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ICT and Productivity in Europe and the United States
Where do the differences come from?

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Bart van Ark, *Robert Inklaar* and *Robert H. McGuckin*[*]

Abstract: *In this paper we analyse labour productivity growth in 51 industries in European countries and the United States. Using shift-share techniques we identify the industries in which the U.S. is leading most strongly. With a detailed decomposition analysis we identify whether the sources of the U.S. advantage are due to faster productivity growth, higher industry productivity levels relative to the country aggregate, different employment shares or faster change in employment shares of rapidly growing industries. The results show that U.S. productivity has grown faster than in the EU because of a larger employment share in the ICT producing sector and faster productivity growth in services industries that make intensive use of ICT. Wholesale and retail trade and the financial securities industry account for most of the difference in aggregate productivity growth between the EU and the U.S.* (*JEL N10, O47, O57)*

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1 Introduction

Explosive growth of investment in information and communication technology (ICT) was at the centre of the unrealistic expectations and excessive enthusiasm that surrounded the "new economy" during the late 1990s. The slowdown in GDP growth and investment in ICT in the United States since 2000 has tempered the hype. But the question how much of the hype will be sustainable beyond the cycle remains.

With the recent boom in ICT investment, labour productivity growth in the U.S. more than doubled. Productivity growth in the United States accelerated from growth of 1.1 percent in 1990-1995 to 2.5 percent in 1995–2000. In contrast labour productivity growth in most European countries slowed during the second half of the 1990s. The average annual growth rate of labour productivity, measured as value added per person employed, in the European Union fell from 1.9 percent to 1.4 percent over the same period (see Table 1).

Table 1: Productivity growth and GDP shares of ICT producing, ICT using and non-ICT industries in the EU and the U.S.

	Productivity growth				GDP share	
	1990-1995		1995-2000		2000	
	EU[b]	US	EU[b]	US	EU[b]	US
Total Economy	1.9	1.1	1.4	2.5	100.0	100.0
ICT Producing Industries	6.7	8.1	8.7	10.1	5.9	7.3
ICT Producing Manufacturing	11.1	15.1	13.8	23.7	1.6	2.6
ICT Producing Services	4.4	3.1	6.5	1.8	4.3	4.7
ICT Using Industries[a]	1.7	1.5	1.6	4.7	27.0	30.6
ICT Using Manufacturing	3.1	-0.3	2.1	1.2	5.9	4.3
ICT Using Services	1.1	1.9	1.4	5.4	21.1	26.3
Non-ICT Industries	1.6	0.2	0.7	0.5	67.1	62.1
Non-ICT Manufacturing	3.8	3.0	1.5	1.4	11.9	9.3
Non-ICT Services	0.6	-0.4	0.2	0.4	44.7	43.0
Non-ICT Other	2.7	0.7	1.9	0.6	10.5	9.8
Pro memoria: with national deflators						
Total Economy	1.9	1.1	1.4	2.5		
ICT Producing Manufacturing	7.8	15.1	10.1	23.7		

a) excluding ICT producing

b) EU includes Austria, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden and the United Kingdom, which represents over 90% of EU GDP. Notes: Productivity is defined as value added per person employed

Source: van Ark, Inklaar and McGuckin (2002, 2003a)

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The acceleration in productivity growth in the U.S. spurred a burst of academic research on both sides of the Atlantic. Most of the macroeconomic research concluded that ICT was responsible for much of the acceleration in productivity growth. In Europe attention focused on the slower growth and how much of it could be tied to differences in ICT diffusion relative to the U.S.. Various studies at the economy-wide level suggested that slower rates of ICT investment were an important factor in the poorer European productivity performance.[1]

In van Ark, Inklaar and McGuckin (2002, 2003a) we took a somewhat different approach compared to the macro-level growth accounting studies referred to above. We developed a database on value added, employment and labour productivity estimates in 16 OECD countries for 51 industries from1990 to 2000. This paper extends our earlier work on this issue with a new decomposition of productivity growth that identifies the main factors underlying differences between the European Union and the United States. The results show that U.S. productivity has grown faster than in the EU because of the dual effects from a larger ICT producing sector and faster growth in services industries that make intensive use of ICT. Three major service industries account for most of the U.S. growth advantage, namely wholesale and retail trade and the financial securities industry.

Hence not unlike the electric motor, the economic impact of ICT partly derives from its production but also – and foremost – from its applications to other processes, products and services (see for example Bresnahan and Trajtenberg 1995). With aggregate evidence that countries in Europe invest less in ICT (see van Ark et al. 2002) and this new evidence that intensive ICT users have shown slower productivity growth in Europe, it appears that the slower diffusion of ICT is the principal factor in explaining the lower European productivity growth.

The paper is organized as follows. In the next Section we give a brief overview of the literature on the growth resurgence in the United States. The evidence suggests an important role for the production and diffusion of ICT in the U.S. growth revival. Section 3 describes the construction of the data and introduces the classification of ICT producing, ICT using and non-ICT industries. Section 4 compares labour productivity growth by industry in the European Union and the United States. Section 5 presents shift-share techniques including our new decomposition to identify which sectors are mainly responsible for the growth differential between Europe and the U.S. as well as the sources of these differences. Section 6 shows the results of this analysis and Section 7 concludes.

2 The New Economy in the United States

Most analysts agree that the second half of the 1990s saw an uncommon resurgence in productivity growth. After decades of relative stagnation, labour productivity and total factor productivity growth returned to rates only rarely seen since the early 1970s (see, for example, Jorgenson 2001 and Oliner and Sichel 2000; 2002). Jorgenson, Ho and Stiroh (2002) attribute most of this acceleration to faster accumulation of ICT capital in a number of specific industries like trade and finance. Total factor productivity (TFP) growth also increased, due mainly to faster technological change in the ICT producing industries. Stiroh (2002) groups U.S. industries into ICT using or non-ICT based on the share of ICT goods in total capital input. Based on this classification he finds that ICT using industries show faster acceleration in labour productivity growth than non-ICT industries.

Studies also have been done at the firm level. For example, Brynjolfsson and Hitt (2000; 2003) survey micro-studies of the effects of ICT on productivity. They find that investment in ICT goods leads to higher productivity, especially if the investment in capital goods is accompanied by complementary investments in organizational change, like reorganizing the supply chain and introducing new workplace methods. Work by McKinsey Global Institute (2001) shows similar results for a selection of industries.

Still, how much of the acceleration in productivity growth is sustainable remains an issue. There are two broad issues to consider. First, labour productivity growth tends to be pro-cyclical, so that with the U.S. boom in the late 1990s the acceleration of structural productivity growth may have been overstated. However, the productivity growth experience in the U.S. since 2000 tends to support the hypothesis of a structural acceleration. Labour productivity growth has remained unusually strong with growth reaching

[1] See, for example, Daveri (2001; 2002), Collecchia and Schreyer (2002), van Ark, Melka, Mulder, Timmer and Ypma (2002) - , hereafter referred to as van Ark et al. (2002) - and Timmer, Ypma and van Ark (2003).

2.8 percent in 2002 (see McGuckin and van Ark 2003). Elsewhere we argue that only a small part of the acceleration in U.S. labour productivity growth (and deceleration in European productivity growth) can be attributed to cyclical factors (see van Ark, Inklaar and McGuckin 2003b). In a recent paper, Gordon (2003) also argues that, taking account of the full set of quarterly data between 1995 and mid-2003, most of the acceleration between 1995 and 1999 was structural instead of cyclical with a temporary bubble in 2002.

Second, even if the productivity acceleration was not so much a cyclical phenomenon, the future structural rate of productivity growth may not be as high since the most profitable innovations have already been implemented. Gordon (2003) argues that productivity growth due to computers may not remain as high as during the boom years in the late 1990s since first-rate inventions such as the Internet are likely to be more important than second-rate inventions like internet-enabled mobile phones. How much weight to give to this argument is not clear. For example, Oliner and Sichel (2002) and Jorgenson, Ho and Stiroh (2003) project that productivity growth will remain strong for the years to come. But in another detailed study of industries in the U.S., Triplett and Bosworth (2002) find that services industries exhibit both strongly positive and negative labour productivity growth rates and that ICT is not the only factor in explaining the differences. Hence while the sustainability of the acceleration is still an open question, it is revealing that while (measured) productivity usually shows some declines in recessions, labour productivity growth in the U.S. in 2001 remained positive at 0.4 percent and rebounded to 2.8 percent in 2002.

Leaving aside sustainability issues, we conclude that the American growth resurgence is based on rapid technological change in the ICT producing industries and rapid ICT investment in other parts of the economy. Important services sectors like distribution and finance have been the main beneficiaries of these investments. However, apart from heavy ICT investment, large complementary investments in intangible assets like the organization of firms are also necessary to achieve productivity gains.

3 Measuring productivity and ICT at the industry level

For the analysis of productivity growth in Europe and the U.S. we developed a database, which contains information on value added and employment in 16 OECD countries for 51 industries between 1990 and 2000. The main source is the new OECD STAN Database of national accounts. The STAN Database contains information on the most important national accounts variables from 1970 onwards on a common industrial classification.[2]

In addition to the fact that the 1990s is the most relevant period for studying the impacts of ITC technology on EU – U.S. differences in productivity growth, the extensive resources required to develop earlier data meant that for practical reasons we only study the period from 1990 onwards.[3] The level of detail has to be very substantial in order to adequately distinguish between the different ICT producing industries. This group of industries, including producers of IT hardware, communication equipment, telecommunications and computer services (including software), was distinguished based on an OECD classification (see for example OECD 2002).

Apart from distinguishing ICT producing industries, we also separate the industries that make intensive use of ICT from those that are less intensive users. This is a less straightforward undertaking since nearly every part of the economy uses some ICT. Nevertheless research for the U.S. has shown that a binary classification based on ICT intensity is preferable as long as the underlying data on ICT capital for the other countries are still very noisy (see McGuckin and Stiroh 2001). As a measure of ICT intensity, we rely on the share of ICT capital in total capital compensation in the United States from Stiroh (2002). Appendix Table A1 gives an overview of all ICT producing, ICT using and non-ICT industries. We also make a distinction between manufacturing and services industries within each industry group.

There are two reasons for applying the classification based on ICT intensity in the U.S. to all countries. The first is the very limited availability of data on ICT investment by industry outside the U.S., let alone

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2 The STAN Database uses the international classification ISIC revision 3. This classification is very similar to the NACA rev. 1 classification that European countries are using, but especially in the U.S., much effort has to be put into reconciling differences in industrial classification, see Appendix B of van Ark, Inklaar and McGuckin (2002).

3 See O'Mahony and van Ark (2003) for backdating of the estimates to 1979.

capital stocks and capital services measures.[4] Second, given the leading role of the U.S., it is reasonable to assume that the distribution of ICT use in the U.S. presents a set of technological opportunities, which may be taken up in other countries.

We classified the top half of industries as ICT user and the bottom half as non-ICT.[5] While this is an arbitrary cut-off point, the analytical results discussed below are robust as long as we can be certain that wholesale trade, retail trade and financial securities are classified as ICT using. In van Ark, Inklaar and McGuckin (2003b) we use newly available data on ICT capital by industry for four European countries to show that the classification is broadly similar, especially in services.

Some additional problems in constructing an internationally consistent productivity database at industry level need to be addressed. These especially concern the method of aggregation, the deflation of ICT products and the measurement of services output. Firstly, many countries still use fixed-weight (Laspeyres) indices to calculate aggregate value added at constant prices. This can lead to serious substitution bias if the structure of the economy is changing over time. To correct for this problem, chain-weighted indices like Fisher or Törnqvist indices are needed. We use Törnqvist indices for aggregation from industry level to higher aggregates. This means that our estimates of change in aggegrate GDP will generally not fully conform to those from national statistical offices. However, our procedure leads to more consistency of the estimates across countries.

The second problem concerns the deflation of ICT goods. It is well known that the technological capabilities of semiconductors and computers have improved tremendously over the past few decades.[6] Since consumers can buy computers with vastly more computing power at comparable prices, the price of computing power has declined enormously. Traditional methods of sampling and calculating price indices for these goods will almost certainly underestimate the rate of price decline and, because of that, the rate of productivity growth. At present there are only a few countries, like the U.S., Canada and France that have a more adequate system, such as hedonic price indices, for measuring prices of computers and semiconductors. This means that measured productivity growth in ICT producing industries is likely to be biased downwards in all other countries. We avoid this downward bias by applying the U.S. deflators for each of the ICT producing manufacturing industries to all other countries after making a correction for the general inflation level.[7] Although this of course influences the productivity growth rates in the ICT producing industries, Table 1 shows that it does not have a large effect on the aggregate growth figures due to the relatively small weight of the ICT producing sector in the total economy.

Finally, compared to manufacturing, measurement problems concerning the change in output are much larger in many services industries. In several industries, such as the banking industry, it is very hard to accurately describe, let alone measure all the outputs the industry provides. For example, and particularly relevant in the context of this paper, measurement problems in the financial securities industry have accumulated over the years. As Stiroh (2002) points out, output in financial services is measured simply in terms of the volume of trade and not as in other trade-related industries in terms of the margin between the purchase and sale of an asset. This may have led to an overstatement of productivity growth during the stock market boom of the late 1990s. However, the impact of such mismeasurement can only be empirically assessed after revisions have been made. For example, in the most recent release of GDP by industry, better deflators have been incorporated and these show that labour productivity growth in this industry remains relatively high, although not as high as before.[8]

In the case of non-market services, one of the major issues is that the real output is still largely based on information on inputs (such as employment input and labour income). While in both Europe and the

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[4] See van Ark et al. (2002) for some of the difficulties in acquiring ICT investment even at the aggregate level for European economies.

[5] The exceptions are education and health, which rank fairly high in terms of the ICT investment share, but are near the bottom on alternative measures such as ICT capital per worker or unit of output.

[6] See Nordhaus (2001) for a long-term perspective on the increase in computing power.

[7] The inflation level is measured here as the change in the deflator of all industries except the ICT producing manufacturing industries. This procedure is similar to that in Schreyer (2000, 2002), which was applied to ICT deflators for investment. The ICT deflators by industry had to be specifically constructed because implicit value added deflators are not available at the requisite detail from the U.S. National Income and Product Accounts. While constructing these deflators not only the output price but also changes in intermediate input prices were taken into account (so-called double deflation). See van Ark, Inklaar and McGuckin (2003a) for more details and Triplett (1996) for the importance of double deflation in the computer and semiconductor industries.

[8] See McCahill and Moyer (2002) for a description of the most revisions to the U.S. GDP by industry figures, and O'Mahony and Van Ark (2003) for productivity growth results using the most recent release of U.S. GDP by industry.

United States improvements in measurement of non-market services output, for example in health and education, are discussed among statisticians and academic scholars, details on the actual implementation of improved measurement methods in the national accounts are often missing.[9] In applying our decomposition method in Section 6 we show how non-market services affect our aggregate results and how this impacts our analysis.

4 Comparing the results between the EU and the U.S.

The latter half of the 1990s showed a decline of labour productivity growth in Europe while growth in the U.S. accelerated. This may suggest Europe has not exploited the productivity effects from ICT to the same degree as the United States. In general, European countries are heavily investing in ICT equipment, but the ICT share in total investment in the EU remains considerably lower than in the United States.[10] While ICT investment (including software) accounted for 17 percent of business investment in Europe in 2000, the corresponding figure for the U.S. was almost 30 percent. By then the U.S. had further increased its lead compared to 1990 when ICT investment was only 12 percent in Europe and 23 percent in the U.S. (van Ark et al. 2002). The result is that ICT contributes nearly twice as much to labour productivity growth in the U.S. as in the EU.[11]

To better understand the sources of the aggregate growth differential between the EU and the U.S. we focus on the industry perspective. Table 1 provides an overview of the growth experience in both regions, showing labour productivity growth for the economy as a whole and for ICT producing, ICT using and non-ICT industries.

Table 1 shows a number of interesting differences between the EU and the U.S. In the ICT producing manufacturing industries, the U.S. has a clear edge over the EU with much higher productivity growth in both periods. Within the European Union productivity growth in ICT producing manufacturing is also highest compared to the other industry groups. The latter result is partly due to the application of U.S. hedonic price indices for ICT products to corresponding industries in Europe. However, as the pro-memoria line on the total economy in Table 1 shows, the comparative growth performance at the aggregate level between the EU and the U.S. is not much affected by our adjustment to national deflators.

Another remarkable feature in Table 1 is the strong acceleration in productivity growth in ICT using services in the U.S. Before 1995, productivity growth in ICT using services was similar in the U.S. and EU at between one and two percent a year. After 1995, however, growth in the U.S. accelerated from 1.9 percent to 5.4 percent on average. Considering that this industry group accounts for more than a quarter of U.S. GDP, the effects on aggregate growth are large. Both in the EU and the U.S., the ICT producing and the ICT using industries show generally faster productivity growth than the non-ICT industries, and this is especially pronounced in the ICT using services industries.

5 A method to decompose productivity growth differences

To get a more quantitative picture of the contribution of an industry to aggregate productivity growth, we employ a shift-share analysis at the detailed level of 51 industries. Aggregate productivity is determined by the productivity levels of the individual industries, weighted by each industry's share in total employment:

(1) $$P = \frac{Y}{L} = \sum_{i=1}^{n}\left(\frac{Y_i}{L_i}\right)\left(\frac{L_i}{L}\right) = \sum_{i=1}^{n}\left(P_i S_i\right)$$

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9 In the United States, the U.S. Bureau of Labor Statistics (which is responsible for the development of price indices) and the Bureau of Economic Analysis (which produces the National Income and Product Accounts) have introduced various improvements in measurement methods (Dean 1999; Gullickson and Harper 1999; Landefeld and Fraumeni 2001). Eurostat also recently evaluated measurement practices in various service activities, such as financial services and public services (Eurostat 2001).

10 Most recently this has been shown in Van Ark, et al. (2002) and Timmer, Ypma and Van Ark (2003). Similar evidence is also provided in for example Colecchia and Schreyer (2002) and Daveri (2001; 2002).

11 This ratio holds for both the contribution from ICT capital deepening and from TFP-growth in the ICT producing industries to labour productivity growth.

In this equation, P is productivity, Y is value added and L is labour input and subscript i denotes the industry. In a time perspective for country A, equation (1) becomes (see Fabricant 1942):

$$\text{(2)} \qquad \frac{P_t^A - P_{t-1}^A}{P_t^A} = \frac{\Delta P^A}{P_t^A} = \sum_{i=1}^{n} \frac{\Delta P_i^A \cdot \overline{S}_i^A}{P_t^A} + \sum_{i=1}^{n} \frac{\overline{P}_i^A \cdot \Delta S_i^A}{P_t^A}$$

In this equation, a bar over a variable denotes a two-period average. The first term on the right-hand side is generally called the within-industry effect ('intra-effect'), while the second is a between-industry effect ('shift-effect'). The first term is the sum of productivity growth for each industry weighted by the industry's share of employment in the economy. The second term accounts for changes in the industry's share in employment weighted by the industries productivity level relative to the aggregate. Looking at each of the two terms in Equation (2) an industry's contribution will increase if, compared to the average for each variable, 1) its productivity growth is higher, 2) its employment share is larger, 3) its employment share increases or 4) its relative productivity level is higher.

Although this analysis can be carried out for individual countries, we use it here to investigate, which industries account for the productivity growth differential we have observed between the EU and the U.S. since 1995. For this purpose the shift-share technique needs to be modified somewhat. We propose a decomposition that splits up the aggregate productivity growth differential into the difference in the contribution of each industry to that growth differential. The differences in contributions are then attributed to differences in each of the four factors mentioned above.

The comparison starts from the basic shift-share analysis. As in equation (2) for country A, aggregate productivity growth in country B can also be decomposed into industry contributions:

$$\text{(2')} \qquad \frac{\Delta P^B}{P_t^B} = \sum_{i=1}^{n} \frac{\Delta P_i^B \cdot \overline{S}_i^B}{P_t^B} + \sum_{i=1}^{n} \frac{\overline{P}_i^B \cdot \Delta S_i^B}{P_t^B}$$

If we want to compare the difference in industry contributions between countries A and B to their aggregate productivity differential, we can simply take the difference of equations (2) and (2'):

$$\text{(3)} \qquad \frac{\Delta P^A}{P_t^A} - \frac{\Delta P^B}{P_t^B} = \sum_{i=1}^{n} \left(\frac{\Delta P_i^A \overline{S}_i^A}{P_t^A} - \frac{\Delta P_i^B \overline{S}_i^B}{P_t^B} \right) + \sum_{i=1}^{n} \left(\frac{\Delta S_i^A \overline{P}_i^A}{P_t^A} - \frac{\Delta S_i^B \overline{P}_i^B}{P_t^B} \right)$$

Equation (3) shows that the difference in aggregate productivity growth is due to the differences between countries A and B in the within and shift contributions of each industry. We can take this decomposition one step further and split the difference into effects which are related to productivity growth (ΔP), productivity levels ($\overline{P}$),the employment share ($\overline{S}$) and changes in the share of employment (ΔS) by industry. More precisely, if the within-effect of industry i in country A is larger than in B, this can be due to a higher productivity growth or due to a larger employment share over the two periods. Likewise, if the between-effect of industry i in country A is larger than in B, this can be due to a bigger change in the employment share or due to a higher productivity level relative to the aggregate productivity level.

To separate these different causes, we define two counterfactual shift-share equations that impose the employment structure of country B on country A and vice-versa. If we impose country B's structure on country A, the two terms on the right-hand side of (2) become:

$$\text{(4)} \qquad \frac{\Delta P^{A|B}}{P_t^A} = \sum_{i=1}^{n} \frac{\Delta P_i^A \overline{S}_i^B}{P_t^A} + \sum_{i=1}^{n} \frac{\Delta S_i^B \overline{P}_i^A}{P_t^A}$$

With this first counterfactual the decomposition is carried out as follows:

- The difference between the first term of (4) and the first term of (2') shows the difference in contribution of industry i to aggregate productivity growth because of a faster (or slower) productivity growth in country A compared to country B, i.e. the "productivity growth effect" (ΔP)

- The difference between the first term of (4) and the first term of (2) shows the difference in contribution of industry i to aggregate productivity growth because of a higher (or lower) employment share of industry i in country A compared to country B, i.e. the "employment share effect" ($\overline{S}$).

- The difference between the second term of (4) and the second term of (2') reflects the difference in contribution of industry *i* to aggregate productivity growth because of a higher (or lower) productivity level in country A compared to country B relative to the aggregate productivity level, i.e. the "productivity level effect" ($\overline{P}$).

- The difference between the second term of (4) and the second term of (2) reflects the difference in contribution of industry *i* to aggregate productivity growth because of a faster rise (or slower fall) in the employment share of industry *i* in country A compared to country B, i.e. the "change in employment share effect" (ΔS).

Parallel to the procedure above, we can also impose country A's employment structure on country B, which transforms equation (2') into:

$$\text{(4')} \qquad \frac{\Delta P^{B|A}}{P_t^B} = \sum_{i=1}^{n} \frac{\Delta P_i^B \overline{S}_i^A}{P_t^B} + \sum_{i=1}^{n} \frac{\Delta S_i^A \overline{P}_i^B}{P_t^B}$$

This second counterfactual results in the same four effects described above, but gives a different result because we now assume country A's employment structure instead of that of country B. As there is no *a priori* reason to prefer one or the other employment structure for the counterfactual, we take a simple unweighted average for each of the four effects based on country A's or country B's structure.

To gain a fuller understanding of what this decomposition procedure delivers, we illustrate it with an example. For the period 1995–2000, productivity growth in the computer industry (ISIC 30) was 49.3 percent per year in the EU, compared to 52.3 percent in the U.S. On average the industry accounted for only 0.14 percent of total employment in the EU and 0.18 percent in the United States. The employment share went down by 0.03 percentage points in the EU and by 0.05 percentage points in the U.S. between 1995 and 2000. To trace the effects of these differences on the industry's contribution to the aggregate productivity growth differential between the U.S. and the EU we run the counterfactuals as in equations (4) and (4').

The matrix in Table 2 shows the within-effects for both countries under both sets of employment shares as well as the differences between the U.S. and EU. Taking the U.S. as country A (and the EU as country B) suggests that the computer industry in the U.S. has a within-effect contribution to aggregate productivity growth of 0.274 percentage-point (according to the first term of equation (2)), which would have been 0.199 percent in case the U.S. had the same employment structure as the European Union (according to the first term of equation (4)). Hence the U.S.-EU productivity differential is 0.075 percentage points due to a bigger share of the U.S. computer industry in total employment ($\overline{S}$). This difference would have been 0.053 percentage points had we looked at the EU within-effects, as is shown in the second column of Table 2 (comparing the first terms of equations (2') and (4')). If we compare across the columns instead of across the rows in Table 2, we find that the contribution to the U.S.-EU productivity growth differential due to faster productivity growth in the U.S. computer industry (ΔP) is 0.066 percentage points when imposing the U.S. employment structure on both the U.S. and the EU (comparing the first terms of equations (2) and (4')). It becomes 0.045 when assuming the EU employment structure for both the U.S. and the EU (comparing the first terms of equations (2') and (4)).

Table 2, Difference in within-effects for the computer industry (ISIC 30) between the U.S. and the EU based on imposition of different employment structures, 1995-2000 (%-point contribution)

		Country productivity growth		Difference (due to productivity growth) U.S.-EU
		U.S.	EU	
Country employment shares	U.S.	0.274	0.207	0.067
	EU	0.199	0.154	0.045
Difference (due to employment shares)	U.S.-EU	0.075	0.053	
Average difference due to employment shares				0.064 [(0.075+0.053)/2]
Average difference due to productivity growth				0.056 [(0.067+0.045)/2]
Total difference in within-effect				0.120 [0.064+0.056]

Overall the within-effect contributed 0.120 percentage points (0.274-0.154) to the aggregate U.S.-EU productivity differential. A straightforward way to calculate the average productivity growth effect is then to take an unweighted average of the two figures in the last column of Table 2 which comes to 0.056 percent (see also the row "Average difference due to productivity growth"). The remainder of the difference in within-effect is then due to differences in industry size. This is equal to the average of the figures in the row "Average difference due to employment shares" or 0.064 percent. Together, these two effects exactly add up to the total difference in intra-effect of 0.120 percentage points.

We can run a similar analysis which focuses on the second terms of equations (2), (2') and (4) and (4'), the "shift or "in between" effect, for the computer industry. The four possible comparisons between these second terms lead to another matrix (Table 3), that shows contributions to the productivity growth differential because of differences in (relative) productivity levels ($\overline{P}$) or because of differences in the change in employment shares (ΔS).

Table 3, Difference in shift-effects for the computer industry (ISIC 30) between the U.S. and the EU based on imposition of different employment structures, 1995-2000 (%-point contribution)

		Country productivity levels U.S.	Country productivity levels EU	Difference (due to productivity levels) U.S.-EU
Country change in employment shares	U.S.	-0.029	-0.022	-0.007
	EU	-0.017	-0.013	-0.004
Difference (due to employment shares)	U.S.-EU	-0.012	-0.009	
Average difference due to employment shares				-0.011 [(-0.012-0.009)/2]
Average difference due to productivity levels				-0.006 [(-0.007-0.004)/2]
Total difference in shift-effect				-0.016 [-0.011-0.006]

Table 3 shows that in the case of the computer industry the between-effects are always negative. This is a consequence of the declining employment share of the computer industry in both Europe and the United States. The bottom row and right hand columns in the Table show that the U.S. between-effect is more strongly negative than in Europe due to both a larger decline in employment share in (–0.012 and –0.009) and a higher productivity level relative to the aggregate productivity level for the U.S. economy (–0.007 and –0.004).[12]

6 Decomposing the Productivity Growth Differential between Europe and the U.S.

Table 4 shows the results of the decomposition method from the previous Section for the 7 industry groups from Table 1. The first two columns show the contribution of each industry group to aggregate productivity growth in the EU and the U.S. respectively. The third column is the difference between the two. This column confirms the main differences identified before. Together ICT producing manufacturing (0.48 percentage-points larger contribution in the U.S.) and ICT using services (0.89 percentage-points larger contribution in the U.S.) account for more than the total productivity growth difference between the EU and the U.S.. There are offsetting effects, mainly in ICT producing services and the non-ICT industries. The remaining columns in Table 4 decompose this difference into the four factors described in Section 5. The decomposition shows that in ICT producing manufacturing the difference in contribution is mainly a case of differences in employment shares in the EU and the U.S., and to a lesser extent differences in productivity growth. This point was already hinted at in the value added shares from Table 1. ICT producing manufacturing makes up 2.6 percent of U.S. GDP versus 1.6 percent of EU GDP. However, within this industry there are important differences as well. The computer industry is only 0.23 percent of EU GDP but 0.35 percent of U.S. GDP. In semiconductors, the difference is even bigger: 0.24 in the EU versus 0.79 percent in the U.S.. Since these two industries have shown productivity growth rates in excess of 50 percent per year on average after 1995, these differences have a large effect on aggregate outcomes.[13]

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[12] The higher productivity level relative to the aggregate productivity level gives a larger weight to the decline in employment share.

[13] See van Ark, Inklaar and McGuckin (2002, 2003a) and Appendix Table A1.

The largest contributor to the overall productivity growth difference between the EU and the U.S. is the ICT using services sector. In this sector, much higher productivity growth rates in U.S. ICT using services explain most of the productivity growth differential. Figure 1 gives a more detailed overview of the differences by showing the total difference in contribution for each of the 10 ICT-intensive service industries (including ICT producing services). The first term within brackets refers to the productivity growth effect and the second to the sum of the other three effects. Only three industries account for the full difference in productivity growth contribution from Table 4, namely wholesale and retail trade and financial securities trade. Together, these industries account for 0.9 of the 1.1 percentage point growth differential between the EU and the U.S. The first number between brackets also makes clear that, especially in the distribution industries, higher U.S. productivity growth – not the other effects - is by far the most important factor. In securities trade, the higher U.S. employment share also plays a considerable role.[14] At the other end of the scale the ICT producing services, telecommunications and computer services, make larger contributions to growth in Europe than in the United States. Productivity growth is again the most important factor, although it is partly offset by a faster increase in the employment share of these industries in the U.S.[15]

Table 4: Contribution of industry groups to aggregate productivity growth and decomposition for the EU and U.S. for 1995-2000

	Contribution to productivity growth		Total difference	Contribution of			
	U.S.	EU	U.S.-EU	*Productivity Growth*	*Employment Share*	*Productivity Level*	*Change share Employment*
Total Economy	2.49	1.40	1.09	0.84	0.35	-0.08	-0.02
ICT Producing Industries	0.99	0.60	0.39	0.00	0.29	-0.01	0.11
ICT Producing Manufacturing	0.73	0.25	0.48	0.18	0.29	0.00	0.01
ICT Producing Services	0.26	0.35	-0.09	-0.19	0.01	-0.01	0.10
ICT Using Industries[a]	1.22	0.42	0.80	0.77	0.13	0.03	-0.12
ICT Using Manufacturing	-0.08	0.01	-0.09	-0.06	-0.01	0.00	-0.02
ICT Using Services	1.30	0.41	0.89	0.83	0.14	0.02	-0.11
Non-ICT Industries	0.28	0.38	-0.10	0.07	-0.08	-0.09	-0.01
Non-ICT Manufacturing	-0.05	0.04	-0.09	-0.01	-0.05	-0.02	-0.01
Non-ICT Services	0.23	0.38	-0.14	0.13	0.04	-0.07	-0.25
Non-ICT Other	0.10	-0.03	0.13	-0.05	-0.07	0.00	0.25
Pro-memoria: contribution of							
Business sector	2.60	1.34	1.26	0.97	0.30	-0.07	0.06
Non-ICT market services	0.35	0.32	0.03	0.26	-0.01	-0.06	-0.17

The last column of table 4 shows that differences in employment share changes are much less important in explaining the U.S.-EU productivity differential at the aggregate level. Nevertheless for a few industry groups the effect of changing employment shares is far from negligible. Table 4 shows that in non-ICT services and other non-ICT industries, changes in employment share show the largest contribution to the difference in productivity growth between the U.S. and the EU.

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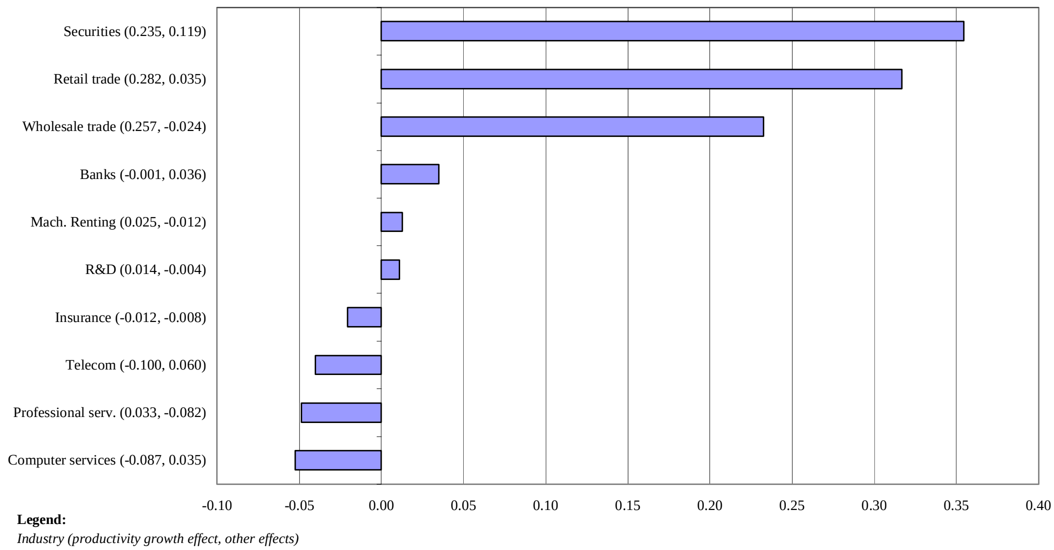
[14] Although the productivity growth effect will be smaller on the basis of the recently revised output numbers for financial securities in the U.S., the large effect from the higher employment share will be maintained.

[15] See Appendix Table A1 for a full list of the industry contributions and the decomposition. Professional services have also shown faster productivity growth in Europe than in the United States, which is mainly due to the rise in the employment share of this industry in the EU from 3.6 to 4.2 percent between 1995 and 2000, while in the U.S. it increased only from 3.1 to 3.4 percent.

Figure 1, Contribution of ICT producing and ICT using services to the U.S.-EU productivity growth differential, 1995-2000



In non-ICT services, the employment share of real estate rises for the EU, but remains constant in the United States. The big impact is striking, as the increase in the employment share is small, from 0.96 percent to 1.03 percent of total employment. The reason for the sizeable effect is that in both Europe and the U.S. real estate has a very high measured labour productivity level, as it includes the (rental) value of residential housing services.[16] From the standpoint of our decomposition, this means any change in the importance of this industry (as measured by its employment share) gets a very large weight because of the high relative productivity level of this industry.

In Section 3 we pointed out that measurement problems in non-market services (government, health and education), which are part of non-ICT services, are particularly large. For that reason many researchers focus on the business sector instead of the total economy. One of the advantages of our decomposition technique is that the contribution of non-market services to aggregate growth can easily be identified (and removed) so that the contribution of the business sector can be studied separately. In Table 4 we show that the difference in productivity growth between Europe and the United States increases if only the business sector is considered. For the business sector of the economy, the growth differential is 1.26 percent in contrast to 1.09 for the aggregate economy. The contribution of non-ICT market services to the U.S.-EU productivity growth differential is slightly positive (0.03), whereas it is negative for all non-ICT services (-0.14).

In other non-ICT industries, large changes in employment shares can be observed as well. The most important of these is a large increase in the employment share of the U.S. construction industry from 5.1 to 5.7 percent of total employment, while this industry showed a decline from 7.3 to 6.9 percent in Europe. In the U.S., this increase accounted for 12 percent of total employment growth, the second largest contribution after “other business services”.

Finally, it is interesting that the productivity level effect is negligible in most industries. In the majority of industries, this effect is rounded to 0.00 in Table A1. This means the industry productivity levels relative to the aggregate productivity level are very comparable across Europe and the United States. This is confirmed by the correlation between those ratios for the EU and the U.S., which is very high at 0.93.[17]

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[16] The reason for this is to preserve the national accounting identities, even though the rental values are not specific services provided by real estate agents.

[17] The outlying productivity level of real estate does not change the basic conclusion. Without that industry, the correlation would be 0.81 and the rank correlation is 0.86.

7 Conclusions

With a spreading consensus that growth in the United States has benefited not only from the production of ICT but also from its adoption in ICT-using industries, more evidence becomes available that Europe is clearly lagging in this respect. Most European economies show considerably lower investment levels in ICT goods and software than the U.S. Furthermore, as productivity growth in the U.S. has accelerated, European productivity growth has slowed down since the mid 1990s. The main contribution of this study is a quantification of the sources of the productivity growth differential at the industry level.

Productivity growth in various ICT-using service industries, in particular wholesale and retail trade and securities tradem was very high in the U.S. during the second half of the 1990s, while European growth in these industries was modest by comparison. While larger employment shares of ICT producing industries, like computers and semiconductors also play a role, it is faster productivity growth in ICT using services which account for the largest part of the productivity growth differential between the U.S. and the EU.

Another question is why ICT-using service industries would show much faster growth in the U.S. than in European countries. It is unlikely to be a matter of insufficient access to new technologies in the EU, as the market for ICT goods and software is essentially global. Also, the strong performance of telecommunications in the EU suggests there are certainly opportunities to benefit from new technologies like wireless telephony in Europe too. Furthermore the growth of ICT investment has been large in Europe as well.

McGuckin and van Ark (2001) argue that structural impediments in product and labour markets hamper the successful implementation of ICT in Europe. Limits on shopping hours and transport regulations and restrictive hiring and firing rules as well as other restrictive labour regulations make it hard for producers to organize their organizations to reap the full benefits from ICT. Furthermore, barriers to entry also limit competitive pressure. Recent research for U.S. retail trade has shown that entry of productive new firms and exit of low-productive firms is responsible for almost all of labour productivity growth in this sector (see Foster et al. 2002). However, one must be careful not to embrace a simple story that is based only on excessive European regulation. The more rapid take-off of wireless technology in Europe suggests that some regulation, for example, setting standards can be productivity enhancing as well. Still, the question why most European economies have been unable to combine employment and productivity growth should remain high on the research agenda.

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Appendix Table A1: Contribution of industries to total labor productivity growth for 1995-2000 for the EU and U.S. and the decomposition into four effects

		U.S.	EU	Difference	*Productivity growth*	*Employment share*	*Productivity level*	*Emp. share change*
Total Economy		**2.49**	**1.40**	**1.09**	**0.84**	**0.35**	**-0.08**	**-0.02**
Total ICT producing manufacturing		**0.73**	**0.25**	**0.48**	**0.18**	**0.29**	**0.00**	**0.01**
30	Office and Comp. Eq.	0.24	0.14	0.10	0.06	0.06	-0.01	-0.01
313	Fiber optics	0.00	0.00	0.00	0.00	0.01	0.00	-0.01
321	Semiconductors	0.50	0.14	0.36	0.13	0.21	0.00	0.02
322	Communication eq.	0.02	0.02	0.00	-0.01	0.00	0.00	0.01
323	Radio and TV eq.	0.00	-0.02	0.01	0.00	0.01	0.00	0.00
331	Instruments	-0.03	-0.03	0.00	0.00	0.00	0.00	0.00
Total ICT producing services		**0.26**	**0.35**	**-0.09**	**-0.19**	**0.01**	**-0.01**	**0.10**
64	Telecommunications	0.16	0.20	-0.04	-0.10	0.01	0.00	0.05
72	Computer services	0.09	0.14	-0.05	-0.09	0.00	-0.01	0.05
Total ICT using manufacturing		**-0.08**	**0.01**	**-0.09**	**-0.06**	**-0.01**	**0.00**	**-0.02**
18	Apparel	-0.02	-0.01	0.00	0.00	0.00	0.00	0.00
22	Printing & Publishing	-0.03	0.00	-0.03	-0.03	0.00	0.00	0.00
29	Machinery	-0.02	0.00	-0.02	-0.01	0.00	0.00	0.00
31-31.3	Electrical machinery	-0.01	0.01	-0.02	-0.02	0.00	0.00	0.00
33-33.1	Watches & instruments	0.00	0.00	-0.01	0.02	-0.01	0.00	-0.01
35.1	Ships	0.00	0.00	-0.01	0.00	0.00	0.00	0.00
35.3	Aircraft	-0.01	0.00	-0.01	-0.02	0.01	0.00	0.00
35.2+35.9	Railroad and other	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36-37	Misc. manufacturing	0.01	0.00	0.01	0.01	0.00	0.00	0.01
Total ICT using services		**1.30**	**0.41**	**0.89**	**0.83**	**0.14**	**0.02**	**-0.11**
51	Wholesale trade	0.30	0.07	0.23	0.26	0.02	0.00	-0.04
52	Retail trade	0.38	0.06	0.32	0.28	0.05	0.00	-0.02
65	Banks	0.10	0.06	0.04	0.00	0.00	0.00	0.04
66	Insurance	-0.03	-0.01	-0.02	-0.01	0.00	0.00	-0.01
67	Securities trade	0.37	0.02	0.35	0.24	0.08	0.02	0.02
71	Renting of machinery	0.04	0.03	0.01	0.03	0.00	-0.01	0.00
73	R&D	0.01	0.00	0.01	0.01	0.00	0.00	0.00
74.1-74.3	Professional services	0.11	0.16	-0.05	0.03	-0.01	0.02	-0.10
Total Non-ICT manufacturing		**-0.05**	**0.04**	**-0.09**	**-0.01**	**-0.05**	**-0.02**	**-0.01**
15-16	Food products	-0.09	-0.02	-0.07	-0.09	0.03	0.00	0.00
17	Textiles	-0.01	-0.01	0.00	0.01	0.00	0.00	-0.01
19	Leather	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
20	Wood products	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00
21	Paper products	-0.01	0.00	-0.02	-0.01	0.00	0.00	-0.01
23	Petroleum & coke	0.00	-0.01	0.01	0.01	0.00	0.00	0.00
24	Chemicals	0.04	0.05	-0.01	0.03	-0.04	-0.02	0.02
25	Rubber and plastics	0.02	0.01	0.00	0.02	0.00	0.00	-0.01
26	Stone, clay & glass	0.01	0.00	0.01	0.01	-0.01	0.00	0.01
27	Basic metals	0.01	-0.01	0.02	0.01	0.00	0.00	0.01
28	Fabricated metal products	0.00	0.01	-0.01	0.00	-0.01	0.00	0.00
34	Motor vehicles	0.01	0.03	-0.02	0.01	-0.01	0.00	-0.03
Total Non-ICT services		**0.23**	**0.38**	**-0.14**	**0.13**	**0.04**	**-0.07**	**-0.25**
50	Repairs	-0.02	0.03	-0.05	-0.05	0.00	0.00	-0.01
55	Hotels & restaurants	0.01	0.02	-0.01	0.05	-0.01	-0.01	-0.04
60-63	Transportation	0.07	0.09	-0.02	-0.01	-0.02	0.00	0.01
70	Real estate	0.14	0.05	0.09	0.23	0.01	-0.02	-0.13
74.9	Other business services	0.14	0.12	0.02	0.04	0.00	-0.03	0.00
75	Government	-0.09	-0.03	-0.06	-0.07	0.04	0.00	-0.02
80	Education	0.00	-0.01	0.01	-0.02	0.01	0.00	0.02
85	Health	-0.01	0.05	-0.06	-0.04	0.00	0.00	-0.02
90-93	Personal & social services	-0.01	0.05	-0.06	0.00	0.00	-0.01	-0.05
Total Non-ICT other industries		**0.10**	**-0.03**	**0.13**	**-0.05**	**-0.07**	**0.00**	**0.25**
01-05	Agriculture	0.06	0.01	0.05	0.05	-0.06	-0.01	0.06
10-14	Mining	-0.05	-0.02	-0.03	-0.05	0.00	0.01	0.00
40-41	Utilities	-0.02	0.02	-0.04	-0.05	-0.01	-0.01	0.03
45	Construction	0.11	-0.05	0.16	0.00	0.00	0.00	0.16