.1. Previous studies

Considering the 1995-2001 period, the hourly labour productivity has evolved in a bracket of 2 to 3%. The contribution of ICT capital to productivity growth has amounted to around 0.7-1 percentage point, and the one of TFP to 0.40-0.99 according to the period considered and the methodology chosen. (Oliner and Sichel, 2002; Van Ark et al., 2003; Council of Economic Advisers, 2002 ; Jorgenson et al., 2003 ; Jorgenson, 2003). The details are shown in table 1[2].

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[1] Dale Jorgenson is revising his sectoral estimates. Those of Bart van Ark et alii (2002) and those of Bosworth and Triplett (2003) bear on productivity per employee.

[2] Hélène Baudchon (2002) and Cette et alii (2001) provide an exhaustive review of the literature on the 1995-98-99-00 period.

**Table 1: Sources of hourly productivity in the US and Europe, 1995-2001**

(average annual growth in percentage points)

| | Oliner & Sichel (2002) | C.E.A. (2002) | Jorgenson et al. (2003) | Van Ark et al. (2003) | |
|---|---|---|---|---|---|
| Field | Private non-agricultural sector | | Total Economy | Total –non residential | |
| | | | | US | Europe |
| Value added per hour | 2.43 | 2.60 | 2.02 | 1.85 | 1.37 |
| Total Capital | 1.19 | 1.29 | 1.39 | 1.05 | 0.90 |
| ICT capital | 1.02 | 1.01 | 0.85 | 0.72 | 0.42 |
| Other Capital | 0.17 | 0.28 | 0.54 | 0.32 | 0.48 |
| Labour Quality | 0.25 | 0.31 | 0.22 | n.c. | n.c. |
| TFP | 0.99 | 0.98 | 0.42 | 0.80 | 0.46 |
| TFP due to ICT | 0.77 | 0.24 | 0.41 | 0.44 | 0.27 |

Note: CEA: extrapolation 2001. Oliner and Sichel and CEA: data from BEA and BLS multifactor dataset.
For the detail of sources, see authors ‘articles.

Europe seems to be embedded in the same dynamics as the US, but with a lag which has not been reduced so far. First, during the last six years, hourly labour productivity and TFP would have decelerated by 1.07 and 0.67 point respectively (Van Ark *et alii*, 2003). Second, even if the contribution of ICT capital deepening to hourly labour productivity growth has accelerated, this increase quite underscores the one of the US.

The lag experienced by Europe in the use of ICT and in TFP acceleration is explained by several factors. Heavy regulation delaying the full ICT adoption, the size of the ICT producing sector, the early investment in ICT that has occurred in the US, and which was accompanied by complementary investment in reorganisation procedures, contributing positively to TFP in the following years.

In most of the explanations proposed, there appears a correlation between ICT capital deepening and increases in TFP, which questions the supposed exogeneity of TFP in growth accounting exercises. However, if we take into account the strong heterogeneity across branches, where ICT producing sectors have a much stronger TFP growth, total factor productivity growth would not be correlated with input growth (Stiroh, 2002)[3].

### 2.2. Methodology

The accounting framework used to estimate the contribution of new technology to growth is based on a standard translog function. The methodology applied is the one proposed by Jorgenson and Griliches (1967) which aims at accounting for the quality of inputs and highlighting the substitutions schemes across factors.

The series used for computing hourly labour productivity and its sources are not exempt from problems related to the aggregation procedure, the shares in total value added and the splitting between volume and prices when calculating ICT investment.

- The construction of an aggregate implies that its components must be weighted by a Tornqvist index (two-year average of the share of investment or value added). Series for investment in real terms and output are obtained by dividing the original series by the corresponding price index, whose value in 1995 is 1.
- Hours worked by self-employed and their compensation are included in the overall series. Their inclusion is justified by the consistency with the use of the value added series for the whole economy. Normally, these series are not available, and they are derived by estimation. If no information is available, hours worked are applied to the difference between total employment and salaried employees.
- Gross operating surplus is computed by subtracting compensation from value added. At the same time, figures are adjusted for the self employed mixed income which is imputed to compensation. For France, INSEE makes out gross operating surplus (GOS) from mixed income. In this case, total compensation is then deduced by removing the GOS series from value added.
- In order to disentangle the effect of prices ant that of volumes in ICT investment, national accounts for the US and some European countries use hedonic regressions as an alternative to the matching methods or to the factor cost approach[4]. Hedonics allow to take into account the increase in the quality of a good whose price is stable over time. If

[3] For example O'Mahony and Vecchi (2002) find opposite results taking into account heterogeneity across industries and time.
[4] A detailed description of the methodology can be found in: Cette, Mairesse and Kocoglu (2000).

computed in this way, the price of hardware decreases substantially, producing a strong increase in investment and output. Data for France is available only for computers produced after 1990. To overcome this problem, we harmonise price series for ICT assets applying the methodology originally proposed by Schreyer (2000). The ratio between non-ICT and ICT investment in the US is applied to the prices of national non-ICT assets. Such a correction is not devoid of consequences: in the case of France, the contribution of ICT to hourly productivity growth would have been 0.09 point of % lower had we have used INSEE price series.

- TFP is obtained as a residual and partially reflects short term phenomena (adjustment costs, input utilisation rate) and structural ones, as well as measurement errors (especially the share of factor income, assumed to be equal to input elasticity), omitted variables (investment in organisation, R&D), and deviations from the assumptions behind the neo-classical production function.

### 2.3. The impact of ICT on total hourly productivity.

As table 2 shows, between 1995 and 2001 the contribution of ICT capital deepening to hourly labour productivity growth was just 0.39 for France and Germany against 0.91 for the US and 0.85 for the UK. The difference in the size of the contribution reflects also the time length of the investment, as Anglo-Saxon countries began investing in ICT earlier in the 80s (table 2)[5].

In all cases, these levels result from a noticeably strong acceleration relative to the previous period, but the levels reached are very different. Otherwise, the parallelism between levels and evolutions in the US and the UK on the one hand, and the ones of Germany and France on the other hand is striking. With respect to the European lag mentioned above, UK shows up as an exception, its ICT contribution being very close to the one of the US.

Labour quality takes into account the effectiveness of hours worked according to the type of the workforce. Quality here is computed using gender, age and education as criteria (see annex 3).

While the contribution of labour quality between 1995 and 2001 is more or less equivalent in the four countries, the underlying conditions contrast sharply.

[5] Capital services are summed on the user cost-weighted growth of capital stock of each asset. As the user cost is calculated from capital stock, the more a country invest in ICT the more important ICT capital services are as the weight is then higher.

Concerning France and Germany, the deceleration in quality is mostly due to age, whereas education explains the deterioration occurred in the US. Labour quality reflects the workings of social policies introduced in France in order to promote the employment of young people, or other phenomena such as the increase of employment of less qualified workers in the US. In the UK, the share of skilled workers increases starting from a very low value.

All the four countries experience a positive TFP growth, with the US paradoxically showing the weakest performance over the 1995-01 period. In the nineties, TFP gains increase in France, Germany and the US. They slowdown in the UK but from a high level over the previous period. Thus, hourly labour productivity gains are comparable across the four countries, but the highest contribution of ICT capital deepening in the US and UK is compensated by lower TFP gains in both countries.

Such a result is in sharp contrast with the much higher TFP gains found in the literature for the US. This difference stems from two sources: the database and the methods employed:

- Concerning data, GDP growth taken from the most recent US national accounts is similar to the one published by the OECD (3.42%), but is lower than the one by Jorgenson (3.58%) or van Ark (3.52%). Our series for hours are taken form D. Jorgenson’s dataset and are close to those by OECD. Therefore, we obtain the same growth rate for hourly productivity over the 1995-01 period (1.92% per year).

  There are two different approaches to the computation of capital series: those by Jorgenson take into account total investment including residential investment, whereas we follow van Ark and OECD and just consider non-residential investment. ICT investment does not include communications equipment in Jorgenson’s study, whereas it includes office machinery in van Ark’s. TFP is obtained as a residual in all the papers except in van Ark *et alii*, where it is based on the one obtained by Jorgenson, Ho and Stiroh (2002).

- Concerning the methods a few important differences come forth:

- Contrary to most of the studies, we integrate labour quality, following Jorgenson. Our results are very close to his.

- Capital services derive from weighting the growth rate of the capital stock by user costs. These are computed by using a rate of return, a depreciation rate and possibly an adjustment for taxes. Following Jorgenson and van Ark, we compute an internal rate of return whereas the OECD use an external one (long term interest rates), what has implications in terms of the weighting scheme used in computing the contribution to growth. Capital services computed with an external interest rate are different from the gross operating surplus given by the national accounts. On the contrary, such an equivalence is respected by definition when an internal rate is used (see annex 3). We compute a geometric depreciation rate as in Jorgenson and van Ark, whereas OECD uses a hyperbolic one. Only Jorgenson adjusts the user cost in order to account for taxes.

- The biggest difference is the share of capital income in value added: 25% for OECD, 41% for Jorgenson, 30% for van Ark, and 37% for us.

Thus, the gap observed between our results and other studies' ones stems from the growth rate of GDP and the definition of ICT (with Jorgenson's), from the rental rate used (with OECD's), from TFP (with Van Ark's).

**Table 2: Contributions to hourly productivity growth: an international comparison**

(average annual growth rate, contributions in percentage points)

| | 1982-90 | | | 1990-95 | | | | 1995-2001 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | USA | UK | FRA | USA | UK | GER | FRA | USA | UK | GER | FRA |
| GVA per hour | 1.65 | 1.84 | 2.60 | 1.35 | 3.19 | 1.87 | 1.80 | 1.92 | 2.22 | 2.05 | 2.21 |
| Capital, of which: | 1.33 | 2.27 | 1.21 | 1.02 | 1.89 | 1.08 | 1.13 | 1.46 | 1.41 | 1.09 | 0.91 |
| ICT | 0.70 | 0.74 | 0.36 | 0.56 | 0.53 | 0.22 | 0.20 | 0.91 | 0.85 | 0.39 | 0.39 |
| Other | 0.63 | 1.53 | 0.85 | 0.46 | 1.37 | 0.86 | 0.93 | 0.55 | 0.57 | 0.70 | 0.52 |
| Labour quality | 0.31 | 0.05 | 0.76 | 0.34 | 0.14 | 0.95 | 0.53 | 0.23 | 0.35 | 0.28 | 0.35 |
| TFP | 0.01 | -0.48 | 0.63 | -0.02 | 1.15 | -0.16 | 0.12 | 0.23 | 0.45 | 0.68 | 0.94 |

Notes: Total Economy-non residential investment.
Germany: 1991-95.
UK.: Investment data for 2001 estimated from investment series from Groningen University.
Source: see annex 1. CEPII, authors' calculations.

Faster growth in the US relative to Europe is not questioned. Our results suggest, however, the American growth stems from the increase in inputs and not from higher productivity gains. It is consistent with the decrease in labour quality that underlies the increased employment of unskilled workers over the last period.

Also, the impact of the 2001 recession influences the results for the US. However it did not prevent investment, and in particular in ICT, from expanding between the periods considered.

The much weaker increase in TFP in the US and UK, where ICT investment was stronger than in France and Germany, seems not to prove the existence of a link between investment in new technology and growth: however, heterogeneity of performances might blur the picture. Then, a clearer answer can be obtained by examining the sectoral evidence.

## 3. Sectoral analysis

ICT can deliver productivity gains both when it is produced and utilised. Most of the empirical works about the US economy found sizeable productivity gains in the ICT producing sectors and an increase in ICT capital accumulation in the economy as a whole. A detailed analysis on the impact of ICT on hourly productivity growth in France, UK and Germany can show if these countries have a pattern similar to the US.

### 3.1. Sectoral Breakdown

We consider two sectors; the sector producing ICT and the sector using it intensively. Data sources are provided in the appendix. Due to the lack of ICT investment data detailed by sector, Germany was dropped.

Contrary to Nordhaus (2000) or Oulton *et alii* (2003), where the user sector is obtained by removing the ICT producing sector from total economy, we define a sector using heavily ICT.

This sector deals with service industries: trade, financial activities, business and personal services (table 3). In the UK, real estate services cannot be dissociated from business services.

The classification we use is not arbitrary. On the one hand, ICT investment (hardware, software and communications equipment) are more likely to increase white collars' productivity rather than blue collars', and on the other hand, it has been shown that service industries are normally more intensive in ICT than the rest of the economy. Data sources are detailed in appendix 2.

The ICT producing sector includes: Manufacture of office machinery and computers (30), Manufacture of radio, television and communication equipment and apparatus (32), post and telecommunications (64) for France. For the US and UK, due to the lack of detailed investment series for industries 30 and 32, we use the aggregate mechanical (29-30) and electrical (31-32) industries for the former and the electrical and instruments industries (30-33) for the latter.

**Table 3: ICT producer and heavy user sectors, NACE nomenclature**

| | Producers | Heavy users |
|---|---|---|
| **France** | 30, 32, 64 | 50-52, 65-67, 71-74, 90-95 |
| **UK** | 30-33, 64 | 50-52, 65-67, 70-74, 90-95 |
| **US** | 29-30,31-32, 64 | 50-52, 65-67, 71-74, 90-95 |

Source: CEPII.

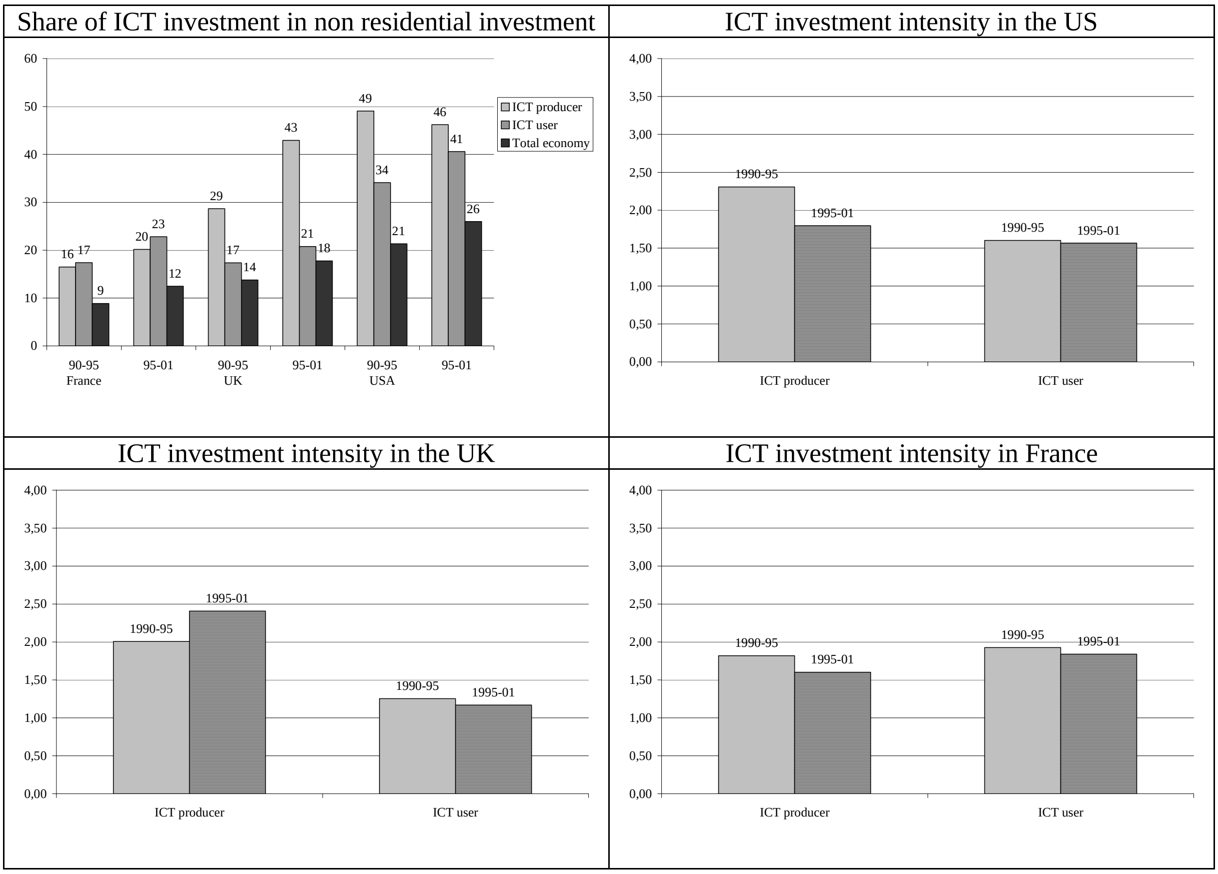
### 3.2. Contribution of ICT in the producing and using sectors

Unfortunately, the definition of the producer sector is quite heterogeneous across countries. On the contrary, the user sector is relatively homogeneous. Its weight is slightly higher than a third of total value added (37% on average).

The share of ICT investment by the producer sector is extremely high in the US and UK (46 and 43% respectively), over the 1995-2001 period. This share, which is roughly twice as great in this sector as what is observed in the rest of the economy, translates into a high ICT intensity in these two countries (graph 1). In France, the producer sector has only 16% of total investment devoted to ICT and this explains the weak intensity observed.

Turning to the user sector, UK and France investment in ICT is nearly one half that of the US (21 and 23 % respectively against 41%). However in France, this sector invested in ICT much more than the economy average (23% and 12% respectively) between 1995 and 2001. ICT investment in this sector is then even higher than in the US.

**Graph 1: Intensity in ICT investment (at current prices): comparison between France, UK and US**




Note: UK: 1995-00.

ICT investment intensity is defined as the ratio between the share of ICT investment in sector total investment and the same share for total economy.

Source: see annex 2. CEPII, authors' calculations.

### *The sources of the hourly labour productivity for the producer and user sectors*

The results presented in table 4, 5 and 6 help identify the sources of hourly labour productivity in France, US and UK for producer and user sectors. They show that growth in hourly productivity and TFP have been much faster in the producer than in the user sector.

Hourly labour productivity in the producing sector grows between 12 and 14 % in the three countries between 1995 and 2001. The comparison between the early 90s and the most recent period shows a marked acceleration.

The splitting of the TFP increase between both sectors is heavily influenced by the use of hedonic prices in order to compute the volume of ICT output and investment. With hedonic prices, the producing sector enjoys higher value added and productivity gains, whereas in the user sector TFP is unchanged and only higher investment in ICT has a positive impact on hourly productivity[6].

In the user sector, the productivity acceleration is general and strong in the nineties (except the UK with respect to hourly labour productivity). In the UK, and even more in the US, the productivity levels reached soar high for a service sector over the 1995-01 period with average yearly gains set at 2.41% in the UK and 3.87% in the US for hourly labour productivity and 1.65 and 2.54 points of % respectively for TFP. These unusual levels suggest that a high diffusion of gains linked to ICT would have taken place, all the more as the ICT contribution is large in both cases (0.66 and 0.99 point of percentage by year, respectively). It should also be noted that the strong TFP gains recorded point to a more efficient mix of inputs in these sectors.

The picture for the user sector in France is substantially different. The evolution of hourly labour productivity there is much lower than in the two other countries and TFP growth remains negative. The negative TFP gains in the French user sector are a challenge. The increase in value added in this sector is considerably smaller than in the US (2.7% and 6.2% respectively), even though they show the same increase in hours worked (2.13% for France and 2.28% for the US).

The main explanation for this divergence might be the low ICT investment growth and level shown by France in the user sector compared to the US where ICT capital deepening is very high over the 1995-2001 period. This being said, these results must be interpreted with caution, so far as the potential sources of mismeasurement are large. Particularly, the assessment of the production volume is chiefly tricky in these sectors (Wölfl, 2003). The definition of a financial service or trade production unit is far from being obvious, not to mention the consideration of their quality. The fall in TFP obtained here could then be more attributed to mismeasurement than to an economic truth.

***Details by sector***

Table 7 provides a breakdown of the sources of hourly productivity in the three countries. In the producing sector, TFP grows between twice and four times as fast in manufacturing as in services in every country. The impact of the use of hedonic prices proves to be sizeable (for example, between 1995 and 2001 the price of investment in computer falls by 80%).

[6] See G. Cette, Y. Kocoglu and J. Mairesse (2000) or Bosworth and Triplett (2003).

In the user sector, the results are more heterogeneous. In the US, TFP gains show up in trade (4.05 points), banking and finance (3.45 points), and personal services (3.72 points) over the last period. The contribution of TFP is however negative in business services (-1.32 point).

In the UK as well as in the US, TFP has a positive contribution to hourly productivity growth in trade (2.94 points), banking and finance (3.41 points) and personal services (1.24 point), but a negative one in business services (-1.41 point) over the 1995-01 period.

In France, the contribution of TFP is negative in all the user industries except trade, namely in banking and finance (-3.65 points), although the ICT capital deepening contribution is very high in this industry (contrary to trade and business services), even more than in the US. The contrast with the American and British high figures is striking even if a slight acceleration in the French productivity growth is recorded. We would have expected, on the contrary, a catching up in this industry, whose levels of hourly productivity were half of those of the US in 1992, according to Pilat (1996).

As emphasised above, productivity comparisons in services are quite awkward due to the difficulty in measuring production. In the US, as opposed to France, production in the banking sector is computed taking into account the quality of services (namely the number of ATMs). Between 1995 and 2001 value added in banking and finance, measured at constant prices has increased by 7.4%, whereas in France it decreases by 0.43%.

As far as the ICT user sector is concerned, a clear link between ICT investment and productivity cannot be found. In the US and UK, high ICT investment in business sectors does not translate into higher productivity, whereas weak ICT investment growth in retail trade in every country does not prevent robust productivity. However, it is still difficult to draw clear-cut conclusions, in so far as some factors could not be controlled for in the analysis, that it be the transitory costs linked to the reorganisation of production processes in the wake of a heavy ICT investment, or other factors not necessarily linked to ICT.

***Contributions of sectors to the aggregate hourly labour productivity***

To sum up, table 8 displays the respective contributions of the producer, user and other sectors to the aggregate hourly labour productivity. Due to the different shares of the ICT producer sector in value added in the three countries, the hourly labour productivity of this sector, though identical in the three countries turns into a higher contribution to the aggregate hourly labour productivity in the US than in the UK or France. The ICT user sector is a good performer in the US, and a poor one in France. In the latter country, the other sector, entailing mainly manufacturing industries, offers the strongest contribution to the aggregate hourly labour productivity. In the US, the ICT user sector is the major contributor to aggregate hourly labour productivity and in the UK, contributions are more balanced across sectors. This suggests that, in France, the source of productivity is to be found elsewhere than in ICT: the manufacturing sector occupying a lesser proportion of employees than the service sector, ICT has then a much lesser impact on hourly labour productivity. On the contrary in the US and to a lesser extent in the UK, the major source of it may be attributed to ICT. The contribution of the other industries to the aggregate hourly labour productivity is even negative in the US.

***What can foster the use of ICT?***

In the US and UK, the faster TFP growth evidenced in several user industries suggest the existence of relatively large spill-over effects. This is an important observation as to the scope of the technical revolution spread through ICT. In the UK and US, TFP gains are not confined to the producer sector. Opposite to the results by Gordon and in accordance with those of Bosworth and Triplett (2003) for the US, spill-over effects are rather important in all industries except business services.

These spill-over effects in the US and UK may also have benefited by a more competitive environment in both countries. As a matter of fact, regulation of activities such as the legal hurdles set on competition and trade or red tape that hinders the creation of firms, price setting and the mode of providing services would have a negative impact on employment and innovation in new sectors (Nicoletti and Pilat, 2004).

If competition is stifled, then the urge to invest in new technologies that would pop up in a competitive context is crushed. It could limit too the need to enlarge the variety of services offered to customers through electronic commerce. The size limit on supermarkets in big cities can also hinder productivity gains in so far as bigger units can cash in on economies of scale and network externalities (supply platforms for example). In France, where such limits exist in order to protect the small retail trade shops, it can play a role. However, the choice to maintain small units increases the consumers welfare as they enjoy more differentiated products and service varieties. It should also be noted that independent shops in France are more and more phased out, as they are gradually replaced by units linked into a network (franchise, etc.). This allows small units to be maintained, and at the same time productivity gains to be recorded through the more intensive use of ICT that ease network transactions to manage stocks, or just in time, redistribution and promotion of products.

Regulations in the labour market may also interact with the goods and services' one. For example, in the trade industry, longer opening hours consistent with the legislation in the labour market impact the volumes sold. Then ICT may help implement the new underlying organisation. Moreover, more flexible labour market laws like in the United States would allow the quicker adoption of productivity-enhancing technologies like ICT (Suppanz *et alii*, 2004). In France, retirement schemes in the next years will alleviate the possible mismatch between ICT and types of labour. Firms will then be able to choose the skills suiting them. This will be the case, chiefly in the banking and finance industries.

All in all, services in France should catch up in the next years allowing the productivity gap observed in the user industries with US and UK to be reduced.

**Table 4: Sources of hourly labour productivity growth in France**

(Average annual growth and contributions in percentage points)

| | 1990-95 | 1995-01 |
|---|---|---|
| **ICT producer sector** | | |
| Hourly labour productivity | 6.03 | 11.73 |
| Total capital | 3.10 | 1.53 |
| ICT | 0.45 | 0.52 |
| Hardware | 0.07 | 0.20 |
| Software | 0.04 | 0.10 |
| Communications | 0.34 | 0.21 |
| Other Capital | 2.65 | 1.01 |
| TFP | 2.93 | 10.20 |
| **Heavy ICT user** | | |
| Hourly labour productivity | 0.03 | 0.56 |
| Total capital | 2.37 | 1.17 |
| ICT | 0.43 | 0.54 |
| Hardware | 0.15 | 0.24 |
| Software | 0.10 | 0.19 |
| Communications | 0.17 | 0.11 |
| Other Capital | 1.94 | 0.63 |
| TFP | -2.34 | -0.61 |

Note: ICT producing sector: 30,32,64 ; using sector: 50-52, 65,66-67,71-74,90-95.

Source: see appendix 2. CEPII, authors' calculations

**Table 5: Sources of hourly labour productivity growth in the US**

(Average annual growth and contributions in percentage points)

| | 1980-90 | 1990-95 | 1995-01 |
|---|---|---|---|
| **ICT producer sector** | | | |
| Hourly labour productivity | 6.80 | 8.20 | 13.81 |
| Total capital | 1.07 | 0.85 | 2.21 |
| ICT | 0.42 | 0.47 | 1.11 |
| Hardware | 0.09 | 0.12 | 0.31 |
| Software | 0.04 | 0.10 | 0.19 |
| Communications | 0.29 | 0.24 | 0.61 |
| Other Capital | 0.65 | 0.38 | 1.10 |
| TFP | 5.73 | 7.35 | 11.60 |
| **Heavy ICT user** | | | |
| Hourly labour productivity | 1.49 | 1.35 | 3.87 |
| Total capital | 0.90 | 0.81 | 1.33 |
| ICT | 0.48 | 0.42 | 0.99 |
| Hardware | 0.24 | 0.20 | 0.50 |
| Software | 0.11 | 0.15 | 0.33 |
| Communications | 0.13 | 0.07 | 0.16 |
| Other Capital | 0.42 | 0.38 | 0.35 |
| TFP | 0.59 | 0.54 | 2.54 |

Note ICT producing sector: 29-30, 31-32, 64; using sector:50-52,65,66,67,71-74,90-95.

Source: see appendix 2. CEPII, authors' calculations

Table 6: **Sources of hourly labour productivity growth in the UK**

(Average annual growth and contributions in percentage points)

| | 1980-90 | 1990-95 | 1995-00 |
|---|---|---|---|
| **ICT producer sector** | | | |
| Hourly labour productivity | 10.08 | 10.22 | 13.88 |
| Total capital | 2.80 | 1.55 | 2.74 |
| ICT | 0.63 | 0.99 | 2.10 |
| Hardware | 0.17 | 0.36 | 1.01 |
| Software | 0.06 | 0.09 | 0.15 |
| Communications | 0.40 | 0.54 | 0.94 |
| Other Capital | 2.17 | 0.56 | 0.64 |
| TFP | 7.27 | 8.67 | 11.14 |
| **Heavy ICT user** | | | |
| Hourly labour productivity | 1.29 | 2.76 | 2.41 |
| Total capital | 1.46 | 1.26 | 0.76 |
| ICT | 0.33 | 0.38 | 0.66 |
| Hardware | 0.24 | 0.22 | 0.50 |
| Software | 0.06 | 0.13 | 0.14 |
| Communications | 0.03 | 0.02 | 0.01 |
| Other Capital | 1.13 | 0.88 | 0.11 |
| TFP | -0.17 | 1.50 | 1.65 |

ICT producing sector: 30-33, 64; using sector: 50-51, 52, 65-67, 70-74, 90-95.
Source: see appendix 2. CEPII, authors' calculations

Table 7: **Sources of hourly labour productivity growth in ICT producer and user sectors**

(Average annual growth and contributions in percentage points)

| **United States** | | | | |
|---|---|---|---|---|
| | VA/H | K/H | ICTK /H | TFP |
| **Producer sector manufacturing (29-32)** | | | | |
| 1990-95 | 11.91 | 0.70 | 0.39 | 11.22 |
| 1995-01 | 18.33 | 1.49 | 0.60 | 16.84 |
| **Producer sector services (64)** | | | | |
| 1990-95 | 2.43 | 1.22 | 0.56 | 1.21 |
| 1995-01 | 7.10 | 3.17 | 1.68 | 3.93 |
| **Trade (50-52)** | | | | |
| 1990-95 | 4.49 | 1.24 | 0.44 | 3.25 |
| 1995-01 | 5.49 | 1.45 | 0.80 | 4.05 |
| **Banking and Finance (65-67)** | | | | |
| 1990-95 | 1.88 | 1.00 | 0.73 | 0.89 |
| 1995-01 | 5.44 | 1.99 | 1.66 | 3.45 |
| **Business services (71-74)** | | | | |
| 1990-95 | 0.02 | 0.19 | 0.23 | -0.17 |
| 1995-01 | 0.05 | 1.38 | 1.22 | -1.32 |
| **Personal services (90-95)** | | | | |
| 1990-95 | 4.66 | 0.90 | 0.29 | 0.01 |
| 1995-01 | 4.91 | 1.20 | 0.59 | 3.72 |

| **United Kingdom** | | | | |
|---|---|---|---|---|
| | VA/H | K/H | ICT K/H | TFP |
| **Producer sector manufacturing (30-33)** | | | | |
| 1990-95 | 13.98 | 1.55 | 0.53 | 12.43 |
| 1995-00 | 17.53 | 2.46 | 0.95 | 15.06 |
| **Producer sector services (64)** | | | | |
| 1990-95 | 7.02 | 1.41 | 1.12 | 5.60 |
| 1995-00 | 10.74 | 2.59 | 2.39 | 8.15 |
| **Trade (50-52)** | | | | |
| 1990-95 | 4.26 | 1.60 | 0.39 | 2.66 |
| 1995-00 | 4.31 | 1.38 | 0.72 | 2.94 |
| **Banking and Finance (65-67)** | | | | |
| 1990-95 | 1.94 | 0.85 | 0.54 | 1.08 |
| 1995-00 | 3.85 | 0.44 | 0.95 | 3.41 |
| **Business services minus real estate (70-74)** | | | | |
| 1990-95 | -0.96 | 1.64 | 0.89 | -2.60 |
| 1995-00 | 0.36 | 1.77 | 1.68 | -1.41 |
| **Personal services (90-95)** | | | | |
| 1990-95 | 5.11 | 0.24 | 0.02 | 4.87 |
| 1995-00 | 1.14 | -0.10 | 0.02 | 1.24 |

**France**

| | VA/H | K/H | ICTK /H | TFP |
|---|---|---|---|---|
| **Producer sector manufacturing (30,32)** | | | | |
| 1990-95 | 15.57 | 2.00 | 0.07 | 13.57 |
| 1995-01 | 20.24 | 1.87 | 0.19 | 18.37 |
| **Producer sector services (64)** | | | | |
| 1990-95 | 2.90 | 3.26 | 0.55 | -0.36 |
| 1995-01 | 8.66 | 1.38 | 0.64 | 7.28 |
| **Trade (50-52)** | | | | |
| 1990-95 | 1.87 | 1.70 | 0.14 | 0.17 |
| 1995-01 | 1.19 | 0.85 | 0.23 | 0.34 |
| **Banking and Finance (65-67)** | | | | |
| 1990-95 | -0.70 | 4.49 | 1.61 | -5.20 |
| 1995-01 | 0.40 | 3.93 | 1.93 | -3.53 |
| **Business services (71-74)** | | | | |
| 1990-95 | -0.90 | 2.54 | 0.38 | -3.43 |
| 1995-01 | -0.19 | 0.39 | 0.37 | -0.58 |
| **Personal services (90-95)** | | | | |
| 1990-95 | -1.73 | 1.16 | 0.21 | -2.89 |
| 1995-01 | 0.90 | 0.99 | 0.49 | -0.09 |

Source: see appendix 2; CEPII, authors' calculations.

Table 8: **Contribution of sectors to aggregate hourly labour productivity growth, 1995-01**

(Average annual growth and contributions in percentage points)

| | Share in value added | Hourly labour productivity | Contrib. to hourly labour prod. |
|---|---|---|---|
| **France** | | | |
| ICT producer | 3 | 11.73 | 0.35 |
| ICT user | 33 | 0.56 | 0.18 |
| Other sector | 64 | 2.61 | 1.67 |
| Aggregate | 100 | 2.21 | 2.21 |
| **USA** | | | |
| ICT producer | 6 | 13.81 | 0.84 |
| ICT user | 37 | 3.87 | 1.43 |
| Other sector | 57 | -0.62 | -0.35 |
| Aggregate | 100 | 1.92 | 1.92 |
| **UK** | | | |
| ICT producer | 5 | 13.88 | 0.69 |
| ICT user | 35 | 2.41 | 0.84 |
| Other sector | 60 | 1.14 | 0.68 |
| Aggregate | 100 | 2.22 | 2.22 |

Source: see appendix 1 & 2; CEPII, authors' calculations.

## Conclusion

The analysis of productivity under the angle of ICT provides different interpretations. The increase in ICT in France, on the whole much weaker than in the UK and US, seems to have no linkage with the increase in productivity (both hourly and TFP). Moreover, ICT explains well the increase in hourly productivity in the US and UK but not in France. In this country, the gains in hourly productivity are high in the manufacturing sector (around 4% between 1995-2001), which is nevertheless less intensive in ICT than services. However, measurement problems affecting services call for caution in interpreting the link between ICT capital deepening and productivity gains in France, especially in banking and finance.

The link between ICT investment and productivity increase in services is an important issue, all the more as services account for 75% of total GDP and employment. Beyond the measurement issues, a more competitive environment may entice firms to adopt new technologies, and then increase production and employment.

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# APPENDIX

## 1. Macroeconomic data

*Capital*

Investment series are taken from the national accounts, provided by INSEE for France, BEA for the US, NIESR for the UK and the University of Groningen for Germany.

For France, UK and US we employ investment in hardware, and for Germany, investment in office and computer equipment.

In all cases an internal rate of return has been estimated in order to calculate the user cost of capital. Price series are the ones published by BEA for the US. For France, UK and Germany, ICT price series are derived using the method proposed by Schreyer (see infra). For the US, the series of private sector non residential investment (excluding household investment) and the series for public investment have been aggregated.

*Labour*

The series for hours worked for the United States come from the Harvard University (via Dale Jorgenson); for the UK the source is the University of Groningen and for Germany the IAB. Self employed workers are always included.

Concerning the quality of labour, series for UK and Germany were calculated at OECD by A. Colecchia, starting from Eurostat labour force surveys, together with the household survey for the European Union and adjusted with national data on hours worked and compensation from the OECD.

For France and the US, labour quality is estimated using the Annual Declarations of Social Data (DADS) and the labour force surveys for the former, and data from the Harvard University for the latter. Labour quality is calculated using three characteristics gender, age and education.

*Factor shares in total income and coverage of the study*

In all countries, when calculating the shares of wage and gross operating surplus in value added, self employed income is subtracted from gross operating surplus and added to wages.

Compensation figures for the US come from the Harvard University, INSEE for France, the University of Groningen for the UK and from National Accounts for Germany. Series for Germany begin in 1991.

We consider the total non residential economy.

## 2. Sectoral data

Investment series for France are taken from INSEE and follow the NES classification (F level). In order to have series at the 2-digit level of the NACE European classification, we use the Annual business survey (EAE) provided by SESSI, which allows us to have total investment, investment in hardware and software for the manufacturing sector as a whole (at the G level). We then compute the investment share of each sector (from business surveys data) in the total provided by INSEE. These ratios are applied to the investment assets series provided by INSEE. Data constraints limit our analysis to the 1990-2001 period.

The prices for ICT investment (hardware, software and communications equipment) by industry are computed by applying the ratio of ICT investment to non ICT investment prices found in the US to non ICT asset price series provided by INSEE according to the method proposed by P. Schreyer. This allows quality to be taken into account in ICT prices as it is done in the US with the hedonic methods.

Series for hours worked in France are obtained from DADS and labour force surveys. We have data for hours worked, compensation by kind of worker (age, gender and education level) and by sector of activity. Data are available for the 1982-01 period.

US data for investment at current and constant prices are published by BEA (Bureau of Economic Analysis). Series for hours worked, compensation and value added come from the University of Groningen productivity database.

Investment series for UK are provided by NIESR. Other variables come from the University of Groningen.

## 3. Methodology

The production function is the following:

$$Y_t = F(K_t, L_t, A) \quad (1)$$

where: $K_t$ represents capital, $L_t$ labour and A total factor productivity.

We estimate the following equation:

$$\Delta \ln y = \bar{v}_{K,t} \Delta \ln k_t + \bar{v}_{L,t} \Delta \ln q_t + \Delta \ln A_t \quad (2)$$

Where $\Delta$ is the first difference operator, y is hourly productivity, k capital per hour worked, q labour quality and A TFP;

$\bar{v}_{K,t}$ is the average share of capital in total income and $\bar{v}_{L,t}$ the corresponding share for labour,

$\bar{v}_{K,t} + \bar{v}_{L,t} = 1$.

The contribution of a factor to growth is then expressed as the product between the growth rate of this factor, in constant prices (which includes the improvement in factor’s quality) and the share of its compensation in value added.

*Capital and labour services*

We classify six types of assets: ICT capital (hardware, software and communications equipment), and three non ICT assets: transport equipment, other equipment and non residential buildings. Capital services are derived from the sum of the growth rate of capital stocks, weighted by the respective asset user costs.

Investment data in constant prices take into account the difference in the performance of the different assets.

Hedonic prices are used just for some types of assets, such as hardware and part of the communications equipment and software, and they are applied to different categories of assets according to country, therefore the first step is to harmonise ICT asset prices. As already said, we apply the method proposed by Schreyer. The ratio between the price of ICT and non ICT assets for the US is calculated and then applied to French non ICT assets.

The user cost of capital is a weighting of the growth rate of every stock of asset. Capital stocks are computed using the permanent inventory model. The user cost of each asset is calculated using an (internal or external) rate of return, a depreciation rate and capital gains or losses.

The user cost is equal to the gross operating surplus found in national accounts. This equality can be used to derive the internal rate of return. Of course, this does not hold when an external interest rate (the long term one) is used. In this paper we use the internal rate, applying the following formula:

$$r_t = \frac{CapRev - \sum_i (\delta_i * P^I_{i,t} - \Pi_{i,t} * P^I_{i,t-1}) * K_{i,t-1}}{P^I_{i,t-1} * K_{i,t-1}}$$

with $\Pi_{i,t} = \frac{P_{i,t}}{P_{i,t-1}} - 1$, the inflation rate for asset i ; caprev= capital revenue ; $\delta_i$ asset i depreciation rate ; $P_{i,t}$ investment price of asset i ; K capital stock in real terms.

**Table 8: Depreciation rate by sector and type of asset**

| | Hardware and software | Communications equipment | Other equipment | Transportation equipment | Non residential buildings |
|---|---|---|---|---|---|
| Producer sector | 0.3150 | 0.1100 | 0.1144 | 0.1890 | 0.0313 |
| User sector | 0.3150 | 0.1100 | 0.1211 | 0.1854 | 0.0347 |

Source: M.O'Mahony (NIESR). authors' calculations

***Labour quality***

Labour quality is defined as the difference between the growth rate of weighted hours worked (or labour services) and that of non weighted hours worked.

Each component is weighted by its marginal product, using the neoclassical hypothesis of each factor being rewarded according to its marginal product. Labour quality is calculated here according to three criteria: gender. age (four categories) and education (six categories). using the following equation:

$$\Delta \ln Q^L = \sum_l \overline{v}_{Ll} \Delta \ln H_l - \Delta \ln H$$

Q is the index of quality. l the labour type (male, female, aged less than 25, with a university degree, and so on.…the unskilled ones). L is the group to which l is referred to (gender, age, education level). H is the number of hours worked. $v$ is the share of each category's wage in the total. The upper bar stands for the Tornqvist index (the average over two consecutive years).

The underlying assumption might be too strong and this calls for prudence when interpreting the results. However, this index allows for gauging the composition effects underlying hours worked.