Catching Up or Getting Stuck?
Europe's Troubles to Exploit ICT's
Productivity Potential

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Abstract
In this paper we extend our previous analysis of the comparative productivity performance of Europe and the U.S. to 2004, thereby covering the latest full business cycle. Our main finding is that the slower contribution of ICT to productivity growth in the EU compared to the U.S. has persisted into the early part of the 21st century. The growth differential even increased since 2000, as the U.S. shows strong labour productivity advances in market services. This may be related to a more productive use of ICT in the U.S.. However, at industry level we find no support for significant TFP (total factor productivity) spillovers from ICT investment, neither in the U.S. nor in European countries. In the 1980s we even find that ICT investment and TFP growth are negatively related, with at best normal returns in the 1970s and 1990s. We speculate that this U-shaped pattern is driven by "hard savings" from ICT investment that first lead to earning normal returns, followed by a period of experimentation during which ICT and TFP growth are negatively related. Ultimately, "soft savings" lead to productivity gains from ICT in line with the marginal cost of ICT. We argue that the realization of productivity effects from soft savings is highly dependent on the competitive process that stimulates complementary innovations and weeds out inefficient users of ICT technology. Europe risks getting stuck in an environment where the productivity gains from soft savings from ICT remain unrealized.

[1] This paper largely builds on earlier work by the authors and their colleagues, including van Ark, Inklaar and McGuckin (2003), O'Mahony and van Ark (2003), Inklaar, O'Mahony and Timmer (2005) and Timmer and van Ark (2005). A more extensive version of this paper can be found in Inklaar (2005, chapter 4). We are grateful to Edwin Stuivenwold, Koen Thijssen and Gerard Ypma for statistical assistance.

1. Introduction

During the second half of the 1990s the comparative growth performance of Europe vis-à-vis the United States has undergone a marked change. For the first time since World War II labour productivity growth in most countries that are now part of the European Union (EU) has fallen behind the U.S. for a considerable length of time. Whereas average annual labour productivity growth in the U.S. accelerated from 1.1% during the period 1987-1995 to 2.5% during 1995-2004, EU productivity growth declined from 2.2% to 1.5%. (see **Table 1**). Despite a slight improvement in productivity and labour input growth in the EU-15 in 2004, this recent improvement cannot yet be seen as a structural improvement. **Figure 1** shows that the EU-15 saw a further drop in its labour productivity growth trend in the 2000–2004 period.[2] In contrast, the results for the U.S. show that the improvement in the productivity trend since 1995 is continuing.

The striking acceleration in U.S. output and productivity growth since the mid 1990s has been much discussed in the literature. Around the turn of the century, a consensus emerged that faster growth can at least in part be traced to the effects of the information and communication technology (ICT) revolution (Oliner and Sichel 2000, 2002; Jorgenson and Stiroh 2000; Jorgenson, Ho and Stiroh, 2003). ICT had an impact on growth through a surge in ICT investment, strong productivity effects from ICT-producing industries and a more productive use of ICT in the rest of the economy. While ICT spillovers are typically not found at industry level (Stiroh, 2002a, 2003), there is firm-level evidence that ICT in the U.S. has a larger impact on productivity than suggested by its share in total cost (Brynjolfsson and Hitt, 2000, 2003; OECD, 2004).

Unfortunately there is less agreement on the reasons for the slowdown of productivity growth in Europe. Compared to the U.S., ICT investment, ICT production and the productive use of ICT in Europe generated less productivity growth during the late 1990s.[3] The reasons for this limited impact of new technology, innovation and structural reforms on economic growth in Europe are still poorly understood. The urgency to better grasp the causes of Europe's growth deficit is underlined in the recent review by the Kok Commission of the Lisbon agenda for reform in Europe, which aims to improve Europe's competitiveness (European Commission, 2004).

The main question this paper poses is to what extent Europe's slow productivity growth is due to a failure to exploit the growth potential of ICT. Specifically, slower ICT investment could be a reflection of a time lag relative to the U.S. or indicate a more structural failure to exploit new technologies. A time lag may be due to the more fragmented nature of

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[2] The trend growth in productivity for both the U.S. and the EU-15 was estimated using historical annual data from 1979–2004. The Hodrick-Prescott (1997) filter we employ separates the cyclical effects from the long-term, or structural, component of productivity growth. Business cycles in the U.S. and the EU are not completed synchronised but the divergent trend growth rates are clear. Note that the trend estimates for especially the final two years are less reliable than for earlier years.

[3] See e.g. van Ark, Inklaar and McGuckin (2003), O'Mahony and van Ark (2003), Inklaar, O'Mahony and Timmer (2005) and Timmer and van Ark (2005).

the European market. The greater scale of the U.S. market can make certain investments more profitable early on, while ICT prices have to fall further before it is profitable in Europe too. On the other hand, ICT investment in Europe might permanently lag the U.S., because regulations hold back the diffusion of complementary innovations. For example, young, innovative firms may face obstacles to fast growth, such as restrictive land-use regulations. This in turn reduces the incentives for incumbent firms to innovate too.

With the availability of industry data on ICT and productivity growth for the U.S. and several European countries, and with updates of these estimates to 2004, the link between productivity and ICT can be investigated in detail. This paper argues that a declining rate of productivity growth in Europe may be a reflection of a slow transition process towards so-called "soft savings" from ICT usage, in particular in market services. These follow the earlier "hard savings" which could be immediately obtained from ICT investment. Along the lines of the literature on general purpose technologies, the results suggest that "soft savings" require investments in intangible capital and organizational innovations, which are most likely to be important in market services. The market services sector is the biggest investor in ICT and is also most dependent on additional innovations to produce new ICT-related services. The European institutional environment, reflected in its labour and product market institutions, tends to hold up the structural adjustment process in Europe and inhibits the reallocation of resources to their most productive uses. The European economic environment creates too little room for good firms to excel and for failing firms to exit the market.

This paper begins with a presentation of the updated macroeconomic evidence on the contribution of ICT to productivity growth, using a growth accounting approach (**Section 2**). We then proceed to examine the differential labour productivity growth performance between the EU-15 and the U.S. at the industry level. This analysis shows that the key to the differences in growth performance between both economies is a better understanding of productivity trends in market services (**Section 3**). Due to the scarcity of data on ICT investment for individual industries, a more detailed analysis of ICT intensity and TFP growth at the industry level can only be carried out for four major European countries (France, Germany, the Netherlands and the UK) and the U.S. (**Section 4**). In this section we also go more deeply into the evidence and implications of the relationship between ICT and TFP growth. In the concluding section (**Section 5**) we focus on the "hard" and "soft" savings of ICT, on the one hand, and differences in the competitive market environment between Europe and the U.S., on the other hand.

2. Macro-economic evidence on the ICT contribution to growth

Productivity growth can be traced to the effects of the ICT revolution through three transmission channels, namely from investment in ICT, the production of ICT, and possible "spillovers" from the use of ICT. In a neo-classical framework, the contribution from ICT investment is well defined: firms will invest in ICT up to the point where further output gains are equal to the marginal cost of the investment. This way the contribution from growth in ICT capital per hour worked to labour productivity growth can be identified. Total factor productivity (TFP) growth in ICT producing industries will quite naturally contribute to aggregate TFP growth and hence labour productivity growth. The final channel, which is TFP growth due to ICT use, is hardest to measure and also raises some conceptual issues. The underlying idea is that ICT enables new organizational models and other innovations in the production process, as well as the production of new goods and services. So although new ICT investment goods are standard products, it enables firms to innovate and accumulate firm-specific capital (see e.g. Brynjolfsson and Hitt, 2000 and OECD, 2004). Insofar as these innovations yield additional output gains, they may show up as additional total factor productivity growth in ICT using industries and may be labelled as "spillovers".

To assess the contribution of these three sources of growth, a growth accounting framework is used (Solow 1957, Jorgenson 1995). Gross domestic product (Y) is produced from aggregate factor inputs X, consisting of ICT capital services (K_{ICT}), non-ICT capital services (K_N) and labour services (L). Total factor productivity (A) is represented as a Hicks-neutral augmentation of the aggregate inputs. The aggregate production function has the following format:

$$Y = AX\left(L, K_N, K_{ICT}\right) \qquad (1)$$

Under the assumption of cost-minimizing producers, competitive factor markets and constant returns to scale, total factor productivity growth is derived as the growth of output minus a share weighted growth of inputs:

$$\Delta \ln A = \Delta \ln Y - \bar{v}_L \Delta \ln L - \bar{v}_N \Delta \ln K_N - \bar{v}_{ICT} \Delta \ln K_{ICT} \qquad (2)$$

where Δ refers to first differences and $\bar{v}$'s denote the two-period average shares in total factor income and because of constant returns to scale: $\bar{v}_L + \bar{v}_N + \bar{v}_{ICT} = 1$. By rearranging equation (2) average labour productivity growth, defined as y = Y/L, can be decomposed into the ratio of capital services to hours worked, k = K/L, and TFP growth. Another useful distinction can be made between TFP growth originating in manufacturing industries producing ICT goods (A_{prod}) and that from other industries (A_{other})

$$\Delta \ln y = \bar{v}_N \Delta \ln k_N + \bar{v}_{ICT} \Delta \ln k_{ICT} + \Delta \ln A_{prod} + \Delta \ln A_{other} \qquad (3)$$

The estimates on the comparative growth performance of the EU-15 and the U.S. presented here are an update from earlier work by van Ark *et al.* (2003), Timmer *et al.* (2003) and Timmer and van Ark (2005). The estimates on investment, capital services, labour input and GDP are updated from 2001 to 2004. Data on investment, GDP and labour compensation are typically derived from national accounts. However, substantial additional work was required to construct separate investment time series for three ICT assets (office and computing equipment, communication equipment, and software) as well as three non-ICT assets (non-ICT equipment, transport equipment and non-residential structures). Although the main sources and methods for constructing the data are similar to previous work, some major changes to ICT investment series were made for several European countries.[4] The resulting real investment series are used to derive capital service growth rates which, in combination with growth rates on total hours by employees (mainly obtained from labour force surveys), give the growth of capital services per hour worked. The contribution of each capital asset to growth was estimated using the share of capital compensation of each asset in total GDP as weights. Aggregate total factor productivity growth (TFP) was derived as a residual from labour productivity growth minus the contribution of capital deepening to GDP growth.

To obtain separate TFP estimates for ICT-producing industries, we assume that TFP growth rates for each of the three ICT-industries (office, accounting and computing equipment, communication equipment and electronic components manufacturing) in the U.S. also apply to the European countries.[5] To measure the ICT industry contributions to total factor productivity growth, Domar weights for the individual countries were used.[6]

Figure 2 summarizes our findings for the EU-15 and the U.S. for the periods 1987-1995, 1995-2000 and (the updated period) 2000-2004 (see also **Table 2**). The chart and table show a decomposition of labour productivity growth into the effects of ICT capital deepening and TFP growth from ICT-producing industries, and two other sources of growth, namely non-ICT capital deepening and TFP growth other than that from ICT production. Our main findings are that the EU-15 as a whole has been lagging behind the U.S. in terms of ICT capital deepening throughout all periods. Both the EU-15 and the U.S. show a strong acceleration of ICT capital deepening during the late 1990s. However, this investment boom was mostly transitory, with ICT capital deepening returning to pre-1995 levels after 2000 in both the EU-15 and the U.S. However, since 2000 U.S. labour productivity accelerated further, while the EU-15 suffered additional slowdown. This divergence between the Europe

[4] We are especially grateful to Gerard Ypma for providing the recent updates for the ICT investment series. See http://www.ggdc.net/dseries/growth-accounting.html for further details on sources and methods and underlying data. The methodology to obtain the ICT investment series, the deflators for ICT series (which are essentially derived from U.S. hedonic price deflators for ICT) and the capital services method can be obtained from Timmer *et al.* (2004) and Timmer and van Ark (2005).

[5] Of course one would ideally use capital service measures at the industry level for individual European countries. To date such detailed TFP estimates are only available for the U.S. and a few European countries. We use these more detailed estimates in Section 4.

[6] The Domar weight of an industry is defined as the industry's gross output divided by aggregate value added. In general, these weights sum to more than one (see Domar, 1961 for the basic method and Inklaar, 2005, Appendix 4A, for details on this specific implementation).

and America mainly relates to TFP growth outside the ICT producing sector. In Europe, TFP growth in outside ICT-production was effectively zero after 2000, while in the U.S. "non-ICT production" TFP growth added almost 1.5 percentage points to labour productivity growth.[7]

"Non-ICT production" TFP growth may include an element of ICT spillovers. A somewhat impressionistic way of getting at possible spillover effects at macro-level is to relate the contribution from ICT-capital deepening to "non-ICT production" TFP growth for the period 2000-2004 (**Figure 3**). This scatter plot shows a very suggestive positive relationship between these two variables, with countries like the U.S., the UK, Finland and Sweden combining high ICT investment and high non-ICT TFP growth, while countries like France, Italy and Spain show the opposite. What is even more striking is that this relationship apparently did not exist before 2000.[8]

However, suggestive of ICT spillovers as these results may be, one has to be very cautious in interpreting this evidence. Firstly, having only aggregate data means that the number of observations is limited, so convincing statistical evidence is difficult to obtain (Inklaar, 2005). Secondly, there are many more differences that affect TFP growth differences between countries such as, for example, differences in market structure and flexibility of product, labour and capital markets between countries.[9] Thirdly, with a declining trend in aggregate TFP growth in most European countries it is hard to interpret this evidence as a sign of increased spillovers compared to the period before 2000. Indeed the significant relationship since 2000 has mainly occurred because some countries have been showing slower TFP growth rather than from accelerations in countries with rapid ICT investment. This might at best imply that some countries have had more trouble to combine ICT with other growth-enhancing sources than others. Finally, without TFP growth estimates for individual industries there is no good way of identifying such spillovers, as the aggregate TFP residual may include a whole range of unmeasured contributions (or detractions) to output growth which are difficult to distinguish at aggregate level. Hence the remainder of this paper focuses on our industry estimates of productivity growth

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[7] Estimates for individual countries can be obtained from Timmer, *et al.* (2003). Although there is much variation in TFP not related to ICT, the trend is generally downwards with the exception of Sweden and the United Kingdom. See also http://www.ggdc.net/dseries/growth-accounting.html.
[8] See Inklaar (2005) for a more detailed analysis of these results.
[9] See, for example, Hall (1988) and Roeger (1995).

3. An Industry Perspective on ICT and Labour Productivity Growth

As discussed above, we ultimately would like to have estimates of TFP growth for individual industries, in addition to the aggregate figures presented above. Only then it is possible to see which industries are heavy ICT investors and whether these industries have higher TFP growth. This can help determine whether ICT spillovers are an important source of growth differences between Europe and the United States. At this moment such estimates are only available for 4 major European countries (France, Germany, the Netherlands, the UK and the U.S.), which will be discussed in Section 4. In the absence of industry-level growth accounts for all EU-15 countries, it is useful to look at the labour productivity growth performance by industry.

The GGDC has developed a database, which contains information on value added and employment for 56 industries (see van Ark, Inklaar and McGuckin, 2003; O'Mahony and van Ark, 2003). This so-called "60-industry database" has now been updated to the year 2003. On the basis of this dataset, measures of labour productivity growth and the contribution of individual industries to aggregate productivity growth can be calculated.[10] These contributions are calculated using a shift-share approach. As Stiroh (2002b) shows, aggregate labour productivity growth can be written as:

$$\Delta \ln y = \sum_i \overline{w}_i \Delta \ln y_i + \left(\sum_i \overline{w}_i \Delta \ln H_i - \Delta \ln \sum_i H_i \right) = \sum_i \overline{w}_i \Delta \ln y_i + R \qquad (4)$$

with w_i as the share of industry i in total value added and a bar over a variable denoting the two-period average. Hence aggregate labour productivity growth is the weighted sum of industry productivity growth plus a reallocation term R. The reallocation term is positive if employment shifts from low productivity industries towards high productivity industries.[11]

Table 3 summarizes the contributions of three major industry groups (ICT-producing industries, other producing industries and other market services) and the

[10] The updated measures will be released on the GGDC website (www.ggdc.net/dseries/60_Industry.shtml) in November 2005. See also van Ark et al. (2003a) and O'Mahony and van Ark (2003). The main source of this database is the new OECD STAN Database of national accounts, but greater industry detail is provided through the use of industry surveys and censuses.

[11] The reallocation term gives the differences between the output-weighted growth of hours and (roughly) the employment-weighted growth of hours. If this term is positive, industries with an output share that is larger than the employment share are showing faster employment growth than industries with an output share smaller than the employment share. This method differs slightly from our earlier shift-share analysis used in van Ark, Inklaar and McGuckin (2003). One of the drawbacks of the earlier method is that the contributions do not add up to aggregate labour productivity growth if a Törnquist index is used to calculate aggregate growth, whereas it does in the present formulation. Moreover in the standard shift-share analysis, any industry with positive employment growth makes a positive contribution to aggregate growth. However, there are ways of modifying standard shift-share analysis to reach similar reallocation concepts as the method adopted here.

reallocation effect to labour productivity growth in the market sector of the economy.[12] By leaving out the public sector of the economy (including health, education and government), for which measurement problems are substantial, the labour productivity growth performance of the market economy shows an even stronger differential between the EU-15 and the U.S. since 1995 and in particular since 2000. **Figure 4** shows that differences in the performance of ICT-producing industries (which include ICT-producing manufacturing and services industries), is not sufficient to explain the growth differences between Europe and the U.S. Instead, most of the labour productivity acceleration in the U.S. can be traced to faster productivity growth in other market services. This difference has become even more striking since 2000: the contribution of other market services to labour productivity growth almost disappeared in the EU-15 whereas it accelerated further in the U.S.

To get a clear view of what is driving the large difference in contribution of market services to labour productivity growth between the EU-15 and the U.S., the percentage point growth differential for the market economy can be decomposed as follows:

$$\Delta \log y^{US} - \Delta \log y^{EU} = \sum_i prodty\_eff_i + \sum_i share\_eff_i + R^{US} - R^{EU} \quad (5)$$

In this equation, *prodty_eff*, the productivity growth effect, weighs the difference in labour productivity growth rates for each industry by the average value added share of the EU-15 and the U.S.:

$$prodty\_eff_i = \frac{1}{2}\left(\overline{w}_i^{US} + \overline{w}_i^{EU}\right)\left(\Delta \ln y_i^{US} - \Delta \ln y_i^{EU}\right) \quad (6)$$

The share effect, *share_eff*, weighs the difference in value added shares by the average productivity growth rates of the EU-15 and the U.S.:

$$share\_eff_i = \frac{1}{2}\left(\Delta \ln y_i^{US} + \Delta \ln y_i^{EU}\right)\left(\overline{w}_i^{US} - \overline{w}_i^{EU}\right) \quad (7)$$

Finally, R^{US} and R^{EU} refer to the original reallocation terms of each country (as in equation (4)). By applying this decomposition, the industries that have contributed most to the growth differential in market services can be identified and the cause of this difference can be traced to either faster productivity growth or a larger output share.

[12] The ICT producing industries include producers of IT hardware, communication equipment, telecommunications and computer services (including software). The distinction is based on an OECD classification (see OECD 2002).

Figure 5 shows that most of the difference in market services productivity growth can be traced to about six industries, concentrated in trade and finance. Part of the difference can be explained by the fact that wholesale trade, retail trade and securities trade are larger sectors in the U.S. than in Europe, but faster productivity growth within each industry is the most important factor.

In earlier work we have extensively focused on ways to distinguish between industries that are intensive users of ICT and those that are less intensive users. Van Ark, Inklaar and McGuckin (2003) looked at four possible measures of ICT intensity, including the ICT share in total investment in both industries, the share of ICT in the total capital stock and in total capital services and the share of ICT capital compensation in total value added. On this basis a typology of intensive ICT-using and less-intensive ICT-using industries was derived, using an arbitrary cut-off point – in this case the median of the industries which were more or less intensive ICT users.

Of course, this typology can be criticized on grounds of the arbitrariness of the cut-off point between more intensive and less intensive ICT-use, and because not all indicators showed the same ranking of industries.[13] Indeed the literature on general purpose technologies suggests that the spectrum of ICT intensity will be much more gradual as technological opportunities only differ gradually across industries. This greater degree of gradualism is shown in **Figure 6**, which ranks industries in the United States on the basis of the share of ICT capital compensation in total value added in 1995.[14]

The figure shows that it is difficult to make a sharp distinction between ICT users and non-intensive ICT industries.[15] However, there is a clear presence of large market service industries in the upper range of ICT use, with the only exception of retail services which falls just below the median.[16]

[13] See, for example, Daveri (2004)

[14] These estimates are based on the U.S. Capital Flow Table for 1997 (see Meade, *et al.*, 2003) and extrapolations using detailed investment by industry and asset tables prepared by the BEA.

[15] These results are confirmed in Inklaar (2005) who uses cluster analysis to identify high- and low-intensity ICT clusters which shows no clear-cut result. Inklaar (2005) also looks at the correlation between ICT-intensity measures between the U.S. and several European countries (France, the Netherlands and the UK), which shows rather high rank correlation coefficients. This suggests that the technological opportunities are pretty much comparable across countries.

[16] McGuckin, Spiegelman and van Ark (2005) extensively discuss the role of ICT in retail services, which clearly is not a major factor on itself but has been an enabler of the introduction of a new more efficient business model, called lean retailing (see also Section 5).

4. An Industry Perspective on ICT and Total Factor Productivity Growth

To explore whether the high intensity of ICT use and the rapid acceleration in labour productivity growth by industry are related, it is not sufficient to group industries into high and low intensity categories. Instead it is necessary to go into more detail and look at TFP measures by industry. Growth accounts at industry level can provide information that is obscured when looking only at labour productivity growth, because the latter does not distinguish between the effects of capital deepening and total factor productivity growth. At this point in time, this can only be reasonably be done for a limited number of European countries (France, Germany, Netherlands, United Kingdom) and for the United States, covering a total of 25 market industries in each country from 1979 to 2003. Together, the four European countries cover about 70 percent of output in the EU-15. The growth accounting methodology is comparable to that described in Section 2 for the aggregate economy, except that the estimates also include a reallocation component and a separate component for labour quality.[17] Moreover, with industry data in hand we can improve the robustness of our aggregate estimates by focusing exclusively on the market sector of the economy.

Table 4 shows the growth accounts for the total market economy as well as for the contributions from two industry groups, namely the (broad) ICT production sector and total market services from 1995 to 2003.[18] In addition to the four European countries, we also added a column showing the (weighted) average results for these countries (referred to as EU-4) which facilitates the comparisons with the macro-results presented in Section 2. Compared to the aggregate growth accounting results from Table 2, the labour productivity growth rates are generally higher due to the focus on the market economy. But otherwise the main findings at macro-level are similar: labour productivity growth in the U.S. is higher than in Europe due to a mix of higher contributions from ICT capital deepening and TFP growth. The EU-U.S. gap in TFP growth from ICT production is somewhat smaller here than at the aggregate level because the industry data also include telecommunications services, for which Europe has a growth edge over the U.S..

The industry results bring some of the findings from Table 2 in sharper perspective. First, market services in both Europe and the U.S. account for between 75 and 80 percent of ICT capital deepening in the total market sector, with much smaller contributions from ICT producing industries. In terms of TFP contributions, however, the ICT producing sector is the most important source of TFP growth in Europe (on average about 75 percent of total growth). In the U.S., ICT production is also important as a contributor to TFP growth, but market services are equally important. Indeed market services generate 52 percent of market economy TFP growth, compared to only 14 percent for the EU-4 average. The UK stands out

[17] A detailed description of the dataset, including sources and methods for the investment data by asset to estimate capital services growth and the employment and wage data by educational attainment to estimate labour quality growth is given in Inklaar, O'Mahony and Timmer (2005). Estimates for recent years follow similar procedures. No educational attainment data has been collected for years after 2000, so labour quality growth is assumed to be zero for the latest years.

[18] The broad ICT production sector includes electrical and optical equipment (ISIC 30-33) and telecommunications (64). Investment data is not available to distinguish computer services (72) in all countries

among the four European countries for its relatively strong TFP performance, although it still lags the U.S.

Table 4 suggests that, at the level of market services, the U.S. has managed to combine high levels of ICT investment with rapid TFP growth. As mentioned before, this might be suggestive of positive spillover effects from ICT use at industry level. The industry data allow us to investigate this issue more rigorously, by estimating the following regression:[19]

$$\Delta \ln A_{it} = \alpha + \beta\left(\bar{v}_{it}^{ICT} \Delta \ln K_{it}^{ICT}\right) + \varepsilon_{it} \equiv \alpha + \beta ICTContr_{it} + \varepsilon_{it} \qquad (8)$$

Equation (8) tests the hypothesis that ICT capital has an additional impact on output, after accounting for the "normal" contribution of ICT capital to output which relates to its cost share. This equation is similar to one of the equations estimated in the more extensive study of Stiroh (2002a) for U.S. manufacturing.[20]

Table 5 shows the estimates of equation (8) for all market industries together. The equation is estimated using ordinary least squares (OLS) and the standard errors of the parameters have been corrected for autocorrelation and heteroscedasticity using the procedure of Newey and West (1987). Estimates in Table 5 are shown with a single constant term as well as for fixed effects models. With only a single constant, one aims to determine whether a higher ICT contribution is directly related to higher TFP growth. The fixed effects models, which include a dummy for each country/industry pair, may be relevant if certain unmeasured industry- and country-specific factors are important. For example, it could be the case that the regulatory environment of an industry in a country influences TFP growth, but not ICT investment. Eliminating this unobserved heterogeneity may be important to identify the impact of ICT on TFP growth (see e.g. Griliches and Mairesse, 1998).[21]

Table 5 shows the estimates of equation (4.16) for all market industries. These estimates suggest little impact of ICT on TFP growth. When pooling across countries, a higher (or rising) ICT contribution actually leads to lower TFP growth. Most of the country estimates are insignificantly different from zero or even negative.[22] Overall, these results are in line with those reported in Stiroh (2002a), who also reports a number of significantly negative estimates of ICT on TFP growth.

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[19] For a more extensive discussion of this specification as well as the subsequent results, see Inklaar (2005).

[20] Stiroh also (simultaneously) estimates the impact of the other inputs on TFP, but these are omitted here to facilitate the focus on ICT capital.

[21] Experiments with demand-side instruments to take further endogeneity problems into account, show comparable results

[22] Removing the ICT producing manufacturing industry from the sample does not change the qualitative results. Estimates for only services industries are also not noticeably different. Similarly, experiments using demand side instruments as in do not produce qualitatively different results. The fixed effects estimates are mostly larger, in absolute sense, than the single constant estimates. The reason for this is not immediately clear since this result also shows up for individual countries. However, in a statistical sense the two sets of estimates do not differ, so the issue is not all that important.

One reason why no positive relationship is found in the industry data may be that the effect of ICT on TFP occurs only with a lag. For example, complementary investments in organizational change may need to be made first before the productivity effect from ICT kicks in. Basu *et al.* (2004) explain TFP growth by industry in the U.S., averaged over 1995 to 2000, with the ICT contribution to growth for 1980-1990, 1990-1995 and 1995-2000. They find a negative effect of ICT for 1995-2005 on TFP and positive effects for the first two periods. This suggests that lags may be important. The analysis of Basu *et al.* (2004) though, is strictly cross-sectional and the choice of periods and lags is somewhat ad-hoc.[23]

Brynjolfsson and Hitt (2003) test a similar hypothesis on possible time lags using firm-level data. They argue that the best way to pick up the effects of earlier ICT investment on current TFP is by taking longer differences of the data. So instead of looking at 1-year growth rates, they take growth rates over 2, 3 and more years. Their main finding is that the ICT impact on TFP growth rises as longer differences are taken, with the 7-year difference showing an impact of ICT that is 5 times as large as the 1-year difference.

It is rather straightforward to use these two methods (long differences and time lags) for testing our industry data. **Figure 7** shows the parameter as well as confidence bands for fixed effects estimates, ranging from 1-year to 23-year differences.[24] The estimate for the 1-year difference is the same as shown for OLS with fixed effects from Table 5. This estimate is significantly negative at the 5% level. From 5-year differences to 12-year differences, the coefficient is insignificantly different from zero and afterwards, the upper bound fluctuates around zero.[25] This result is confirmed when looking at the specification with lags in **Figure 8**. The contemporaneous effect is negative, just as Table 5 showed, but from a lag of two years onwards, the effect is insignificantly different from zero. Although these results, based on the full sample of industry and country observations, do not suggest any significant positive spillover, it also does not support Stiroh's finding of significant negative coefficients over longer periods of time (Stiroh, 2002a).

So far, we have analyzed the full sample of observations for all countries and all years. One might argue, however, that the relationship between ICT and TFP growth has changed over time. To investigate this, we also estimated equation (8) for each 5-year period in our sample.[26] **Figure 9** first shows the regression coefficient for 1979-1984, then the 1980-1985 coefficient up to the 1998-2003 coefficient. Throughout the 1980s, the ICT effect

[23] Other methods have also been used to distinguish short-run and long run effects of ICT use. O'Mahony and Vecchi (2003) apply the pooled mean group (PMG) estimator of Pesaran et al. (1999) to estimate the output contribution of ICT capital. With this methodology, O'Mahony and Vecchi (2003) find a long-run effect of ICT on output that is higher than is expected on the basis of cost shares. This again implies evidence of spillovers from ICT use.
[24] To estimate fixed effects, at least two observations per industry are needed, so 23-year differences is the maximum possible.
[25] If only a single constant is used, the coefficient remains significantly negative, even for very long differences. This is mainly the result of tighter confidence intervals and not so much lower point estimates. As the fixed effects model removes certain unobserved heterogeneity, it seems preferable.

remains significantly negative, but starting with the 1991-1996 period, the coefficient becomes indistinguishable from zero. So during the 1990s, ICT capital generated productivity effects in line with the cost of ICT capital, suggesting normal returns.

Figure 10 takes the use of subsamples one step further by carrying out the 5-year regressions separately for the three continental European countries (France, Germany and Netherlands) and Anglo-Saxon countries (UK and U.S.). As noted above, the UK stands out among the European countries as showing a relatively good productivity performance. To simplify the presentation of the results, the chart only shows the upper bound results for the two groups, because the ICT coefficient itself does not become significantly positive at any point. Figure 10 shows that the effect of ICT on TFP growth is U-shaped for the Continental European countries: zero up to the mid-1980s, significantly negative until the 1991-1996 period and again zero from the 1991-1996 period onwards. There is some suggestion that a similar U-curve might exist for the Anglo-Saxon countries, but as it is situated a couple of years earlier, the left tail of the U-shape cannot be directly observed because of lack of data. It should be stressed once again, however, that ICT has at best no effect on TFP growth in both the Continental European and Anglo-Saxon countries. The main change from the 1980s is that ICT is no longer a drag on TFP growth.

There is some corroborating evidence in the literature for a U-shape pattern in savings from ICT. Morrison (1997) shows that high tech capital in U.S. manufacturing earned its marginal cost during the early 1970s, the late-1970s and the 1980s, whereas the effect turned negative in the late 1980s, early 1990s after which it became positive again. In other words, it seems likely that the U-curve can be found in all countries in our sample. As we argue in the next section, this pattern could be indicative of relatively straightforward, ‘hard’ savings from ICT that can be realized early on in the diffusion of this new technology. However, before further savings can be realized, new organizational forms need to be developed and experimented with. In addition a strong competitive process is needed to weed out failing experiments with investments in organizational innovations.

[26] Five-year differences were chosen since Figure 7 shows that on average over the full period, the ICT effect is not significantly different from zero. Using differences of other lengths does not alter the qualitative results.

5. Conclusions and Implications

In this paper we have revisited the evidence on the relationship between ICT and productivity growth from an international comparative perspective. We have provided updates of our earlier work on the EU-U.S. productivity growth differential, bringing the analysis up to 2004. The post-2000 estimates show that the EU-U.S. productivity growth gap has further increased. We find this to be mainly due to the sharp acceleration of total factor productivity growth in the U.S., which appears to be located mainly in market service industries. In Europe we find no improvement in productivity growth, and in particular market services have performed quite badly recently. This evidence gives support to the hypothesis that the European Union is presently not on a track to realize the same productivity gains from ICT as the U.S.

We also investigated the possibility, also raised in our earlier work, that there is still a difference in timing of the productivity effects of ICT between Europe and the U.S. (O'Mahony and van Ark, 2003). The argument goes that many European countries are still in a transition process towards a next phase of productivity gains from ICT usage, which the United States have already realized. To this end we analyzed the direct relationship between ICT use and TFP growth at the industry level, to identify the occurrence of any productivity spillover effects from ICT use. For the aggregate sample of four European countries (France, Germany, the Netherlands and the UK) and the U.S. we established a pattern which suggests that ICT earns its normal returns, but no super-normal returns, in the early phase of ICT investment, followed by a period of negative TFP effects from ICT on productivity with a return to normal returns after several years. When distinguishing between the countries we find this U-shaped pattern of returns on ICT for the three continental European countries (France, Germany and the Netherlands), and some evidence for a similar pattern in the UK and the U.S. several years earlier.

These results might be better understood when relating them to the literature on general purpose technologies and, more specifically, to the indication that the pervasiveness of technologies, such as ICT, involves a significant amount of time before its productivity effects are exploited (see, for example, Bresnahan and Trajtenberg, 1995). One might speculate that the early normal returns on ICT are the result of the direct productivity effects of ICT production and ICT investment (which we call the "hard savings"). The "negative spillover"-period may be related to a phase of investments in human capital and knowledge capital as well as organizational innovations which do not immediately result into an acceleration of productivity growth. It takes time before the combination of ICT investment and intangible investments and innovations (here called the "soft savings"), have an effect on productivity. This interpretation of the results is also in line with the firm-level evidence which also emphasizes the importance of skills and organizational innovations (Brynjolfsson and Hitt, 2000, 2003; OECD, 2004).

The idea that ICT can generate 'hard' and 'soft' savings with an impact that is phased over time is consistent with detailed studies at industry level. For example, McGuckin, Spiegelman and van Ark (2005) show that in the retail industry, ICT investment had an immediate impact on productivity growth through hard savings. For example, the introduction of barcode scanning allowed for more efficient check-out systems without much further investment. However, the same barcode technology has enabled a reorganization of the supply chain and the introduction of new shopping concepts. These soft savings do not only require heavy investment in ICT, but also in newer complementary technologies (such as RFID, transportation technology) and organizational change (new shopping concepts, adjustment in the logistic chain of supplying the shops more frequently, etc.).

This leaves open the question why firm-level studies find positive spillovers and our estimates show neutral effects. A plausible explanation would be that within an industry, some leading firms invest heavily in ICT and organizational change and reap the accompanying productivity gains. But there are also laggards with lower productivity growth. These laggards may have also invested heavily in ICT, but were less successful in realizing soft savings. Although in time these laggards are likely to either exit or catch-up with the leaders due to competitive pressures, this inevitably takes time. In the meantime, industry performance will reflect both leading and lagging firm performance. To find out whether this explanation holds in practice, further research is needed into these aggregation effects.

The most relevant issue for policy is why Continental European countries may be slower in realizing these effects from soft savings than the UK and the U.S.? One possible line of argumentation is that the process of realizing the soft savings involves more trial-and-error. It therefore requires an entrepreneurial environment and competitive labour and product markets that allow efficient firms to grow and weed out inefficient ICT users. There is substantial evidence from industry level studies on regulation (e.g., Nicoletti and Scarpetta, 2003) as well from firm-level studies on the dynamics of firm performance (e.g, Bartelsman, Haltiwanger and Scarpetta, 2005) that confirm the need for such a conducive environment to generate productivity growth. Many of the continental European institutions, in particular in the area of labour and product markets, inhibit the reallocation of resources to the most productive companies. The European economic environment appears to create too little room for good firms to excel and for failing firms to exit the market so as to free up resources for the much-needed transition. This may particularly affect investments in firm-specific resources, such as human and organizational capital, which unlike ICT are not easily transferred on markets and may stay for too long in firms that are not productive. This direct link between regulation and soft savings is an important area for further research.

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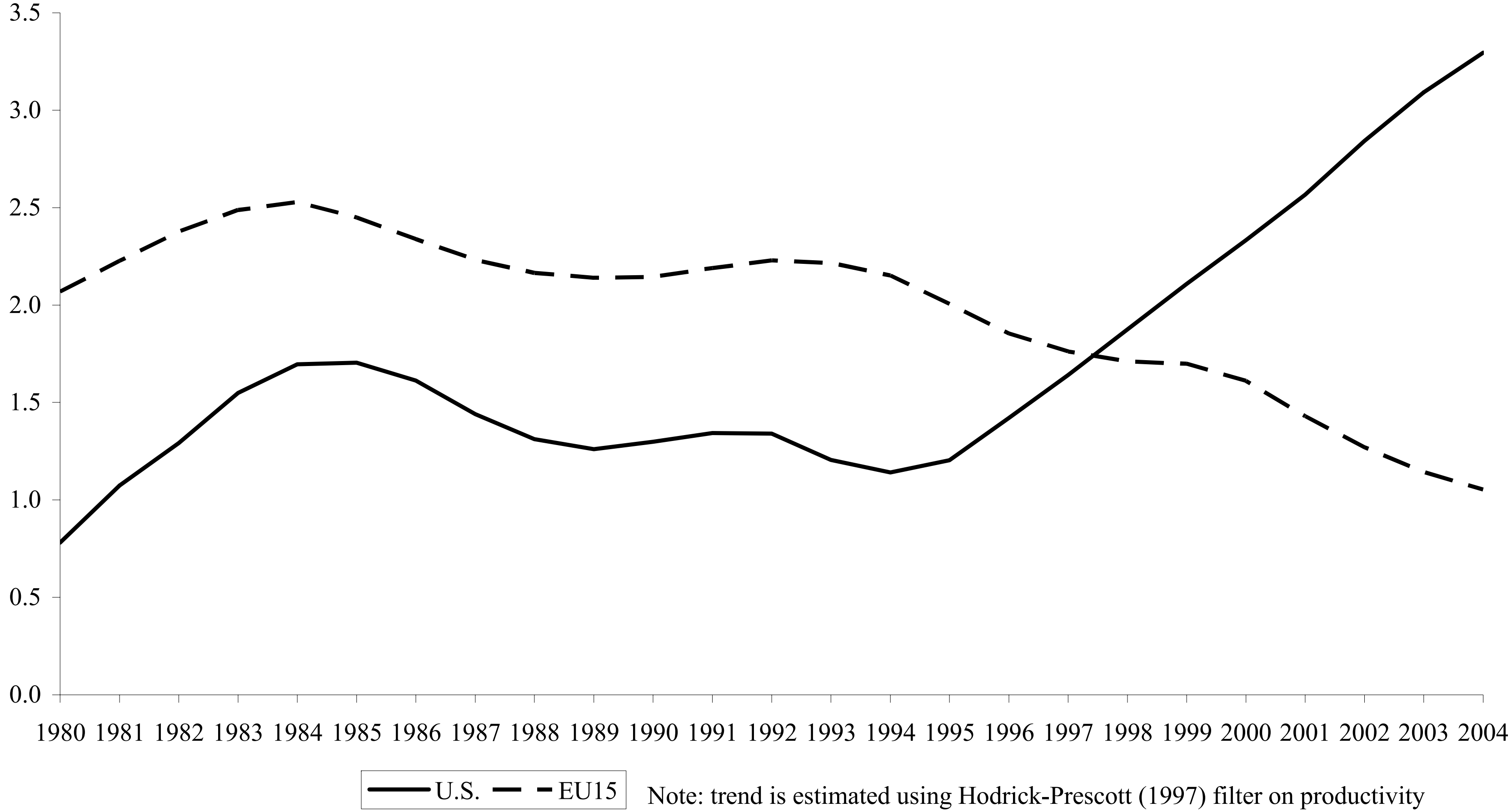
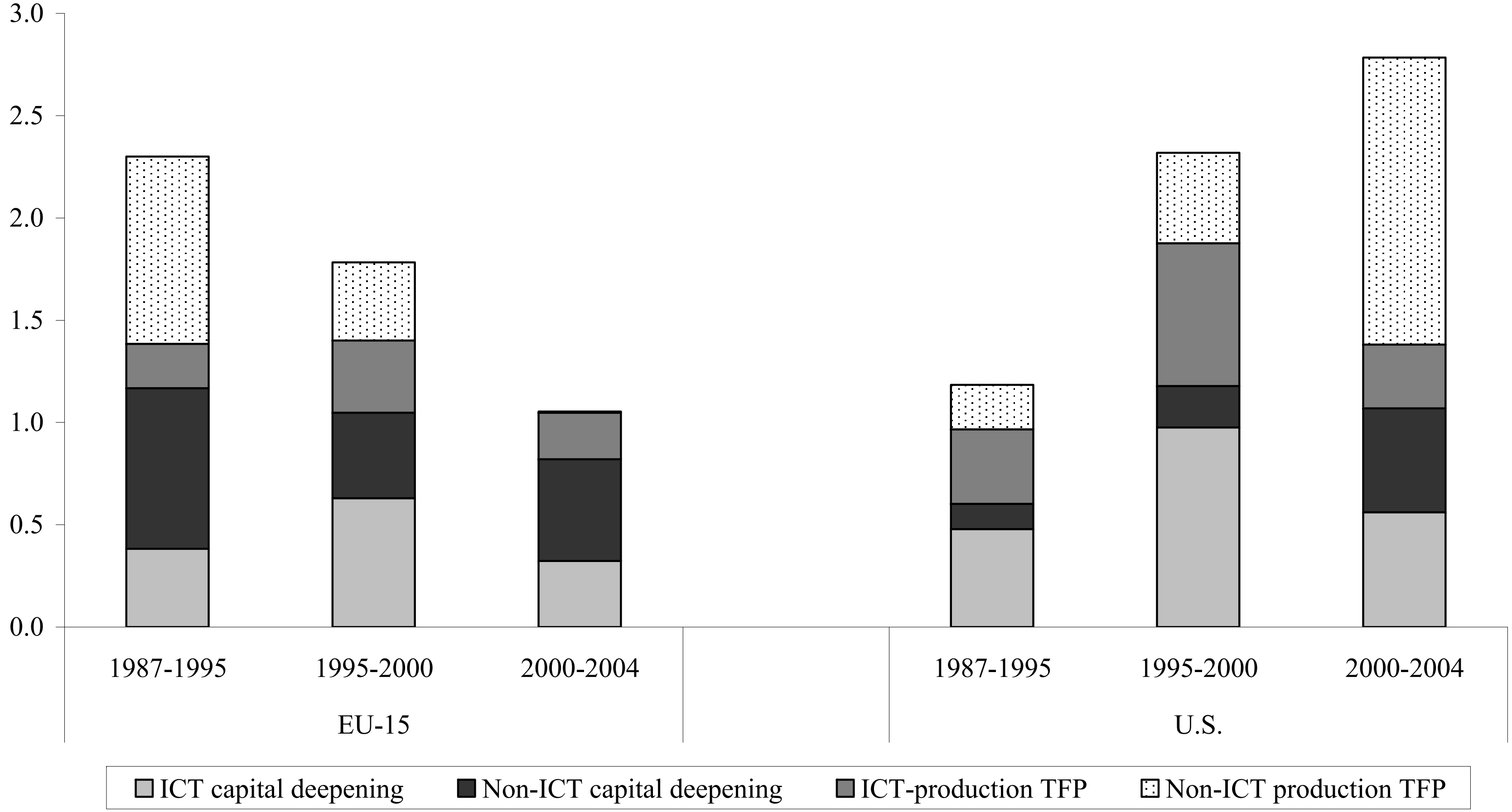
Figure 1: Trend growth in GDP per hour worked EU-15 and U.S., 1979-2004



Note: trend is estimated using Hodrick-Prescott (1997) filter on productivity

Source: McGuckin and van Ark (2005)

Figure 2: Sources of labour productivity growth, EU-15 and U.S., 1987-2004



Source: Groningen Growth and Development Centre (http://www.ggdc.net/dseries)

Figure 3: ICT contribution and non-ICT TFP growth, 2000-2004

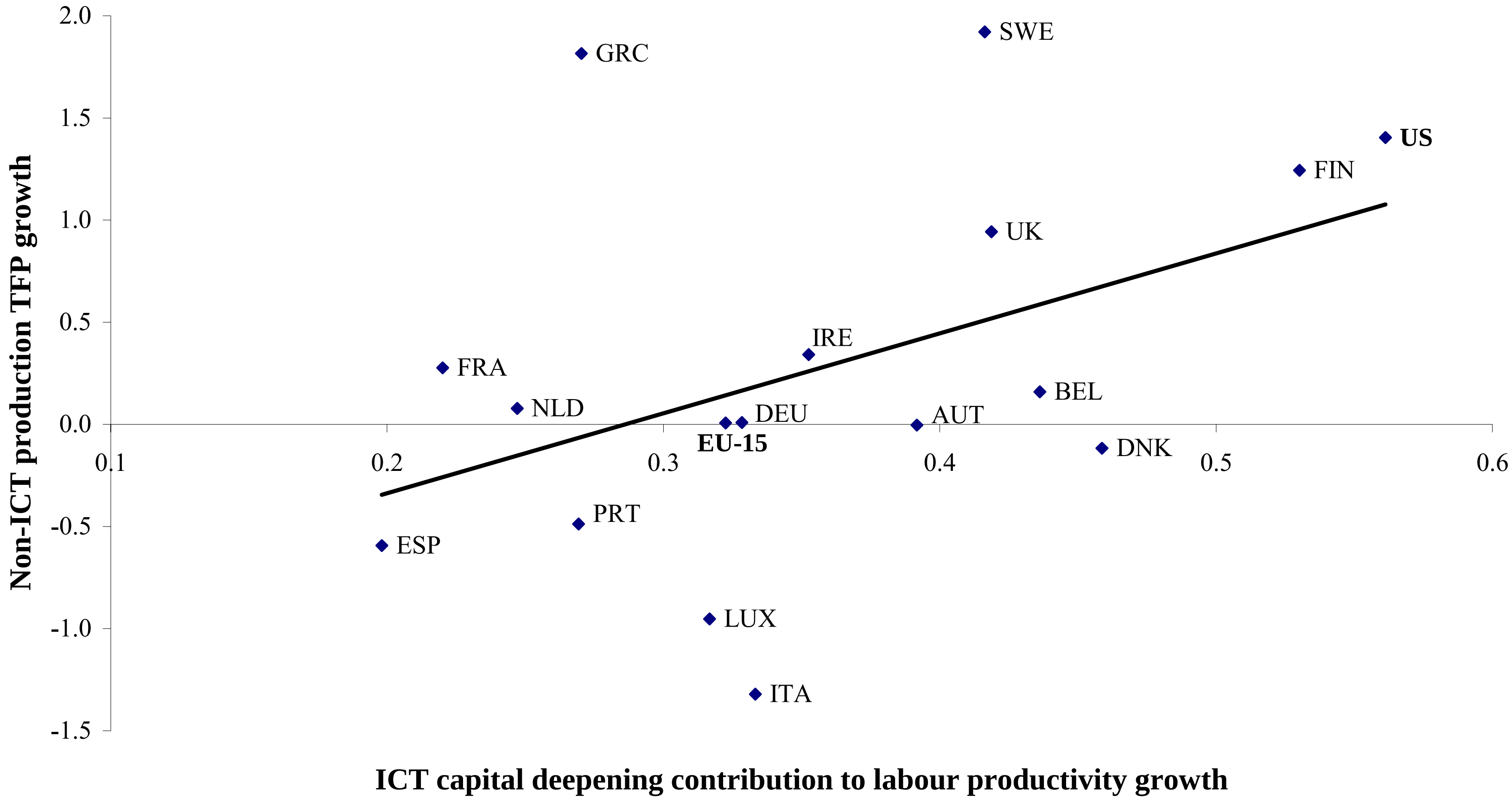
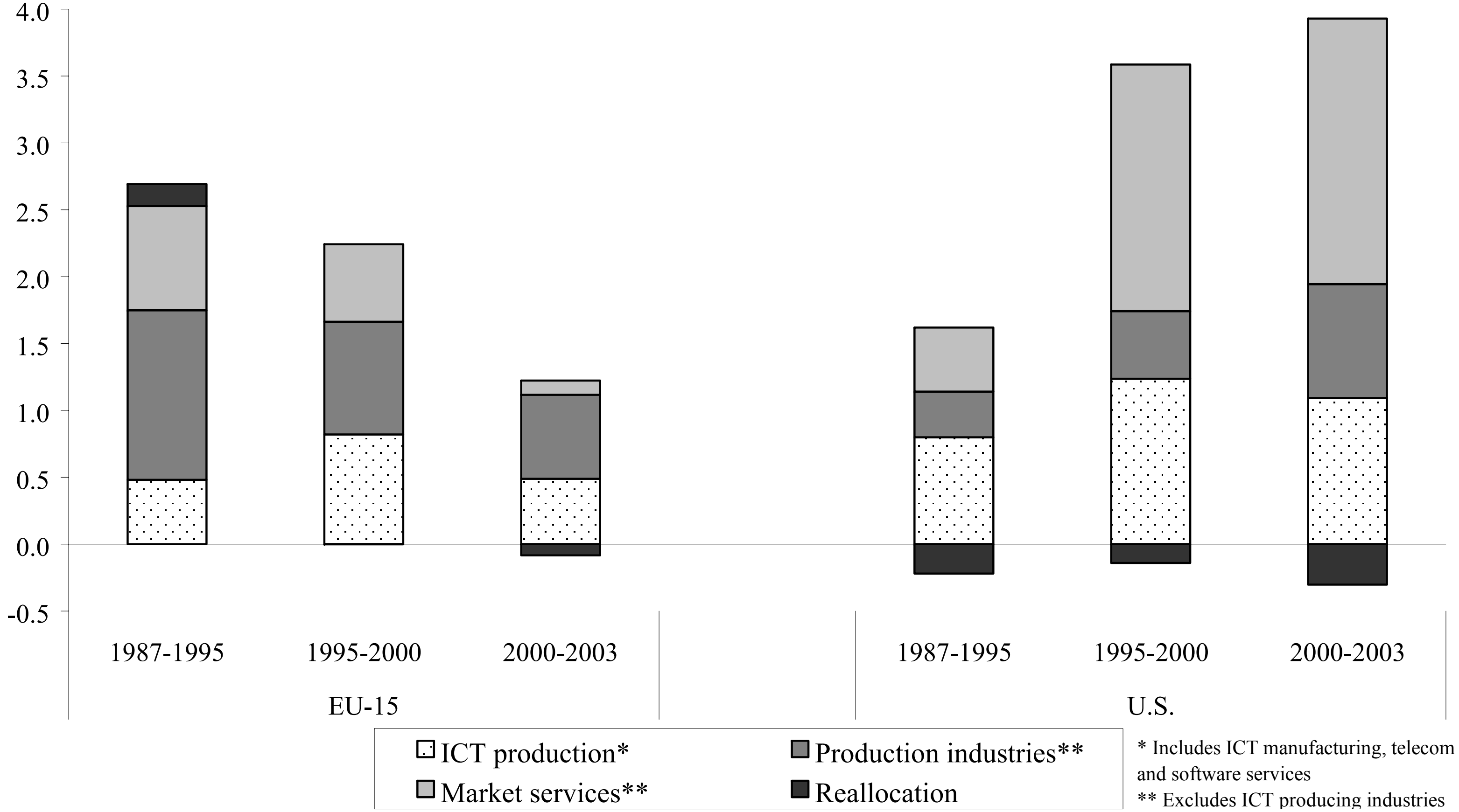


Figure 4, Industry contributions to market economy labour productivity growth EU-15 and U.S., 1987-2003



* Includes ICT manufacturing, telecom and software services
** Excludes ICT producing industries

Figure 5: Difference in labour productivity contribution in market services, U.S.-EU-15, 1995-2003

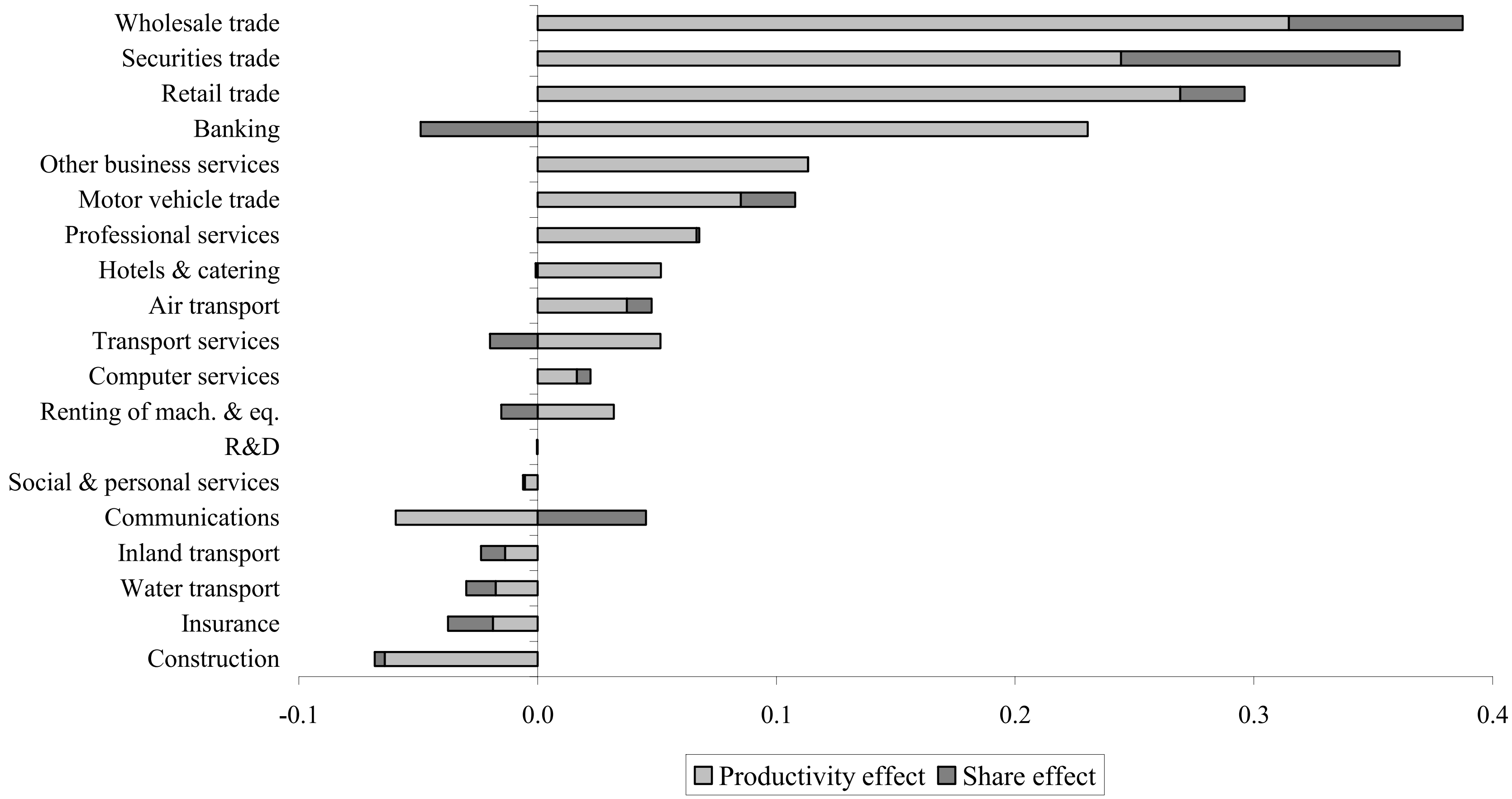


Figure 6: Share of ICT capital in total capital services, 1995

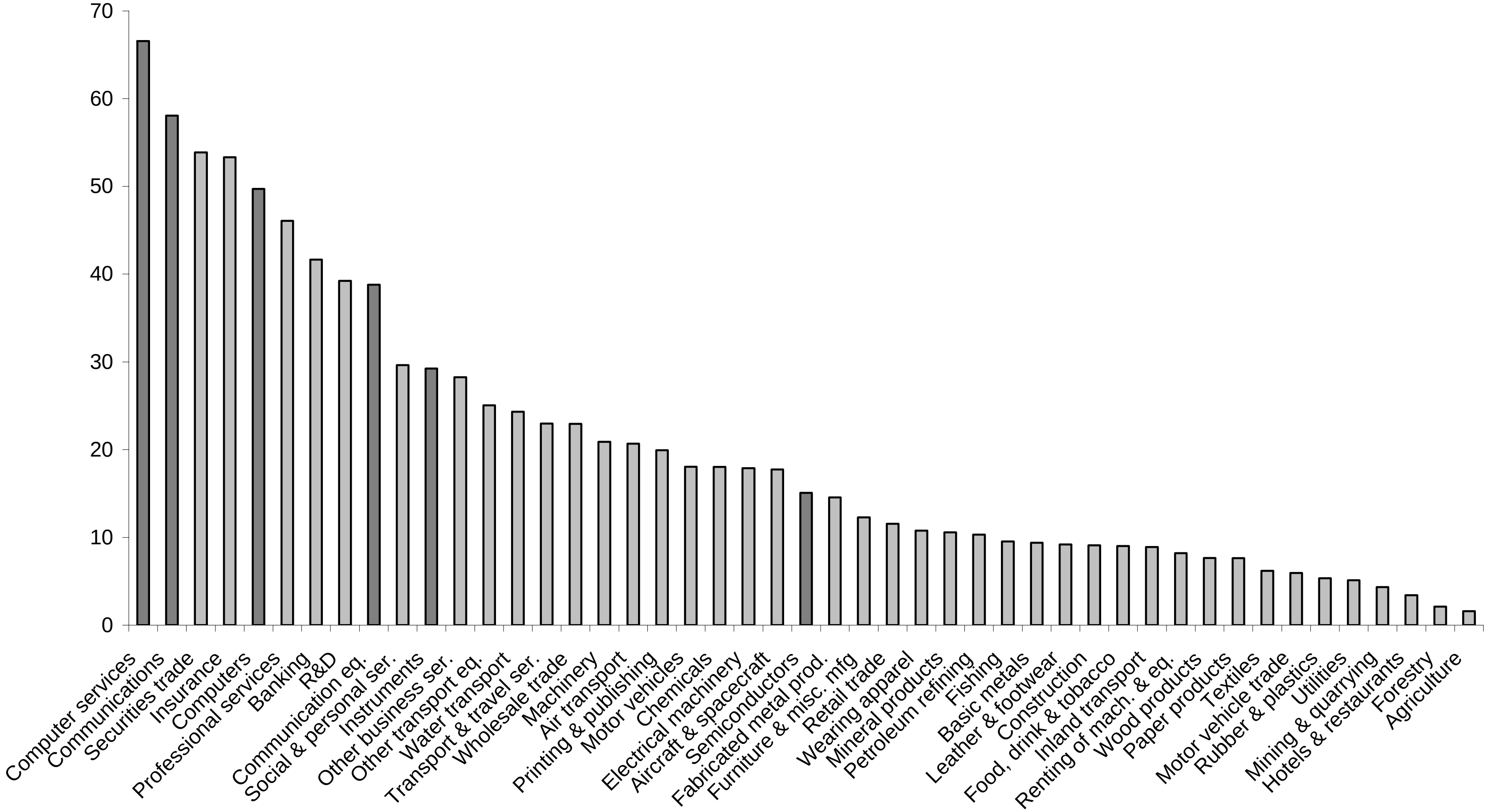


Figure 7: The relation between ICT contribution and TFP growth in all market industries and countries, 1-year to 23-year differences

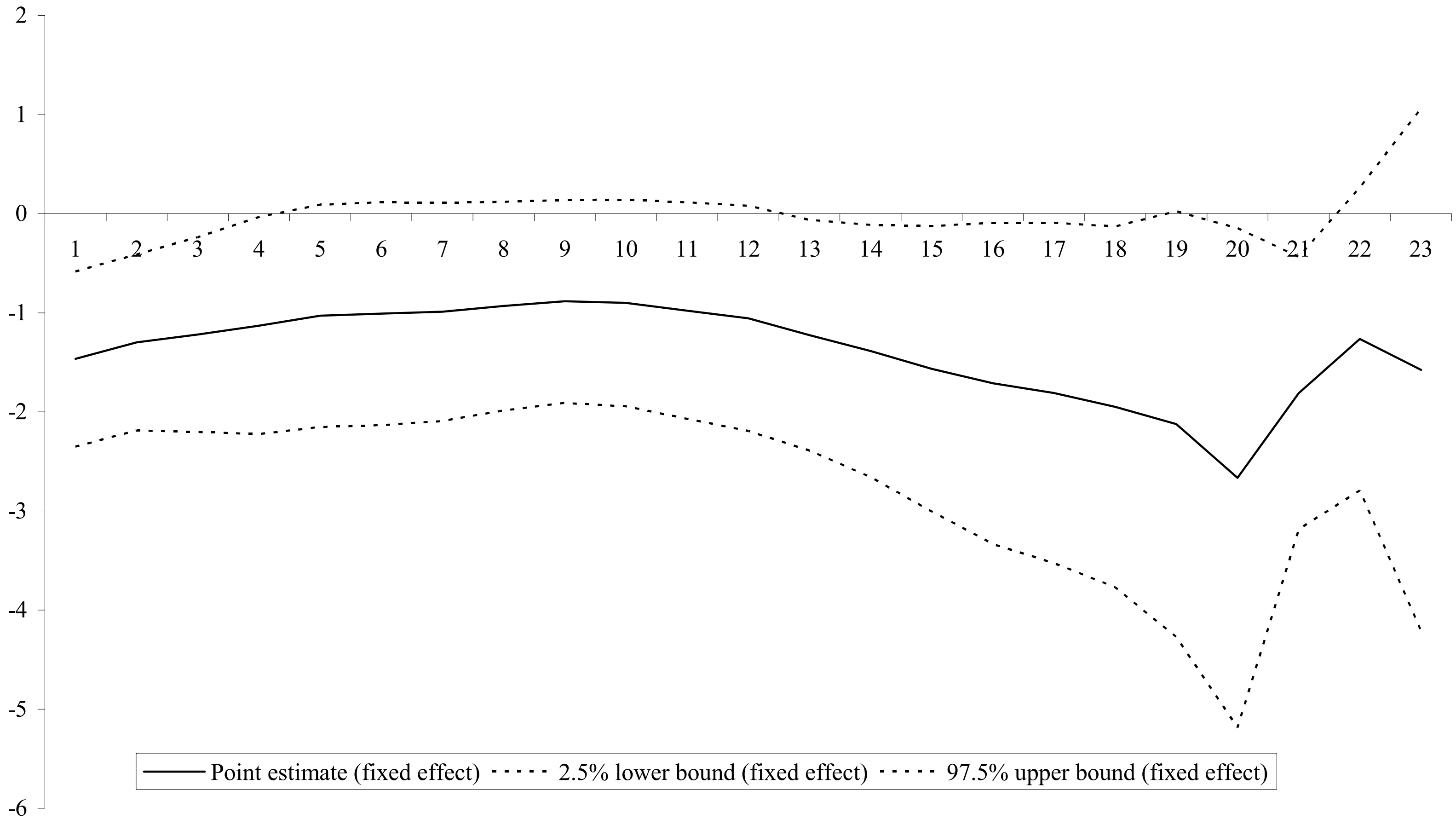


Figure 8: The relation between ICT contribution and TFP growth in all market industries and countries, contemporaneous effect to 22-year lag

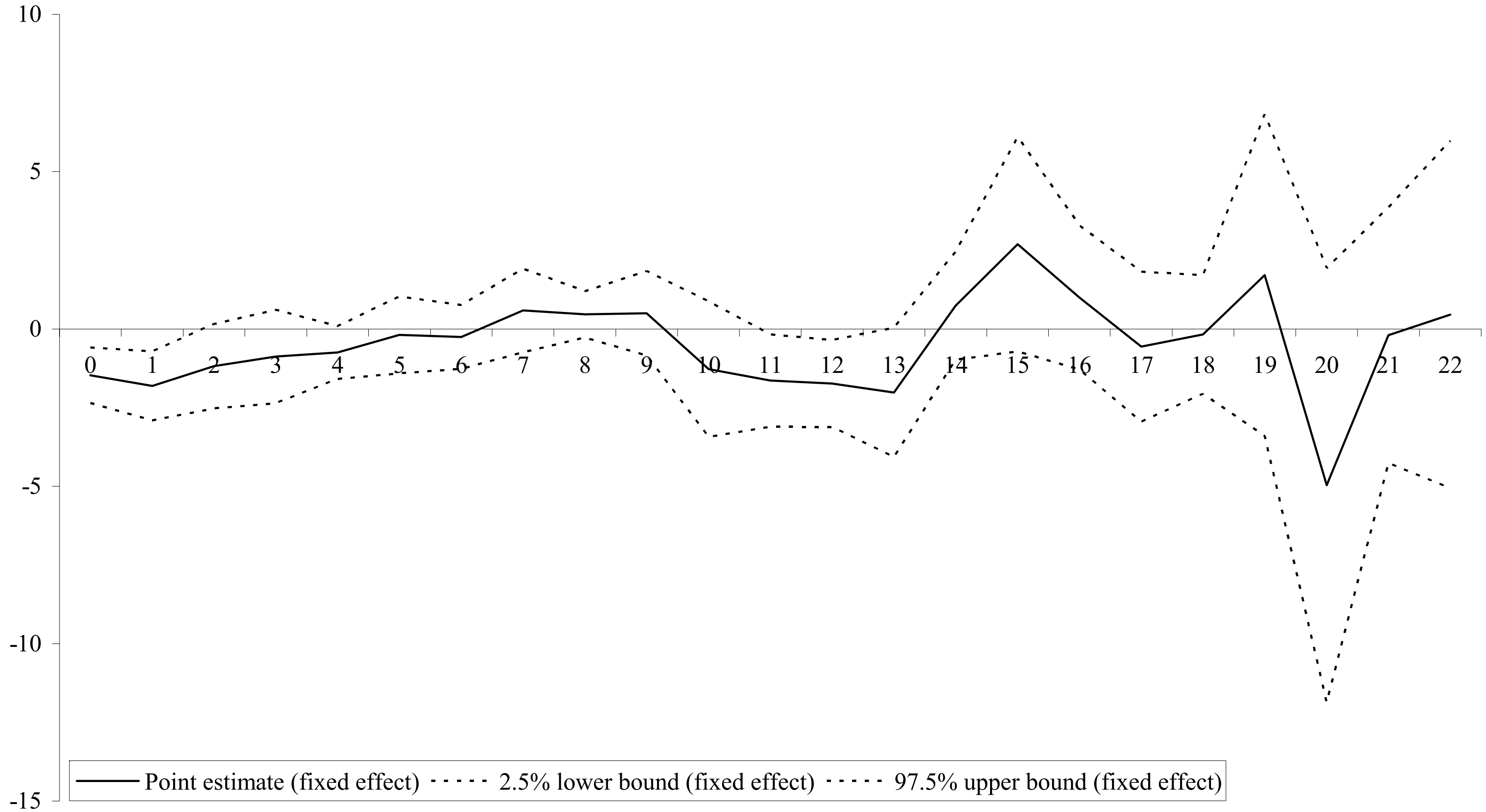


Figure 9: The relation between ICT contribution and TFP growth for subsequent sets of 5-year differences, 1979-1984 to 1998-2003

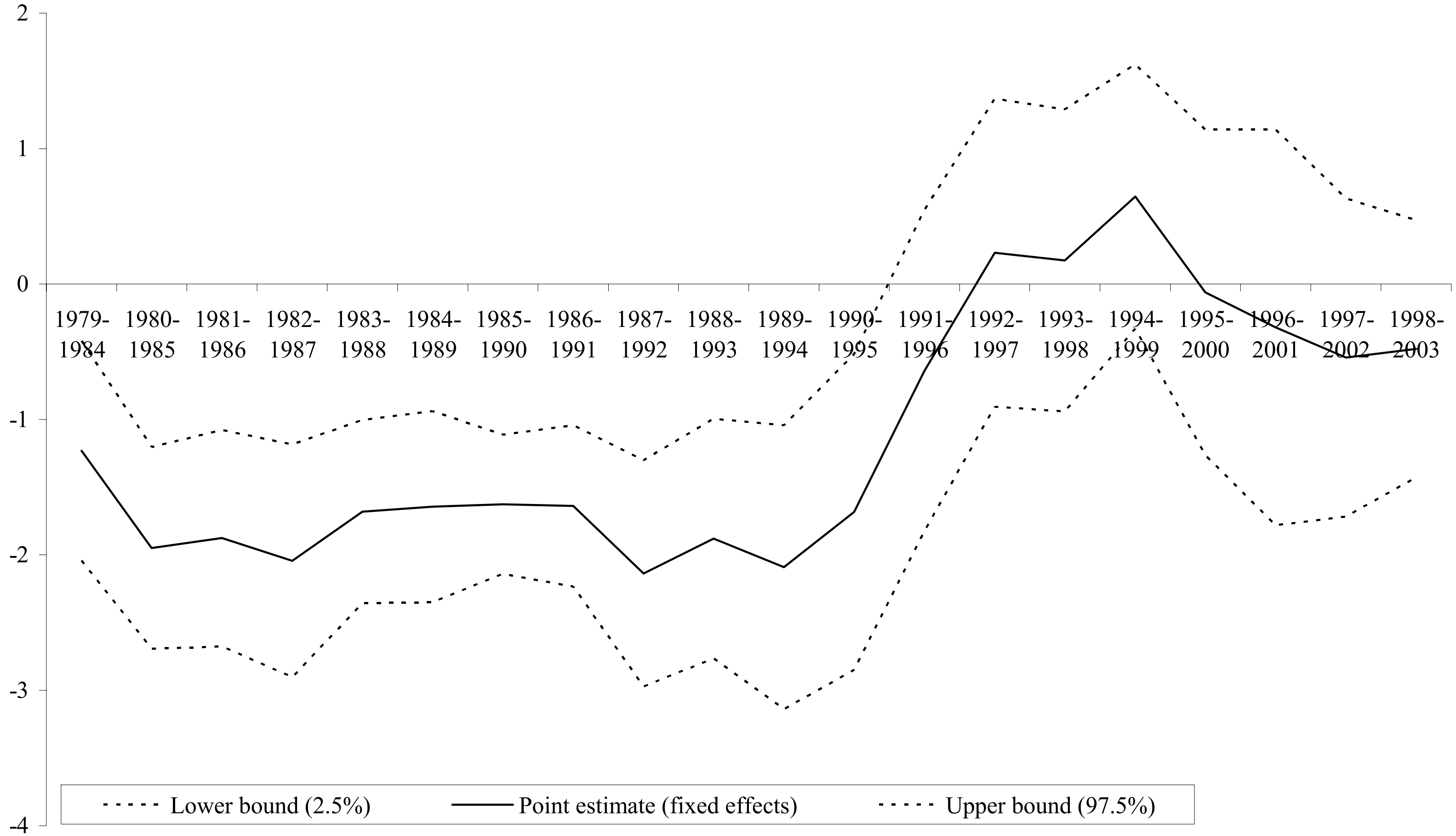


Figure 10: The upper bound of the relation between ICT contribution and TFP growth for subsequent sets of 5-year differences, Continental Europe vs. Anglo-Saxon countries

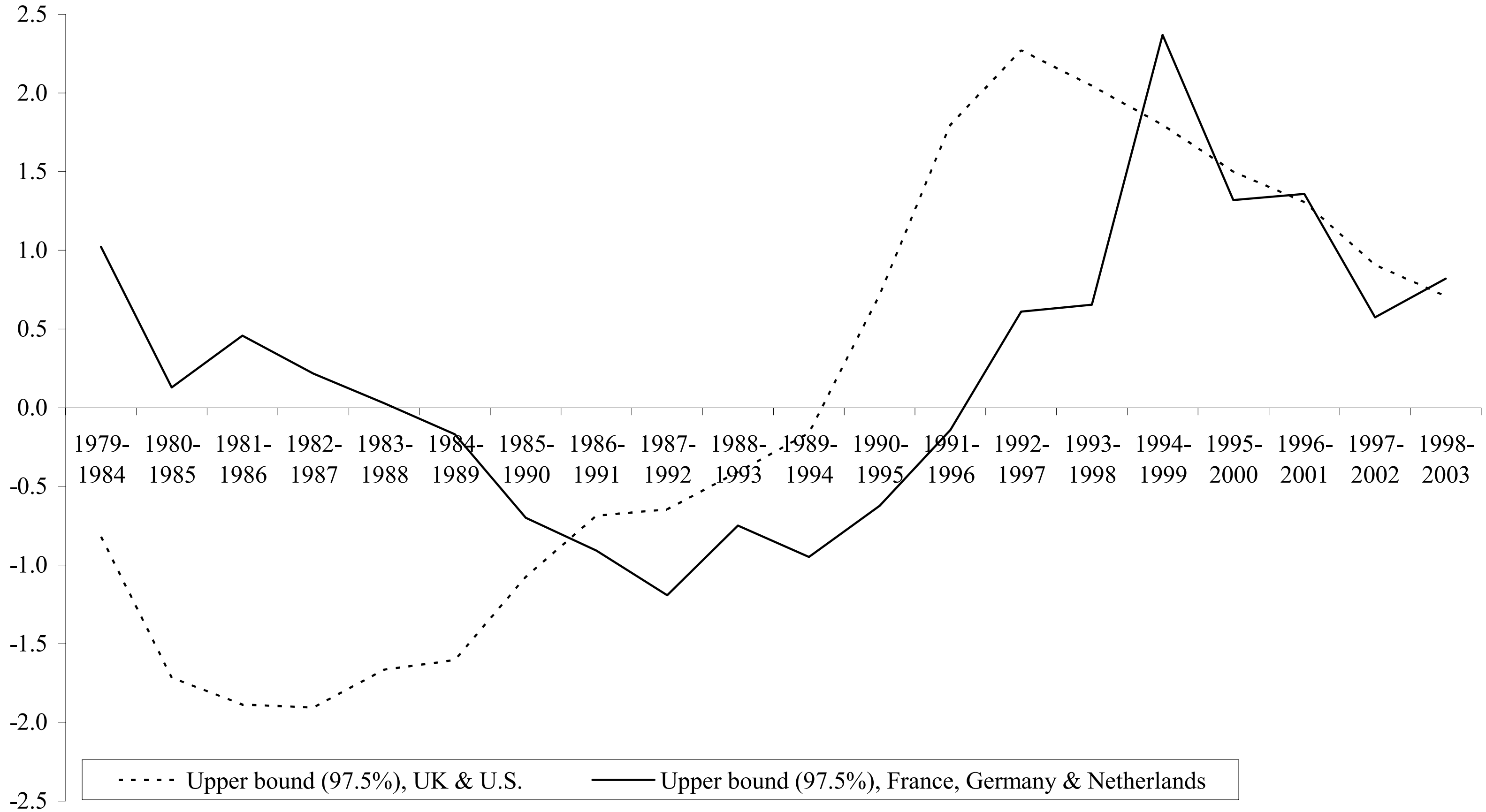


Table 1: Growth of GDP, hours worked and labour productivity in Europe and the U.S., 1987-2004

	EU-15			U.S.		
	1987-1995	1995-2004	2004	1987-1995	1995-2004	2004
GDP growth	2.2	2.1	2.1	2.7	3.3	4.4
Growth in total hours worked	0.0	0.7	0.8	1.4	1.6	0.9
Growth in GDP per hour worked	2.2	1.5	1.3	1.1	2.5	3.0

Source: McGuckin and van Ark (2005)

Table 2: Sources of labour productivity growth in the EU-15 and U.S., 1987-2004

	1987-1995	1995-2000	2000-2004
European Union-15			
Aggregate Labour Productivity Growth	2.3	1.8	1.1
of which:			
ICT capital deepening	0.4	0.6	0.3
Non-ICT capital deepening	0.8	0.4	0.5
ICT-production TFP	0.2	0.4	0.2
Non-ICT production TFP	0.9	0.4	0.0
United States			
Aggregate Labour Productivity Growth	1.2	2.3	2.8
of which:			
ICT capital deepening	0.5	1.0	0.6
Non-ICT capital deepening	0.1	0.2	0.5
ICT-production TFP	0.4	0.7	0.3
Non-ICT production TFP	0.2	0.4	1.4

Source: Groningen Growth and Development Centre (http://www.ggdc.net/dseries)

Table 3, Industry contributions to market economy labour productivity growth, 1987-2003

	1987-1995	1995-2000	2000-2003
European Union-15			
Market economy labour productivity growth	2.7	2.2	1.1
of which:			
ICT production*	0.5	0.8	0.5
Production industries**	1.3	0.8	0.6
Market services**	0.8	0.6	0.1
Reallocation	0.2	0.0	-0.1
United States			
Market economy labour productivity growth	1.4	3.4	3.6
of which:			
ICT production*	0.8	1.2	1.1
Production industries**	0.3	0.5	0.9
Market services**	0.5	1.8	2.0
Reallocation	-0.2	-0.1	-0.3

* Includes ICT manufacturing, telecom and software services

** Excludes ICT producing industries

Table 4, Sources of industry labour productivity growth, 1995-2003

	France	Germany	Netherlands	United Kingdom	EU-4	United States
Market Economy Labour Productivity Growth	***1.80***	***2.08***	***1.41***	***2.59***	***2.12***	***3.51***
of which:						
ICT capital deepening	0.46	0.54	0.81	0.77	0.63	1.27
Non-ICT capital deepening	0.32	0.37	0.71	0.71	0.54	0.60
Labour quality growth	0.21	0.05	0.12	0.23	0.14	0.11
Reallocation of hours	0.01	0.25	-0.35	-0.26	-0.08	-0.26
Total factor productivity growth	0.79	0.88	0.14	1.13	0.89	1.78
Contribution of ICT producing sector	*0.71*	*0.84*	*0.41*	*0.87*	*0.83*	*1.15*
of which:						
ICT capital deepening	0.03	0.06	0.08	0.14	0.09	0.23
Non-ICT capital deepening	0.02	0.07	0.11	0.05	0.05	0.08
Labour quality growth	0.02	0.01	0.03	0.02	0.03	0.01
Total factor productivity growth	0.64	0.69	0.19	0.65	0.67	0.83
Contribution of market services	*0.12*	*0.34*	*0.63*	*1.29*	*0.57*	*2.02*
of which:						
ICT capital deepening	0.33	0.38	0.60	0.53	0.44	0.84
Non-ICT capital deepening	0.00	0.13	0.25	0.40	0.20	0.27
Labour quality growth	0.15	0.02	0.07	0.15	0.07	0.07
Total factor productivity growth	-0.36	-0.19	-0.29	0.21	-0.14	0.85

Table 5: The effect of ICT on TFP growth

TFP=a+b*ICT+e	*All countries*	*France*	*Germany*	*Netherlands*	*UK*	*U.S.*
Single constant	-1.01*	-0.99	-1.43	-1.25*	-0.78	-0.96*
	(0.27)	(0.9)	(0.81)	(0.48)	(0.66)	(0.42)
Fixed effects	-1.47*	-1.98	-3.14*	-1.49	-0.71	-1.11
	(0.45)	(1.39)	(1.5)	(0.89)	(0.5)	(0.69)

Notes: * denotes significantly different from zero at 5% level. Standard errors, consistent for heteroscedasticity and autocorrelation are shown in parentheses. Dependent variable is industry TFP growth between 1979 and 2003. Independent variable is the contribution of ICT capital to output growth. In the fixed effects estimates, a dummy is introduced for each country/industry pair. Estimates for all market industries and all countries include 2875 observations (23 years, 25 industries, 5 countries), the other columns include 525 observations.

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