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ICT AND EUROPE'S PRODUCTIVITY PERFORMANCE: INDUSTRY-LEVEL GROWTH ACCOUNT COMPARISONS WITH THE UNITED STATES

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In this paper we present a new industry-level database to analyze sources of growth in four major European countries: France, Germany, Netherlands and the United Kingdom (EU-4), in comparison with the United States for the period 1979–2000. Aggregate labor productivity growth is decomposed into industry-level contributions of labor quality, ICT and non-ICT capital deepening and TFP. A small set of service industries is mainly responsible for the acceleration in ICT capital deepening in both regions, but their contribution to growth is lower in the EU-4 than in the U.S. TFP in these ICT-intensive services accelerated in the U.S. in the 1990s, but not in Europe. In addition, widespread deceleration in non-ICT capital deepening in the EU-4 has led to a European labor productivity slowdown.

1. Introduction

The late 1990s have seen a major change in the comparative growth performance of Europe and the United States. Since the Second World War labor productivity growth in Europe had outstripped that of the United States, leading to rapid catch-up. However, since 1995 U.S. labor productivity growth has nearly doubled compared to earlier periods, while European growth rates declined.

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Much research based on growth accounting has tried to explain the U.S. growth surge, as well as why Europe has fallen behind, by focusing on investment in ICT assets. In the first round of studies aggregate trends in the U.S. were analyzed. Accelerating labor productivity growth was mainly attributed to increasing investment in ICT-goods and improvements in TFP (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000). Industry-level TFP trends were still unavailable, but rough estimates by "backing out" TFP growth in IT production suggested that most of the aggregate TFP acceleration could be traced back to rapid technological change in ICT goods production.[1] But as more detailed industry-level data became available, the focus broadened to include not only ICT-goods producing industries but also service industries that are heavy users of ICT. Studies by Triplett and Bosworth (2004) and Jorgenson *et al*. (2005) show that the biggest contributors to aggregate ICT capital deepening are a limited number of service industries, in particular trade, finance and business services. Besides TFP growth in ICT-goods manufacturing, TFP acceleration in the ICT-using service industries appears to be important as well.

The first set of growth accounting studies for Europe relied heavily on private data sources on ICT expenditure collected outside the system of national accounts (Schreyer, 2000; Daveri, 2002). They found that although ICT-investment *growth* also accelerated in Europe, its lagging behind the U.S. was mainly due to lower *levels* of ICT investment. This conclusion was confirmed once investment series from national accounts became available (Colecchia and Schreyer, 2002; van Ark *et al*., 2002; Vijselaar and Albers, 2002). Typically, they found that the contribution of ICT capital deepening to aggregate labor productivity growth in Europe was only half the contribution in the U.S.

Secondly, the studies unveiled that the European slowdown after the mid-1990s was not directly related to developments in information and communication technology. Instead the explanation can be found by trends in more traditional sources of growth. In contrast to the U.S., contributions from non-ICT capital deepening declined considerably after 1995 and appeared to be an important determinant of the European labor productivity slowdown (Timmer and van Ark, 2005).

Thirdly, it was found that in contrast to the U.S., aggregate TFP growth in Europe did not accelerate. This difference could only partly be attributed to the smaller ICT-producing sector in Europe compared to the U.S. and hence must be sought elsewhere in the economy (Timmer and van Ark, 2005). A detailed study of labor productivity growth at the industry level by van Ark *et al*. (2003) suggested that much of the failure of Europe to achieve its own labor productivity growth revival in the late 1990s can be traced to the same industries that performed

[1]The latter point is stressed especially by Gordon (2000). Triplett and Bosworth (2004) and Jorgenson *et al*. (2005) show that this "backing out" of IT-production TFP from aggregate TFP can be highly misleading as it generates only a *net* measure of TFP growth outside IT-production. Industry-level studies show that TFP growth rates outside IT-goods manufacturing have also been high. However, high growth in some industries was cancelled out by low or negative TFP growth in many other industries (see Section 5).

so well in the United States, particularly trade and finance. Labor productivity growth in these intensive ICT-using industries lagged severely in Europe.

However, without detailed information on ICT and non-ICT investment for individual industries, it remains unclear which industries are responsible for the gap in ICT investment between Europe and the U.S., the European slowdown in non-ICT capital deepening and its sluggish TFP growth compared to the U.S. The main novelty of this study is the incorporation of ICT and non-ICT capital service flows in a growth accounting decomposition of labor productivity growth at the industry level for European countries. This is done for twenty-six industries and four major European countries (France, Germany, the Netherlands and the U.K.) in comparison with the U.S. for the period from 1979 to 2000. Together these four countries make up about 70 percent of total GDP in the European Union and are referred to as EU-4 in the remainder of this paper.

Table 1 provides a decomposition of aggregate labor productivity growth into the contributions from labor quality, ICT and non-ICT capital deepening and TFP growth for EU-4 and the U.S. Decompositions are provided for the total economy (upper panel) and the market sector (lower panel). The results for the total economy in Table 1 reflect previous findings on comparative EU and U.S. performance discussed above. The main source of the EU-4 slowdown is a deceleration of non-ICT capital deepening and, in contrast to the U.S., a lack of acceleration of TFP growth. This becomes even more pronounced when focusing on the market economy (by excluding non-market services). Given the difficulties in measuring output and productivity in non-market services, this provides a more relevant comparison of productivity performance. It appears that TFP growth accelerated particularly in the business sector in the U.S., but not in the EU. This suggests once more that a further decomposition of relative TFP performance by industry is needed to understand divergent growth paths.

Part of the reason for focusing on the aggregate of the four European countries is to simplify exposition. Obviously, the four EU countries do not form a single well-integrated economy as the states in the U.S. Therefore it is important to realize that in some cases the EU-4 aggregate results hide considerable cross-country variation. Space constraints preclude a full examination of results by European country but a short description highlighting the main differences is included below (Section 7).

The rest of the paper is organized as follows. In the next section we describe the data and methods used in constructing our industry growth accounting database, focusing in particular on the derivation of the investment series. It also describes the method to derive the contributions of industry-level capital deepening and TFP growth to aggregate labor productivity growth, which is the main focus of this study. Subsequent sections in turn consider the components that make up aggregate labor productivity growth: industry-level ICT investment, TFP growth, labor quality and non-ICT investment. In Section 3 we show that the industries responsible for ICT capital deepening are the same in the EU and the U.S. and ICT investment has been growing at a similar pace. However, the contribution to aggregate labor productivity growth is lower in almost all EU industries due to smaller ICT capital stocks. TFP growth is analyzed in Section 4. Both the EU and the U.S. enjoyed accelerating TFP growth in ICT-producing

TABLE 1

SOURCES OF LABOUR PRODUCTIVITY GROWTH IN THE EU-4 AND THE UNITED STATES, 1979–2000

	1979–1995			1995–2000			Change 1995–2000 Over 1979–1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy									
Labour productivity	2.30	1.21	–1.09	2.02	2.46	0.43	–0.27	1.25	1.52
Contribution of									
Labour quality	0.31	0.28	–0.03	0.22	0.22	–0.01	–0.09	–0.07	0.02
Reallocation of hours	0.02	–0.15	–0.16	–0.04	–0.09	–0.05	–0.06	0.05	0.11
ICT capital deepening	0.33	0.46	0.12	0.53	0.86	0.33	0.19	0.40	0.21
Non-ICT capital deepening	0.70	0.35	–0.35	0.25	0.43	0.18	–0.45	0.08	0.53
TFP growth	0.94	0.26	–0.67	1.07	1.05	–0.02	0.13	0.79	0.66
Market economy									
Labour productivity	2.69	1.76	–0.93	2.38	3.50	1.13	–0.32	1.74	2.06
Contribution of									
Labour quality	0.35	0.29	–0.06	0.20	0.18	–0.02	–0.15	–0.12	0.04
Reallocation of hours	0.02	–0.21	–0.23	–0.10	–0.17	–0.07	–0.12	0.05	0.16
ICT capital deepening	0.42	0.67	0.24	0.67	1.27	0.60	0.24	0.60	0.36
Non-ICT capital deepening	0.82	0.45	–0.38	0.43	0.61	0.18	–0.39	0.17	0.56
TFP growth	1.08	0.57	–0.50	1.18	1.62	0.44	0.11	1.05	0.94

Notes: EU-4 includes France, Germany, Netherlands and the U.K., which makes up 70% of EU-15 GDP.

Labour productivity growth is defined as the growth in real value added per hour worked. Labour quality takes account of changes in the skill composition of the workforce. Reallocation of hours reflects shifts in employment to or from high productivity industries.

Capital deepening is the change in capital services per hour worked (see Section 2).

Source: See Section 2 and the Appendix.

industries.[2] In contrast the contribution of ICT intensive industries, such as trade and finance, accelerated in the mid-1990s only in the U.S. During 1995–2000, aggregate TFP growth in the EU still matched that in the U.S. but only because of higher contributions from industries that are neither ICT producers, nor intensive ICT users. In Section 5 we look at the role of labor quality. Its contribution in both the EU and the U.S. decreased slightly in the second half of the 1990s but the industry location varies across the two regions. In Section 6 it is shown that the deceleration in non-ICT capital deepening in Europe is widespread. Our results show that nearly every European industry exhibited a deceleration in non-ICT capital deepening, but about half of the deceleration can be traced to mining and manufacturing industries. Another quarter is due to slower investment in non-ICT assets in business services. Comparison of non-ICT capital input levels suggest that the catch-up potential in Europe has been exhausted. Section 7 discusses performance within the EU-4 and Section 8 provides comparisons of the results of this study with similar industry decomposition studies for the U.S. and the U.K. Section 9 concludes.

2. Data and Methods

Data

In this paper we use a database on output and labor and capital inputs for 26 industries in France, Germany, the Netherlands, the United Kingdom and the United States, covering the period 1979 to 2000 (GGDC, 2003b). In this section we give a brief overview of the sources and methods used to construct this database. More detailed information on sources and methods can be found in the Appendix of this paper and in Inklaar *et al*. (2003).

Our output measure is value added at constant prices and is based on the Groningen Growth and Development Centre *60-industry database* (GGDC, 2003a). This database is from detailed national accounts as compiled in the OECD STAN database and from industrial and business surveys.[3] Deflators for ICT-producing manufacturing industries have been harmonized across countries as discussed below.

Labor input is measured as hours worked defined as the total number of persons employed (including self-employed) times the average number of hours worked. It is taken from the 60-industry database. In addition, for each country we distinguish between several different types of labor based on educational attainment. To avoid having to force different educational systems into a common classification, the number of labor types per country varies between three in Germany and seven in the Netherlands.

To construct our capital input measure we use data on investment in current and constant prices for six asset types. Of these assets, three refer to ICT goods

[2]We find a similar acceleration in TFP growth partly because we use harmonized U.S. ICT deflators in Europe (see Section 2).

[3]For the most recent version of the 60-industry database as well as detailed descriptions of sources and methods, see www.ggdc.net.

(computers, communication equipment and software) and three to non-ICT goods (transport equipment, other (non-ICT) machinery and equipment and non-residential structures).[4] Residential buildings are not taken into account to allow for a sharper focus on the productivity contribution of business-related assets.[5] Since most of the outputs and inputs of the real estate industry consists of housing and imputed rents from housing we have to make an adjustment for this. However, it is hard to separate imputed rents only, so we decided to leave out the real estate industry from both outputs and inputs. To estimate capital stocks we also need depreciation rates. For this we rely on industry-specific geometric depreciation rates for detailed assets. These are based on asset-specific rates in the United States provided in Fraumeni (1997) and industry shares of these assets from the BEA NIPA. Rates for ICT equipment are taken from Jorgenson and Stiroh (2000). These rates are applied to all countries; see Inklaar *et al.* (2003) for details.

The starting year for our investment data differs by country, beginning as early as 1901 in the United States and as late as 1970 in Germany. Estimates in O'Mahony (1999) provide data on capital stocks for long-lived assets such as non-residential structures up to the year in which the investment data start.

Deflation of ICT Goods

It is well known that the capabilities of semiconductors and computers have improved tremendously over the past few decades. At present there are only a few countries, like the U.S., that have an adequate system in place for measuring prices of computers and semiconductors. This means that measured ICT output and ICT investment growth in all other countries is likely to be biased downwards. Using a method that mirrors Schreyer's (2000, 2002) "harmonization" method we (partly) avoid this bias. This involves applying U.S. deflators to the ICT-producing manufacturing industries in European countries. We apply U.S. double-deflated value added deflators to each of these industries separately after making a correction for the difference in the general rate of inflation in the U.S. and the European country under consideration. In the case of investment deflators, we calculate (industry-specific) investment goods deflators for computers, communication equipment and software for the U.S. and apply these to all other countries after making a correction for the general inflation level.[6]

Calculating Capital Stocks and Rental Prices

Capital input is measured by capital service flows, following the methodology pioneered by Jorgenson and Griliches (1967) and more recently implemented in

[4]In the case of the Netherlands, there is currently no data on investment in communication equipment by industry, so estimates were made using information from the other countries.

[5]We focus on investment in fixed reproducible assets as distinguished in the System of National Accounts (1993), and hence do not include land, inventories and consumer durables as capital as in Jorgenson *et al.* (2005).

[6]In the case of industry deflators, the general inflation level is measured as the deflator of all industries except the ICT-producing manufacturing industries. For investment deflators, the inflation level is defined as the price change of non-ICT investment goods.

Jorgenson *et al.* (2005). Capital stocks are constructed using the perpetual inventory method (PIM):

(1) $$K_{j,t} = (1 - \delta_j)K_{j,t-1} + I_{j,t},$$

where $K_{j,t}$ is the capital stock of asset j at time t, δ_j is the (geometric) depreciation rate of asset j and $I_{j,t}$ is investment at constant prices. Rental prices for each asset are given by:

(2) $$r_{j,t} = (R_t + \delta_j - \dot{p}_{j,t})p_{j,t}$$

The rental price of the asset is defined as investment price times the nominal rate of return R at time t plus the depreciation rate minus the rate of inflation of the asset in question. We assume the rate of return to be the same across industries and equal to the internal rate of return for the total economy. Other assumptions could be made, such as using an external ex-ante rate or industry-specific internal rate, but this does not affect our main empirical results (see Appendix). Growth in capital input is measured by capital service flows as follows:

(3) $$\Delta \ln K_t = \sum_j \bar{v}^K_{j,t} \Delta \ln K_{j,t}$$

where $\bar{v}^K_{j,t}$ is the two-period average share of asset type j in total nominal capital compensation. For our growth accounts we use ICT capital services, which are calculated by weighting each of the ICT capital stocks by the share of the asset in total ICT capital compensation. Non-ICT capital services are calculated analogously.

Growth Accounting and Industry Contributions

To assess the contribution of the various inputs to aggregate growth, a growth accounting framework is followed as developed by Jorgenson and associates and used in, for example, Jorgenson *et al.* (2005). For each industry, gross value added (Y) is produced from an aggregate input X, consisting of ICT capital services (K^{ICT}), non-ICT capital services (K^N) and labor services (L).[7] Productivity is represented as a Hicks-neutral augmentation of aggregate input (A). The industry production function (industry and time subscripts are omitted) takes the following form:

(4) $$Y = AX(L, K^N, K^{ICT})$$

with superscript N indicating services from non-ICT capital and superscript ICT indicating services from ICT capital. Under the assumption of competitive factor markets, full input utilization and constant returns to scale, the growth of output can be expressed as the (compensation share) weighted growth of inputs and total factor productivity, denoted by A, which is derived as a residual.

(5) $$\Delta \ln Y = \bar{v}^L \Delta \ln L + \bar{v}^N \Delta \ln K^N + \bar{v}^{ICT} \Delta \ln K^{ICT} + \Delta \ln A$$

[7]In this database we do not allow for a separate role for intermediate inputs, as the required input/output tables to do so are not yet available for all countries. This means our TFP measure is based on value added instead of gross output.

where $\bar{v}^i$ denotes the two-period average share of input i in total factor income. Imposing constant returns to scale implies $\bar{v}^L + \bar{v}^N + \bar{v}^{ICT} = 1$. Capital services are defined in (3) as a compensation share weighted aggregate of capital stocks.

As in Jorgenson *et al.* (2005), we define labor quality growth ($\Delta \ln q^L$) as the difference between the growth of labor input and the growth of total hours worked:

(6) $$\Delta \ln q^L = \sum_h \bar{v}_h^L \Delta \ln L_h - \Delta \ln \sum_h L_h = \Delta \ln L - \Delta \ln H$$

where L is the labor input index, aggregated over the h labor types using labor compensation shares and H_t is total hours worked, summed over the different labor types.

By rearranging equation (5) the results can be presented in terms of average labor productivity growth defined as the ratio of output to hours worked, $y = Y/H$, the ratio of capital services to hours worked, $k = K/H$, labor quality and TFP as follows:

(7) $$\Delta \ln y = \bar{v}^L \Delta \ln q^L + \bar{v}^N \Delta \ln k^N + \bar{v}^{ICT} \Delta \ln k^{ICT} + \Delta \ln A.$$

In this paper we focus on the contribution of industry input growth and TFP growth to aggregate labor productivity growth. As shown by Stiroh (2002b), aggregate labor productivity growth can be decomposed into industry contributions as follows:

(8) $$\Delta \ln y = \sum_i \bar{v}_i^Y \Delta \ln y_i + \left(\sum_i \bar{v}_i^Y \Delta \ln H_i - \Delta \ln H \right) = \sum_i \bar{v}_i^Y \Delta \ln y_i + R$$

where $\bar{v}_i^Y$ is the two-period average share of industry i in aggregate value added. The term in brackets in equation (8) is the reallocation of hours and reflects differences in the share of an industry in aggregate value added and its share in aggregate hours worked. This term will be positive when industries with an above-average labor productivity level show positive employment growth or when industries with below average labor productivity have declining employment shares.

Combining the decomposition of industry labor productivity in (7) with equation (8), the full decomposition of aggregate labor productivity growth can be written as:

(9) $$\Delta \ln y = \sum_i \bar{v}_i^Y (\bar{v}_i^L \Delta q_i^L + \bar{v}_i^{ICT} \Delta \ln k_i^{ICT} + \bar{v}_i^N \Delta \ln k_i^N + \Delta \ln A_i) + R.$$

In this way, the contribution of input and TFP growth from each industry to aggregate labor productivity growth can be calculated. For example, the contribution of ICT-capital deepening in industry i to aggregate labor productivity growth is given by:

(10) $$LPCON_i^{ICT} = \bar{v}_i^Y (\bar{v}_i^{ICT} \Delta \ln k_i^{ICT})$$

which is the growth of ICT capital per hour worked in industry i weighted by the share of ICT capital compensation in industry i in aggregate nominal value added. The weight is the product of the share of industry i in aggregate value added

($\bar{v}_i^Y$) and the share of ICT capital compensation in industry value added ($\bar{v}_i^{ICT}$). Similar calculations are carried out for the contributions of non-ICT capital, labor quality and TFP.[8]

Aggregation

There are a number of ways to aggregate output and inputs across industries. Each of these methods corresponds to different assumptions regarding relative price movements of output and inputs across industries. Jorgenson *et al.* (2005) distinguish three methods, namely the aggregate production function, the aggregate production possibility frontier and aggregation over industries. In this paper we employ the third method, which requires the weakest assumptions regarding equality of prices of value added and inputs across industries. This means that we weight industry growth rates of output and inputs by their share in aggregate value added to calculate the contributions as in Table 1 and subsequent tables.

Also we calculate an aggregate of the four European countries, which we refer to as EU-4. Since output prices of each industry generally differ across countries we use industry-specific output purchasing power parities (O-PPPs) to aggregate value added at current prices across the EU-4 in a single deflation procedure. These output PPPs are also used to aggregate labor and capital compensation. In theory, we would like to have used specific intermediate input, labor and capital service PPPs, but consistent estimates of input and output PPPs are not yet available.[9] Growth of output and inputs are then aggregated across countries in a similar manner as aggregation across industries.

Industry Groupings

Previous studies on U.S.–EU labor productivity growth differences suggested that the key to understanding the acceleration in U.S. labor productivity growth and the lack of it in the EU is the difference in performance of industries that intensively use ICT and those that do not (van Ark *et al.*, 2003). In this paper, forming groups of industries is not necessary for analytical purposes, since we have ICT investment data for each of our industries. Such grouping does, however, ease exposition quite substantially, so we adopt it here as well (see Appendix Table A1 for an overview of the classification used in this paper). In each of our tables we not only show the total contribution of each industry group, but also the contributions from the most important industries in that group. This brings some of the results in clearer perspective, but can also be used to test the robustness of our conclusions to the exact industry grouping. Due to their size, we show mainly services industries, while consolidating manufacturing industries. Those interested in

[8]For a more extensive description of methodology, see Inklaar *et al.* (2003).

[9]See Inklaar *et al.* (2003) for a description of the construction of these PPPs. Although the theoretical case for using specific PPPs for the various inputs is not in dispute, the main problem is the practical implementation. If PPPs for inputs and outputs diverge, the inputs are not likely to add up to output converted using output PPPs. The choice of PPPs is not crucial to our results however. Some experiments using the same PPP across all inputs and industries did not lead to significantly different results for the EU-4.

individual manufacturing industries and other consolidated industries are referred to Inklaar *et al*. (2003).

3. ICT Capital Services Growth

In Tables 2–4, we analyze the growing importance of ICT capital and its contribution to aggregate labor productivity growth based on equation (10). But its component parts also convey interesting information about the changing role of ICT in economic growth. In Table 2 we show the industry contributions to aggregate ICT capital deepening (using industry shares in ICT compensation as weights) to single out the most important ICT-using industries. In Table 3 the share of ICT capital compensation in industry value added is given ($\bar{v}_i^{ICT}$) to indicate differences in importance of ICT in various industries. In Table 4 we bring together the results in the previous two tables to show the contribution of growth in ICT capital in industry *i* to aggregate labor productivity growth ($LPCON_i^{ICT}$).

Looking at Table 2, it is striking to see that the figures for the EU-4 and U.S. do not differ by much: ICT capital deepening has been progressing at double-digit growth rates since 1979 in both regions. Although growth has been faster in the U.S., the differences are relatively minor. This picture extends quite well to each of the industry groups, but at the industry level, notable differences start to appear. Within ICT-producing industries, the U.S. clearly leads in terms of ICT investment growth in manufacturing industries, while ICT investment in the telecommunication services industry grows much faster in the EU-4 in both periods. In ICT-using industries, both the wholesale and retail trade sectors in the U.S. clearly invested at a faster pace in ICT assets between 1979 and 1995 but subsequently the EU-4 had mostly closed this growth gap. In business services, on the other hand, the EU-4 showed considerably stronger investment growth in both periods than the U.S. In non-ICT industries, the most noticeable difference between the two regions is faster EU-4 ICT investment growth in non-ICT manufacturing between 1979 and 1995.

The fact that ICT capital service growth is roughly similar in the EU-4 and the U.S. does not contradict our earlier finding in Table 1 that ICT capital deepening makes a much larger contribution to aggregate labor productivity growth in the U.S. than the EU-4. The larger contribution is due to the fact that ICT capital compensation makes up a much larger share of value added in the United States than in the EU-4 as shown in Table 3. This mirrors the finding of others (Oulton, 2001; Colecchia and Schreyer, 2002; Timmer and van Ark, 2005). The higher share is due to the fact that the *levels* of ICT-investment in the EU have been much lower than in the U.S. in the period under consideration, although *growth rates* are comparable. Consequently, the absolute gap in ICT-capital intensity is increasing steadily. Table 3 shows that this is true for all industry groups.

Between 1979 and 1995, ICT capital made up only 2.5 percent of aggregate value added in the EU-4 but 3.4 percent in the United States. For the 1995–2000 period, the gap had grown to nearly two percentage points. This gap can be found in all of the industry groups and is biggest in ICT-producing industries. When comparing the two periods, the ICT share in the ICT-using industries stands out as having grown much more in the U.S. than in EU-4. Between 1979 and 1995,

TABLE 2

INDUSTRY CONTRIBUTIONS TO AGGREGATE ICT CAPITAL DEEPENING, EU-4 AND U.S.

	1979–1995			1995–2000			Change 1995–2000 Over 1979–1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	13.70	14.21	0.51	17.33	16.80	–0.53	3.63	2.59	–1.04
ICT-producing industries	1.74	2.07	0.33	2.24	2.23	–0.01	0.50	0.16	–0.34
Electrical and electronic equipment & instruments	0.59	1.14	0.55	0.54	0.97	0.43	–0.05	–0.17	–0.12
Communications	1.15	0.93	–0.22	1.70	1.25	–0.44	0.54	0.33	–0.22
ICT-using industries	8.40	9.13	0.72	11.55	11.49	–0.06	3.15	2.37	–0.78
ICT using manufacturing	0.70	0.55	–0.15	0.85	0.54	–0.31	0.15	–0.01	–0.16
Wholesale trade	0.82	2.25	1.43	1.79	2.19	0.40	0.96	–0.06	–1.03
Retail trade	0.46	0.99	0.54	0.76	0.91	0.15	0.30	–0.08	–0.38
Financial intermediation	3.23	2.71	–0.51	3.76	4.54	0.79	0.53	1.83	1.30
Business services	3.20	2.62	–0.58	4.40	3.31	–1.09	1.20	0.69	–0.51
Non-ICT industries	3.56	3.01	–0.54	3.54	3.08	–0.46	–0.01	0.07	0.08
Agriculture, forestry and fishing	0.02	0.03	0.01	0.03	0.04	0.01	0.01	0.01	0.00
Mining and quarrying	0.18	0.33	0.15	0.05	0.07	0.01	–0.13	–0.26	–0.13
Non-ICT manufacturing	1.71	0.98	–0.73	1.20	0.88	–0.32	–0.51	–0.10	0.41
Transport & storage	0.13	0.14	0.01	0.39	0.31	–0.08	0.26	0.16	–0.09
Social and personal services	0.31	0.33	0.03	0.40	0.54	0.14	0.09	0.21	0.12
Non-market services	0.49	0.63	0.14	0.52	0.74	0.21	0.03	0.11	0.07
Other non-ICT	0.72	0.57	–0.15	0.95	0.51	–0.44	0.23	–0.07	–0.29

Notes: An industry's contribution is calculated as industry ICT capital deepening weighted by the share of the industry's ICT capital compensation in aggregate ICT capital compensation. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT includes utilities, construction and hotels & restaurants.

Source: See Section 2 and the Appendix.

the ICT share in value added was relatively close, but by 2000, the gap had grown to the point where ICT capital made up more than 7.5 percent of value added in U.S. ICT-using industries, while it remained below 6 percent in the EU-4. At the industry level, some of the differences that stood out in Table 2 can be seen in Table 3 as well. The ICT share in ICT-producing manufacturing industries, as well as the finance and trade sectors is considerably higher in the U.S. than in the EU-4. In fact, with the exception of business services, all industries have a higher ICT share in the U.S. This even holds for industries such as telecommunications where the *growth* of ICT capital services was higher in the EU-4. Nevertheless there is a noticeable similarity in the cross-section pattern of ICT shares in the two regions as shown in Figure 1, which sorts industries according to U.S. ICT shares. With the exception of oil refining, all industries that are near the top of the distribution in the U.S., are also near the top in the EU-4.

Using ICT capital deepening by industry from Table 2 and the shares in Table 3, one can arrive at the contribution of ICT capital deepening in each industry to aggregate labor productivity growth (equation (10)). The results are shown in Table 4. The first row shows the contribution to aggregate labor productivity growth of ICT capital deepening in all industries, reproduced from Table 1. Subsequent rows decompose the contributions given in the first row by industry. So, for example, the entry 0.35 for ICT-using industries in the EU-4 for the 1995–2000 period indicates that ICT-capital deepening in the ICT-using industries in the EU-4 contributed 0.35 percentage points to aggregate labor productivity growth in this period. In contrast, ICT capital deepening in ICT-producing industries only contributed 0.07 percentage points.

This table makes clear that ICT-using industries are responsible for the largest part of the difference in the aggregate contribution of ICT capital to labor productivity growth between the EU-4 and the United States (0.22 percentage points out of 0.33 percentage points). It is also the industry group where the difference has grown most in the late 1990s (0.15 percentage points). This table shows how only a few industries are responsible for the acceleration. In the U.S., nearly half of the aggregate acceleration can be traced to financial intermediation (0.17 percentage points out of 0.40). Together with wholesale trade and business services, this rises to 0.27 percentage points. In the EU-4 these same industries are also responsible for most of the acceleration, but in absolute terms both the contributions and the accelerations are much smaller than in the United States. Outside the ICT-using industries, the contributions are much lower. In the case of ICT-producing industries this is mostly related to their smaller size. In non-ICT industries, however, it is clear that the low level of ICT investment diminishes their contributions. A ranking of the contributions from ICT capital deepening for all industries for the 1995–2000 period in Figure 2 shows similar distributions in the U.S. and the EU-4 but also indicates the overwhelming impact of the finance sector on the overall difference in contribution between both regions.

4. TFP Growth

Although the differences in ICT investment are quite important for explaining the aggregate labor productivity growth differential, TFP growth also has a

TABLE 3

SHARE OF ICT CAPITAL COMPENSATION IN VALUE ADDED, EU-4 AND U.S.

	1979–1995			1995–2000			Change 1995–2000 Over 1979–1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	2.49	3.37	0.87	3.28	5.22	1.93	0.79	1.85	1.06
ICT-producing industries	6.18	13.21	7.03	8.40	15.59	7.19	2.22	2.38	0.16
Electrical and electronic equipment & instruments	2.75	6.55	3.80	3.54	9.02	5.48	0.78	2.46	1.68
Communications	10.30	22.21	11.90	13.13	23.79	10.66	2.83	1.58	–1.25
ICT-using industries	4.61	4.95	0.34	5.75	7.64	1.89	1.14	2.69	1.55
ICT using manufacturing	1.72	3.06	1.34	2.70	4.07	1.37	0.97	1.01	0.04
Wholesale trade	2.49	5.51	3.02	5.28	9.53	4.25	2.79	4.02	1.23
Retail trade	2.10	2.79	0.69	3.91	3.96	0.05	1.81	1.16	–0.65
Financial intermediation	7.77	9.79	2.02	10.23	15.20	4.97	2.46	5.41	2.95
Business services	7.46	3.87	–3.58	5.85	4.25	–1.60	–1.61	0.37	1.98
Non-ICT industries	0.99	1.34	0.35	1.20	2.26	1.06	0.21	0.92	0.71
Agriculture, forestry and fishing	0.14	0.30	0.16	0.33	0.82	0.49	0.18	0.51	0.33
Mining and quarrying	0.88	1.37	0.50	0.89	1.87	0.97	0.02	0.49	0.48
Non-ICT manufacturing	1.57	1.75	0.17	1.85	3.03	1.18	0.27	1.28	1.01
Transport & storage	0.56	1.40	0.84	1.47	3.27	1.81	0.90	1.87	0.97
Social and personal services	2.24	4.90	2.66	1.74	7.05	5.30	–0.50	2.15	2.64
Non-market services	0.49	0.75	0.26	0.57	1.25	0.67	0.09	0.50	0.42
Other non-ICT	0.94	1.35	0.40	1.40	2.19	0.79	0.46	0.84	0.38

Notes: The share of ICT capital in value added is calculated as the sum of capital compensation for computers, telecommunication equipment and software, divided by the industry's value added. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT includes utilities, construction and hotels & restaurants.

Source: See Section 2 and the Appendix.

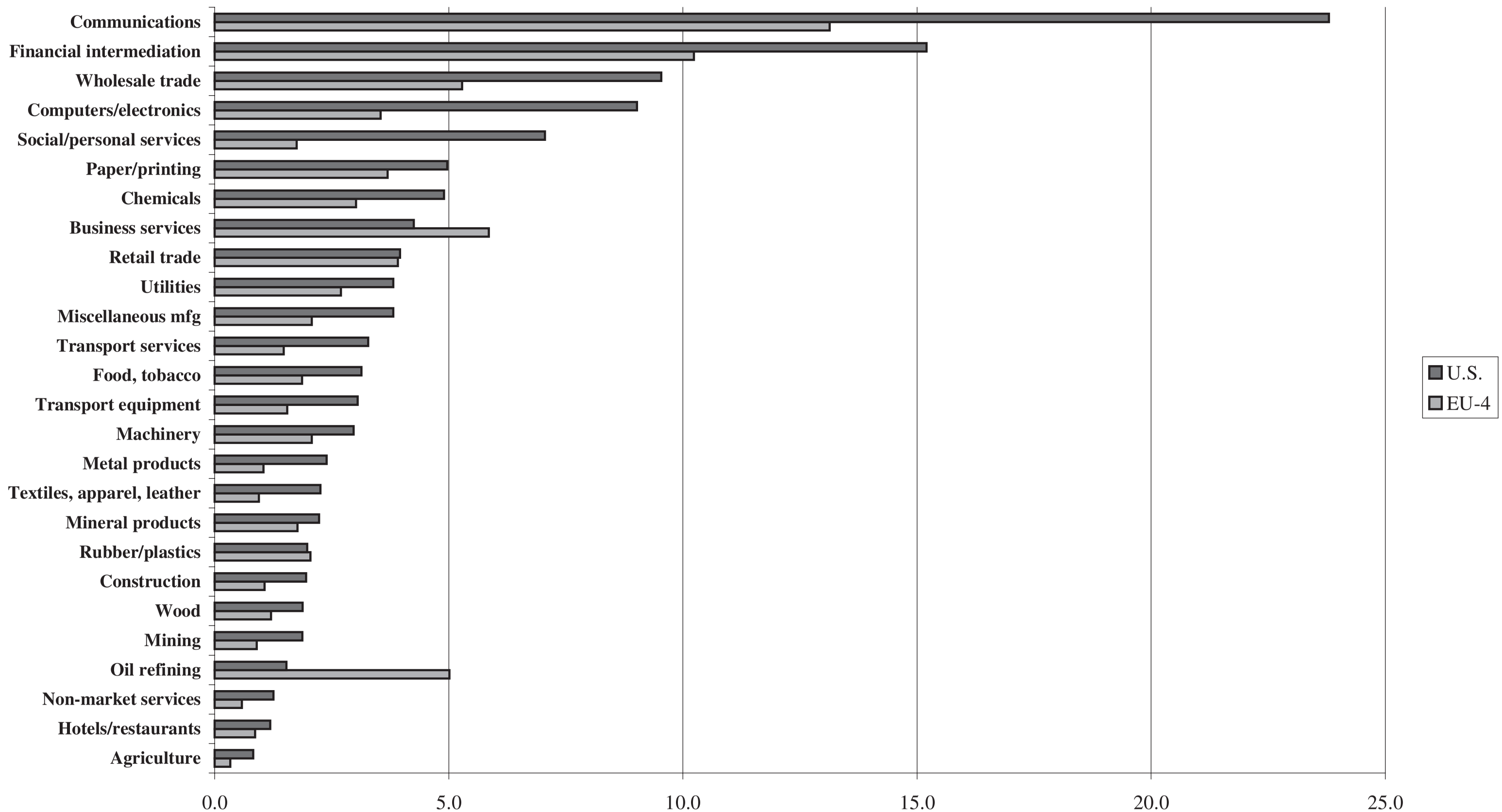

Figure 1. Share of ICT Capital in Value Added, EU-4 and U.S., 1995–2000

Source: See Section 2 and Appendix.

TABLE 4

Contributions to Aggregate Labour Productivity Growth of Industry ICT Capital Deepening, EU-4 and U.S.

	1979–1995			1995–2000			Change 1995–2000 Over 1979–1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.33	0.46	0.12	0.53	0.86	0.33	0.19	0.40	0.21
ICT-producing industries	0.04	0.06	0.02	0.07	0.11	0.04	0.03	0.04	0.02
Electrical and electronic equipment & instruments	0.01	0.04	0.02	0.02	0.05	0.04	0.00	0.02	0.01
Communications	0.03	0.02	0.00	0.05	0.05	0.00	0.02	0.03	0.01
ICT-using industries	0.21	0.28	0.07	0.35	0.57	0.22	0.14	0.29	0.15
ICT using manufacturing	0.02	0.02	0.01	0.03	0.03	0.01	0.01	0.01	0.00
Wholesale trade	0.03	0.08	0.05	0.07	0.13	0.06	0.05	0.05	0.01
Retail trade	0.01	0.04	0.03	0.03	0.05	0.02	0.01	0.01	0.00
Financial intermediation	0.08	0.11	0.03	0.10	0.27	0.17	0.02	0.17	0.15
Business services	0.07	0.04	–0.03	0.12	0.09	–0.04	0.05	0.05	0.00
Non-ICT industries	0.08	0.11	0.03	0.11	0.18	0.07	0.03	0.07	0.04
Agriculture, forestry and fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.00	0.01	0.01	0.00	0.00	0.00	0.00	–0.01	0.00
Non-ICT manufacturing	0.04	0.04	0.00	0.04	0.05	0.01	0.00	0.01	0.02
Transport & storage	0.00	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.00
Social and personal services	0.01	0.01	0.01	0.01	0.03	0.02	0.01	0.02	0.01
Non-market services	0.01	0.03	0.01	0.02	0.04	0.03	0.00	0.02	0.01
Other non-ICT	0.02	0.02	0.00	0.03	0.03	0.00	0.01	0.01	0.00

Notes: An industry's contribution is calculated as industry ICT capital deepening weighted by the share of the industry's ICT capital compensation in aggregate value added. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT includes utilities, construction and hotels & restaurants.

Source: See Section 2 and the Appendix.

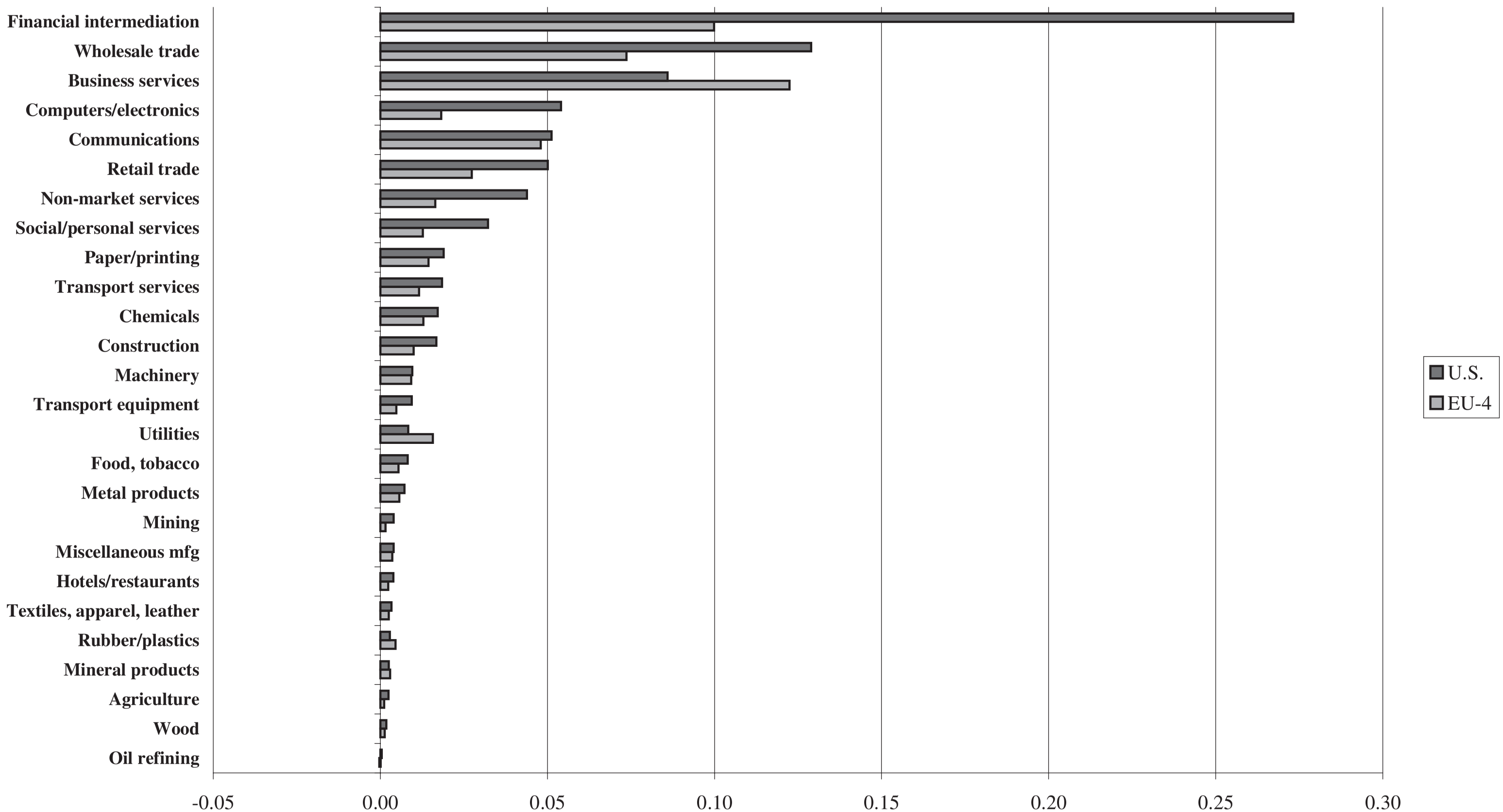

Figure 2. Contributions to Aggregate Labour Productivity Growth of Industry ICT-Capital Deepening, EU-4 and U.S., 1995–2000

Source: See Section 2 and Appendix.

substantial role to play as shown in Table 1. While aggregate TFP growth in the EU-4 increased only slightly after 1995, U.S. growth accelerated strongly. Which industries were responsible for this acceleration? The contribution to aggregate labor productivity growth, and hence to aggregate TFP growth, can be calculated as the growth of TFP in industry *i* weighted by the share of industry *i* in aggregate value added. The results are given in Table 5 and should be interpreted analogously to the results in Table 4. The first row shows the contribution to aggregate labor productivity of TFP growth, from Table 1, aggregated over all industries.

In contrast to the extent of ICT investment, the industry pattern of TFP performance is much more heterogeneous. ICT-producing industries make the largest contribution to TFP growth in both the EU-4 and U.S. In the U.S. most of the contribution can be traced to ICT-producing manufacturing while in the EU-4 communications services play a much more important role. After 1995, ICT-producing industries still make the largest contribution to overall U.S. TFP growth, but the contribution of ICT-using industries is almost as large. The acceleration in the TFP contribution of ICT-using industries in the U.S. is mostly related to accelerations in three industries: wholesale trade, retail trade and financial intermediation. The U.S. findings broadly confirm those of Jorgenson *et al.* (2005) and Triplett and Bosworth (2004) (see also Section 8).

In contrast, in the EU-4 none of these industries is an important contributor to aggregate TFP growth. The only reason that aggregate TFP in the EU-4 is still on par with the U.S. is due to the much higher contribution from TFP growth in non-ICT industries. During the 1995–2000 period it added 0.35 percentage points to aggregate labor productivity growth in the EU-4, but it contributed negatively in the U.S. This mainly involved contributions from transport and storage, non-market services and other non-ICT industries. In contrast, in the U.S. the contributions from non-ICT sectors were small or even negative. These were largely driven by the substantial negative values in non-market services. But there is a large question mark regarding the reliability of output measurement in these sectors and it is unclear whether these differences between the U.S and Europe are due to differences in output measurement methodologies or reflect underlying differences in performance.[10]

Figure 3 shows TFP contributions of all industries for the 1995–2000 period for the EU-4 and U.S. While Figures 2 and 3 showed considerable similarities, TFP performance is much more heterogeneous. This is noticeable in industries such as telecommunications, transport services and utilities, where EU-4 contributions are much higher than in the U.S., as well as wholesale trade and retail trade, where the U.S. industries are near the top of the distribution.

5. Labor Quality Growth

Differences in labor quality growth are relatively unimportant in terms of explaining the aggregate labor productivity growth differential between the EU-4 and the U.S. However, the results at the industry level do point to some noticeable

[10]See Triplett and Bosworth (2004) for a discussion.

TABLE 5

INDUSTRY CONTRIBUTIONS TO AGGREGATE TOTAL FACTOR PRODUCTIVITY GROWTH, EU-4 AND U.S.

	1979–1995			1995–2000			Change 1995–2000 Over 1979–1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.94	0.26	–0.67	1.07	1.05	–0.02	0.13	0.79	0.66
ICT-producing industries	0.30	0.35	0.06	0.53	0.71	0.18	0.24	0.36	0.12
Electrical and electronic equipment & instruments	0.21	0.36	0.15	0.27	0.63	0.35	0.07	0.27	0.20
Communications	0.09	–0.01	–0.10	0.26	0.08	–0.18	0.17	0.09	–0.08
ICT-using industries	0.17	–0.15	–0.31	0.19	0.68	0.50	0.02	0.83	0.81
ICT using manufacturing	0.03	–0.07	–0.11	0.03	–0.01	–0.05	0.00	0.06	0.06
Wholesale trade	0.11	0.04	–0.07	0.08	0.35	0.27	–0.02	0.31	0.34
Retail trade	0.06	0.10	0.05	0.03	0.39	0.36	–0.03	0.28	0.31
Financial intermediation	0.00	–0.19	–0.19	0.06	0.08	0.02	0.06	0.27	0.22
Business services	–0.03	–0.02	0.01	–0.02	–0.12	–0.11	0.01	–0.10	–0.11
Non-ICT industries	0.48	0.06	–0.42	0.35	–0.34	–0.69	–0.13	–0.40	–0.27
Agriculture, forestry and fishing	0.09	0.13	0.04	0.06	0.16	0.10	–0.03	0.03	0.06
Mining and quarrying	–0.01	0.00	0.01	0.01	–0.02	–0.04	0.02	–0.02	–0.05
Non-ICT manufacturing	0.21	0.17	–0.04	0.08	–0.07	–0.15	–0.14	–0.25	–0.11
Transport & storage	0.09	0.05	–0.04	0.13	0.05	–0.08	0.04	0.00	–0.04
Social and personal services	–0.02	0.00	0.02	–0.02	–0.11	–0.09	0.01	–0.10	–0.11
Non-market services	0.07	–0.24	–0.31	0.07	–0.30	–0.37	0.00	–0.06	–0.06
Other non-ICT	0.04	–0.05	–0.09	0.02	–0.05	–0.07	–0.03	0.00	0.03

Notes: An industry's contribution is calculated as industry TFP growth weighted by the industry's share in aggregate value added. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT includes utilities, construction and hotels & restaurants.

Source: See Section 2 and the Appendix.

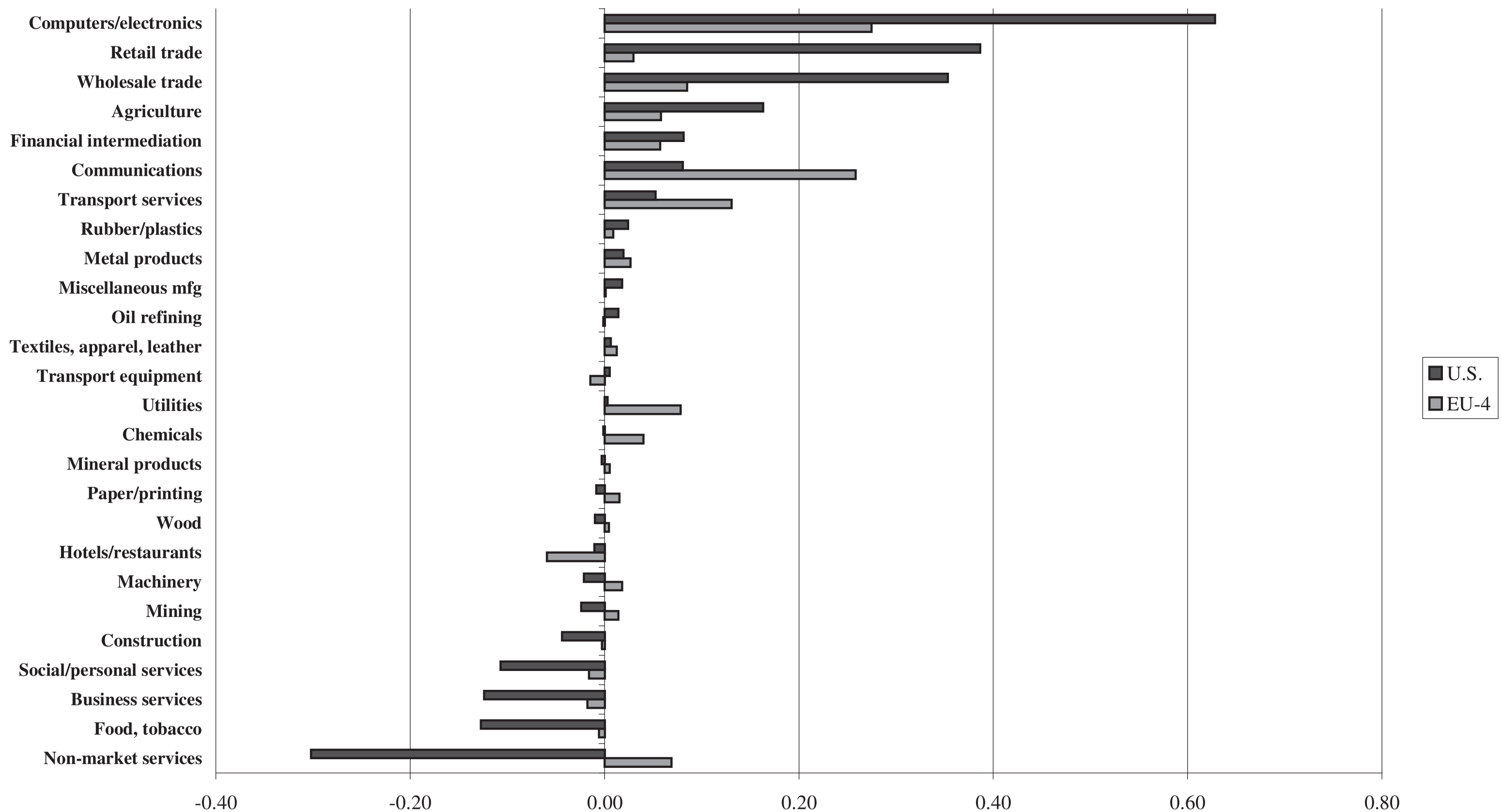

Figure 3. Contributions to Aggregate Labour Productivity Growth of Industry TFP Growth, EU-4 and U.S., 1995–2000

Source: See Section 2 and Appendix.

differences between the two regions. The contribution to aggregate labor productivity growth can be calculated as the growth of labor quality in industry *i* weighted by the share of labor compensation in industry *i* in aggregate nominal value added. The results are given in Table 6 and should be interpreted analogously to the results in Tables 4 and 5.

Table 6 shows that after 1995 the contribution of labor quality growth to aggregate labor productivity growth slowed down in both the EU-4 and the U.S. Throughout the period the EU-4 had a somewhat higher contribution, but the contributions were generally close. This table shows that between 1979 and 1995, non-ICT manufacturing in the EU-4 shows particularly large contributions. These are sectors that intensively use craft level skills, a traditional area of focus of European upskilling. Together with the larger contribution from non-market services, these larger contributions more than account for the aggregate differential. After 1995 the differential in these industries between the EU-4 and U.S. mostly disappeared, largely due to a large drop in labor quality contributions in non-ICT manufacturing in the EU-4.

In the U.S. on the other hand, the labor quality contribution of finance and business services was noticeably higher than in the EU-4. These industries intensively use university graduates, which has long been an area of strength of the U.S. skill acquisition system. In business services, this position was reversed after 1995 with the EU-4 showing a larger contribution. In terms of labor quality contributions, in the period 1995–2000 the EU-4 converged on the U.S. in ICT-producing and ICT-using industries. Furthermore, the earlier lead of the U.S. in these industries points to possible ICT–skill complementarities. However, the issue of factor complementarities cannot be handled in a growth accounting framework and needs factor demand analysis such as in Chun (2003).

6. Non-ICT Capital Service Growth

Differences in ICT capital deepening and TFP growth by industry appeared to be important in explaining the aggregate labor productivity divergence between the EU-4 and the U.S. They explain well why Europe is lagging behind the U.S. in the period 1995–2000, but they do not provide an explanation why Europe's labor productivity growth slowed down so much compared to the previous period. As discussed in the previous section, this deceleration also can only be marginally explained by trends in labor quality growth. Therefore we now turn to investment trends in non-ICT assets. As Table 1 shows, EU-4 non-ICT capital deepening decelerated sharply after 1995. Due to the relatively large share of non-ICT capital in total capital this is a major factor in explaining the deceleration of labor productivity growth.

The contribution of non-ICT capital deepening in industry *i* to aggregate labor productivity growth can be calculated as the growth of non-ICT capital per hour worked in industry *i* weighted by the share of capital compensation in industry *i* in aggregate nominal value added. The results are given in Table 7 and should be interpreted analogously to the results in previous tables. The first row shows the contribution to aggregate labor productivity growth by non-ICT capital deepening in all industries. It corresponds to the row "contribution from non-ICT

TABLE 6

CONTRIBUTIONS TO AGGREGATE LABOUR PRODUCTIVITY GROWTH OF INDUSTRY LABOUR QUALITY GROWTH, EU-4 AND U.S.

	1979–1995			1995–2000			Change 1995–2000 Over 1979–1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.31	0.28	–0.03	0.22	0.22	–0.01	–0.09	–0.07	0.02
ICT-producing industries	0.03	0.04	0.01	0.02	0.01	–0.01	–0.01	–0.02	–0.02
Electrical and electronic equipment & instruments	0.02	0.03	0.01	0.01	0.01	0.00	–0.01	–0.02	–0.01
Communications	0.01	0.01	0.00	0.01	0.01	–0.01	0.01	0.00	–0.01
ICT-using industries	0.07	0.10	0.03	0.08	0.07	–0.01	0.01	–0.03	–0.04
ICT using manufacturing	0.02	0.02	–0.01	0.01	0.01	0.00	–0.01	–0.01	0.01
Wholesale trade	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Retail trade	0.01	0.01	0.00	0.01	0.01	0.00	–0.01	0.00	0.00
Financial intermediation	0.01	0.03	0.02	0.01	0.01	0.00	0.00	–0.01	–0.02
Business services	0.01	0.03	0.02	0.04	0.03	–0.01	0.02	0.00	–0.03
Non-ICT industries	0.21	0.14	–0.07	0.12	0.13	0.01	–0.09	–0.01	0.08
Agriculture, forestry and fishing	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-ICT manufacturing	0.07	0.04	–0.03	0.03	0.02	–0.01	–0.04	–0.02	0.02
Transport & storage	0.02	0.01	–0.01	0.00	0.01	0.01	–0.02	0.00	0.02
Social and personal services	0.01	0.02	0.01	0.01	0.01	0.00	0.00	–0.01	–0.01
Non-market services	0.08	0.06	–0.02	0.06	0.08	0.01	–0.01	0.02	0.03
Other non-ICT	0.03	0.01	–0.02	0.01	0.01	0.00	–0.01	0.00	0.02

Notes: An industry's contribution is calculated as industry labour quality growth weighted by the share of the industry's labour compensation in aggregate value added. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT includes utilities, construction and hotels & restaurants.

Source: See Section 2 and the Appendix.

TABLE 7

CONTRIBUTIONS TO AGGREGATE LABOUR PRODUCTIVITY GROWTH OF INDUSTRY NON-ICT CAPITAL DEEPENING, EU-4 AND U.S.

	1979–1995			1995–2000			Change 1995–2000 Over 1979–1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.70	0.35	–0.35	0.25	0.43	0.18	–0.45	0.08	0.53
ICT-producing industries	0.08	0.05	–0.02	0.03	0.06	0.04	–0.05	0.01	0.06
Electrical and electronic equipment & instruments	0.04	0.04	0.00	0.01	0.04	0.03	–0.03	0.01	0.04
Communications	0.04	0.02	–0.02	0.02	0.02	0.00	–0.02	0.00	0.02
ICT-using industries	0.18	0.12	–0.05	–0.03	0.10	0.13	–0.20	–0.02	0.18
ICT using manufacturing	0.05	0.01	–0.04	0.02	0.01	–0.01	–0.03	0.00	0.03
Wholesale trade	0.02	0.04	0.02	0.01	0.03	0.02	–0.02	–0.01	0.01
Retail trade	0.02	0.04	0.02	0.01	0.04	0.03	–0.01	0.00	0.01
Financial intermediation	0.03	0.08	0.05	0.00	0.08	0.08	–0.03	0.01	0.03
Business services	0.05	–0.04	–0.10	–0.07	–0.06	0.01	–0.12	–0.02	0.10
Non-ICT industries	0.44	0.17	–0.27	0.25	0.26	0.02	–0.20	0.09	0.29
Agriculture, forestry and fishing	0.03	0.00	–0.04	0.03	0.02	0.00	–0.01	0.03	0.03
Mining and quarrying	0.13	0.10	–0.03	0.04	0.02	–0.01	–0.09	–0.07	0.02
Non-ICT manufacturing	0.14	0.06	–0.08	0.06	0.08	0.02	–0.08	0.02	0.10
Transport & storage	0.01	–0.02	–0.03	0.00	0.01	0.01	–0.01	0.03	0.04
Social and personal services	0.02	0.01	–0.02	–0.01	0.02	0.03	–0.04	0.01	0.05
Non-market services	0.04	0.03	–0.01	0.03	0.04	0.01	0.00	0.01	0.02
Other non-ICT	0.07	0.01	–0.06	0.10	0.07	–0.03	0.03	0.06	0.03

Notes: An industry's contribution is calculated as industry non-ICT capital deepening weighted by the industry's share of non-ICT capital compensation in aggregate value added. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT includes utilities, construction and hotels & restaurants.

Source: See Section 2 and the Appendix.

capital deepening" in Table 1. Subsequent rows decompose the contributions given in the first row by industry group.

The striking finding in Table 7 is that the deceleration in the EU-4 has been very widespread as almost all industries show declines in non-ICT capital deepening contributions after 1995.[11] A number of industries stand out. First of all, manufacturing (ICT-producing, ICT-using and non-ICT manufacturing) is responsible for around one-third of the aggregate deceleration, which is much bigger than its share in GDP. More than a quarter of the aggregate deceleration can be traced to business services where non-ICT capital per hour worked was actually declining after 1995. Finally, mining makes up another 20 percent of the deceleration. This industry showed a similar decline in contribution in the U.S.

In focusing on the slowdown in non-ICT capital deepening in the EU-4 we should not lose sight of the fact that before 1995, non-ICT capital deepening progressed at a much faster pace than in the U.S. in almost all industries, except some ICT-using industries. After 1995 the contributions in the EU-4 and U.S., in particular from the non-ICT industries, are more similar. This becomes especially clear in Figure 4, which ranks the contributions to aggregate labor productivity from non-ICT capital deepening for the 1995–2000 period. While the ranking of industries differs in some cases, contributions in many industries are remarkably close. One interpretation of the decline in contributions after 1995 is that the possibilities for European catch-up were mostly exhausted by 1995 and that growth slowed down to a pace more comparable to the productivity leader.

To investigate this hypothesis, relative levels of output and inputs would be required. These are provided in Table 8. Levels of ICT and non-ICT capital input per hour worked are shown for the EU-4 and the U.S., for both the total economy and the three industry groups. It follows that in 1999, the EU-4 has indeed taken over the U.S. in levels of non-ICT capital intensity by almost 20 percent. This has generally been attributed to higher wages in Europe relative to the U.S., leading to a deeper substitution process of capital for labor. This process has stopped. However, for ICT capital, sizeable gaps exist. In 1999, ICT capital service input in the EU-4 was barely 50 percent of the U.S. level. This suggests that catch-up potential for Europe in non-ICT capital has already been exhausted, but that a new gap has opened in ICT capital input.

7. Results Within Europe

The main reason for comparing the EU-4 and the U.S. is that many of the observations about comparative EU-4 growth hold for each of the four individual countries as well. In Figure 5 we show the decomposition of aggregate labor productivity growth for the individual European countries as well as the EU-4 and U.S. First, the European countries all had higher labor productivity growth than the U.S. before 1995 and all except the U.K. had lower growth after 1995. Furthermore, the contribution of ICT capital deepening is lower than in the U.S. in all European countries throughout the period but all four show accelerations in

[11]The only exception is in the other non-ICT industries group, with most of this acceleration stemming from utilities.

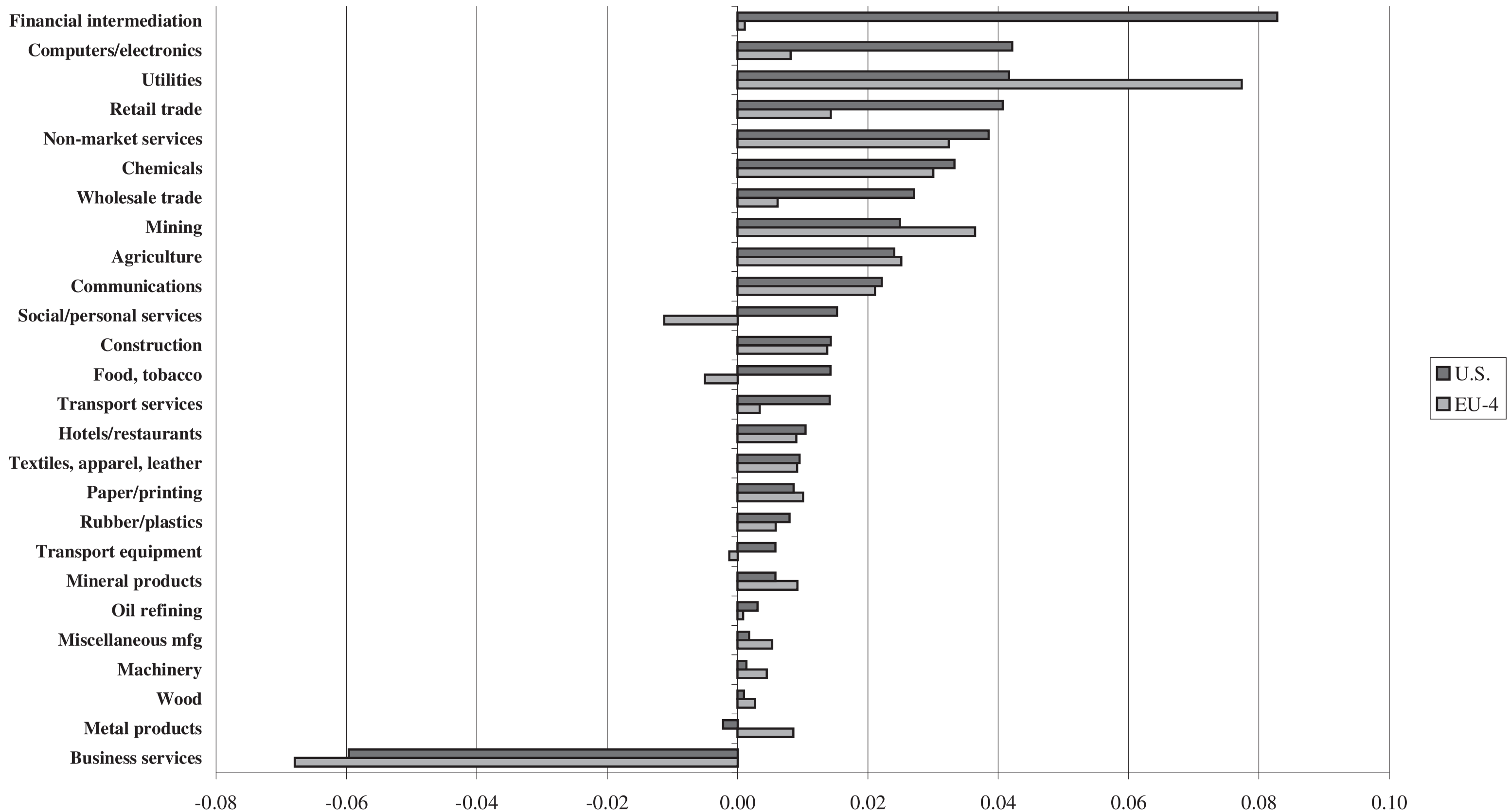

Figure 4. Contributions to Aggregate Labour Productivity Growth of Non-ICT Capital Deepening, EU-4 and U.S., 1995–2000

Source: See Section 2 and Appendix.

TABLE 8

Level of ICT and Non-ICT Capital Input Per Hour Worked in U.S. Dollars in 1999

	ICT Capital			Non-ICT Capital		
	EU-4	U.S.	EU-4 (U.S. = 100)	EU-4	U.S.	EU-4 (U.S. = 100)
Total economy	0.88	1.68	52.4	8.70	7.37	118.1
ICT producing industries	3.51	7.36	47.7	12.55	11.67	107.5
ICT using industries	1.31	2.72	48.1	7.84	7.28	107.8
Non-ICT industies	0.44	0.67	66.2	8.73	7.15	122.2

Note: Capital compensation per hour worked converted to U.S. dollars using capital service PPPs, see Appendix.

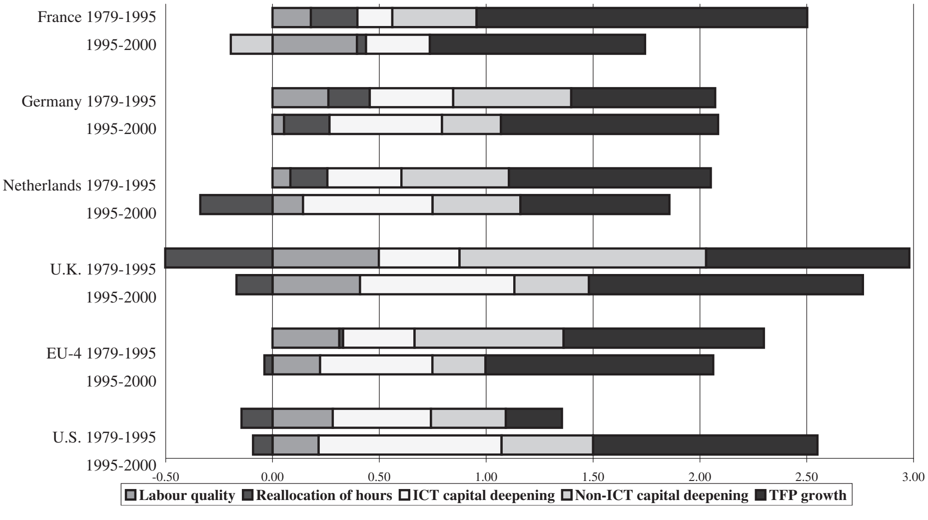

Figure 5. Sources of Labour Productivity Growth in Europe and the United States, 1979–2000
Source: See Section 2 and Appendix.

their ICT capital contributions. In addition all four show decelerations in contributions of non-ICT capital deepening. The magnitudes of these common trends do however vary across countries. Finally the time pattern of TFP growth shows more variation, with accelerations in the U.K. and Germany and decelerations in France and the Netherlands.

As argued above, in contrast to the U.S. intensive ICT users have not generated faster TFP growth in the EU-4. In the individual European countries, there are some exceptions to this pattern. Notably, TFP growth in U.K. retail trade, and wholesale trade in the Netherlands accelerated notably after 1995. It is beyond the scope of the paper to discuss the individual country results in more detail; the interested reader is referred to Inklaar *et al*. (2003).

8. Comparisons with Other Industry Studies

Industry level growth-accounting decompositions of aggregate labor productivity trends are still few. The main ones include Jorgenson *et al.* (2005) and Triplett and Bosworth (2004) for the U.S., and Basu *et al*. (2003), which compares the U.S. with the U.K. The findings for the U.S. in this paper are broadly consistent with the findings of the other studies. However, estimates sometimes differ greatly at the detailed industry level, for example about the relative importance of the TFP growth acceleration in ICT-goods manufacturing versus ICT-using industries. In Triplett and Bosworth (2004, Tables 2–6) the contribution of services to TFP growth acceleration is much bigger than in Jorgenson *et al.* (2005, Figure 26). And while Jorgenson *et al.* (2005) show an acceleration in TFP growth in retail trade and a deceleration in wholesale trade, Triplett and Bosworth (2004) find an acceleration in both. Our estimates, and those of Basu *et al*. (2003), are much closer to those of Triplett and Bosworth (2004) than to Jorgenson *et al.* (2005).

The different findings are due to many differences both in data sources and methodology. We mention three important ones. First, our analysis is based on value added measures and therefore does not take into account the role of intermediate inputs as the U.S. studies do. This will affect TFP growth estimates, but much less so measures of TFP acceleration or deceleration, which are the main focus here. Second, the capital concept of Jorgenson *et al.* (2005) is broader than in the other studies by including inventories, land and consumer durables. Third, the data used in this study is benchmarked on industry accounts from the BEA NIPA for output, labor input and investment flows. Triplett and Bosworth (2004) use a hybrid database by combining BEA industry accounts with capital service flows from the BLS.[12] Basu *et al*. (2003) use a similar database as Triplett and Bosworth (2004).[13] Jorgenson *et al.* (2005) on the other hand combine BLS inter-industry accounts with investment flows from the BEA and they benchmark labor input on BEA NIPA hours. BLS and BEA datasets show important differences in some industries, even for relatively simple measures such as gross output and value added at current prices. Triplett and Bosworth (2004) provide a discussion of these differences and their possible origins but they conclude that many questions still remain.

An important difference between the dataset of Basu *et al.* (2003) and our data for the U.K. comes from the estimates for aggregate software investment. Both estimates scale up software from the national accounts as this is widely regarded as an underestimate, since it is not consistent with survey based evidence. But the adjustment in this paper is smaller. As a result, our estimates of the share of ICT capital in value added come out lower than the estimates of Basu *et al.* Whereas both this paper and Basu *et al.* (2003) find TFP acceleration in finance and wholesale trade, this paper also finds a small increase in other ICT-using sectors. Further research is needed to reconcile these findings.

[12]In contrast to the other studies, they do not correct labor input for hours worked, nor for quality changes.

[13]Except for labor input where they use estimates of hours worked by industry from the BLS instead of persons engaged in production from the BEA.

9. Concluding Remarks

This paper began by raising the question why U.S. productivity growth accelerated after 1995, while growth in four major EU countries (France, Germany, Netherlands and the U.K.) decelerated. Much of the growth accounting literature in recent years has been dominated by trends in the U.S. and so has focused largely on the impact of ICT on output growth. This new technology focus has also dominated the analysis of productivity growth for other industrial countries. But by doing so, there is a danger that research ignores the possibility that the stylized facts on output and productivity growth in other nations may be different from those in the U.S. Indeed, as was shown in earlier work that focused on aggregate trends, the sources of U.S. acceleration and EU slowdown are very different (Timmer and van Ark, 2005). In this paper we have added detail to this difference by analyzing productivity growth at the industry-level. It appears that aggregate trends conceal much heterogeneity among the industries.

To understand the U.S. acceleration it is important to focus on services industries that use ICT intensively. These industries, mainly trade and finance, are responsible for most of the acceleration in ICT capital deepening and TFP growth alike. Together with faster technical progress in ICT-producing industries, they explain most of the acceleration in U.S. labor productivity growth after 1995.

In contrast, in the EU-4 the contributions from ICT capital deepening and TFP growth are much lower than in the U.S. It is true that the same industries as in the U.S. make the largest contribution to ICT capital deepening, but the absolute contributions are much lower due to lower levels of ICT capital stocks. Furthermore, these intensive ICT users have not generated faster TFP growth and instead, EU-4 TFP growth remained mostly confined to industries that produce ICT goods and services. This raises important questions on the extent to which these European countries are merely lagging the U.S., given the latter country's faster adoption of ICT, or whether there are institutional constraints that prevent EU countries from realizing the full benefits from ICT.

This paper also shows that ICT is not the dominant explanation of the slowdown in labor productivity growth, at least in the four large EU countries studied. To explain the slowdown in the European countries we need to look at non-ICT capital deepening, whose contribution slowed down in most of the EU-4 industries, with the largest declines occurring in manufacturing, business services and mining. The pervasive nature of this slowdown suggests economy-wide factors may be important. We found that catch-up potential in non-ICT capital has been exhausted by the end of the 1990s in almost all industries.

There are also other important analytical issues that cannot be easily understood in a simple growth accounting framework. These include possible spillovers of ICT to TFP growth, complementarities between ICT and skills and the importance of investment in intangibles such as organizational capital.[14] So far the evidence available on these issues has focused almost solely on the U.S. However,

[14]See, for example, Stiroh (2002a) and O'Mahony and Vecchi (2005) for some evidence on the possibility of ICT spillovers, Chun (2003) for evidence on ICT-skill complementarities, Brynjolfsson and Hitt (2000) for the importance of organizational capital and Basu *et al.* (2003) for a discussion of complementary capital and consequences for lagged TFP responses.

the dataset used in this paper and the stylized facts that were presented should allow more and better research into these issues for Europe.

Appendix: Detailed Source and Method Description

The full set of data underlying the results presented above can be downloaded from the Groningen Growth and Development Centre website (http://www.ggdc.net). In this appendix we provide more information about the sources we used to estimate our investment and labor quality series. We also provide further discussion on some of the intricate methodological choices we made regarding software investment, the rate of return and the PPPs used to aggregate output and inputs across European countries.

Labor Quality

Information on the share of each labor type in total employment and their shares in total labor compensation is drawn from national labor force surveys. For the U.K. this was the Labor Force Survey for numbers employed throughout and for wages by skill type from 1993. Prior to this information on wages were taken from the General Household Survey. U.S. data were taken from the Current Population Survey. Data for the Netherlands are only available from 1990 onwards and are based on annual data from the Labor Force Survey and wage surveys for 1995, 1997 and 1998. Due to small samples for some industries, we can only distinguish ten sectors. Employment and labor compensation shares for detailed industries are assumed equal to the higher aggregates. Data for France were based on estimates by INSEE, supplied by CEPII, and for Germany were based on data from the German Employment Statistics and Wage and Salary Statistics produced by the Statistiches Bundesamt. Details of the skill categories for each country are given in O'Mahony and Van Ark (2003, Chapter VII, p. 243).

We apply the employment shares by type to the total number of hours worked from the GGDC 60-industry database and the compensation shares to total labor compensation. The 60-industry database contains information on labor compensation of employees, which includes wages and salaries as well as supplements such as social security payments. Labor compensation of self-employed is part of the operating surplus, so we have to make an estimate to back it out. Based on evidence for the U.S. from Jorgenson *et al.* (2005), we put the average wages of self-employed at 70 percent of employee wages for each country, industry and year. Although this is a simplification, we currently lack the data to make more detailed estimates.

Investment by Industry and Asset Type

In the case of France, the Netherlands and the U.S., the investment data are based on detailed files from the national statistical offices, which are not published as part of the regular national accounts. However, the data are consistent with total investment by industry and total investment by asset from the national accounts. In the case of the Netherlands the industry classification maps onto our industry set in a straightforward way, as does the asset classification (with the exception of communication equipment). For France and the U.S., the industry classification differs considerably in some cases. In France the classification of manufacturing industries is quite different from the one we adopt in this paper, while in the U.S. the main problems occur with retail trade (which includes restaurants under the U.S. SIC87 classification), the computer industry (included with machinery) and cable television services (included with television broadcasting). For both France and the U.S., we use detailed investment data from industrial surveys to reallocate investment of manufacturing industries. For reallocations of service industries in the U.S., we use capital flow tables for 1982 and 1992.[15] In making these reallocations, we assume the asset composition is the same for each part of the industry. Aggregation across assets and industries takes place by summing current investment and Törnqvist aggregating investment at constant prices.

In the case of Germany and the U.K., derivation of detailed industry-level investment series required the use of data from secondary sources such as input–output investment flow matrices and dedicated investment surveys. For the U.K. the main problem is estimating investment in ICT assets by industry, as investment in transport equipment, structures and plant and equipment is readily available. Shares of industries in aggregate investment in ICT goods are derived using capital flow tables from Supply-Use Tables from 1992 and periodic input output tables before then, interpolating for missing years. Economy wide series for ICT investment are based on Oulton (2001), except that the benchmark level of software investment in 1998 is derived using data on software sales from the *Computer Services Survey* by ONS, excluding consulting and software maintenance. Net exports were then subtracted using data from *United Kingdom Balance of Payments, 2000 Edition* (ONS, 2001). Finally an allowance was made for consumer expenditure on software from *Family Spending: A Report on the 1999–2000 Family Expenditure Survey* (ONS, 2001) (see also the discussion on software below).

German investment data by industry is only available from 1991 onwards. We extrapolate these figures using data for West Germany for the period 1970–91. In the German National Accounts, only investment in structures is distinguished from investment in other assets. We use data from the *Ifo Investitionenrechnung* to estimate industry shares of aggregate investment in computers and communication equipment, scaled up to include software using industry scaling factors for other countries combined with aggregate data from the national accounts. After applying the industry shares to aggregate investment, investment in non-IT equipment is calculated as a residual.

One important problem in estimating ICT investment is differences across countries in how software investment is measured. A major problem is the measurement of own-account software, since these products are not sold on the market, but instead produced and used within businesses. Another problem is which part of computer services is classified as investment and which part is considered intermediate use. As Ahmad (2003) shows, there are important differences across countries in statistical practices. One indicator of the severity of the problems is the software-to-hardware investment ratio. It is not likely that this differs highly between countries. Based on official figures, this ratio is particularly low in the U.K.

[15]At the time of analysis, the 1997 U.S. capital flow table had not yet been released, so these estimates are not incorporated in our results.

compared to the other countries, as noted also by Oulton (2001). We therefore made an upward adjustment to the software investment figures for the U.K., as detailed above, without claiming that all comparability issues have been resolved. This remains an important area for further research and data development.

Rate of Return

As discussed in the main text, we use the aggregate internal rate of return in our rental price calculations. The internal rate of return is the rate at which capital compensation equates total operating surplus, in effect imposing constant returns to scale. We applied the aggregate return to all industries, mainly because industry-level estimates of internal rates of return are highly volatile and can become persistently negative. We could also have applied an external rate of return, such as government bond yields or corporate yields. Although these choices have important theoretical implications, our empirical results are not sensitive to the specific choice we made. Experiments suggest that total capital services growth would change by about 0.1–0.2 percentage point per year if an external rate of return would have been used instead of the aggregate internal rate, which translates into a maximum change of around 0.05 percentage point in TFP growth rates.

Industry Classification

Table A1 gives the classification of our 26 industries into IT-producing, ICT-using and non-ICT. First, ICT-producing industries are identified using a classification from the OECD (2002b), which identifies manufacturing and services industries that supply ICT goods and services. However, this classification identifies more detailed industries than we can distinguish in our dataset, so some compromises have to be made. Most importantly, we do not separately distinguish the computer services industry (ISIC 72), which is part of business services.

To distinguish ICT-using industries, we rely on the classification from van Ark *et al.* (2003). In that paper, industries are classified as ICT-using if the ICT share in U.S. capital compensation in 1995 is higher than the median. This classification also distinguishes more detailed industries than we have in our dataset, so we classify our industries as ICT-using if the majority of its output is classified as ICT-using in van Ark *et al.* (2003). As discussed in the main text, this grouping of industries mainly serves to present and discuss our results in an accessible way.

Comparing Capital Service Levels

The current value of capital compensation for each capital asset in European countries in converted to U.S. dollars using investment PPPs corrected for differences in annualization factors. The price of capital services is the rental price as shown in equation (A1). For comparisons across countries, we need an estimate of the rental price in one country relative to another, the so-called capital service *PPP* (PPP^K):

$$PPP^K_{k,m,j} = \frac{r_{k,j}}{r_{m,j}} = \frac{(R_{k,t} + \delta_j - \dot{p}_{k,j,t})}{(R_{m,t} + \delta_j - \dot{p}_{m,j,t})} PPP^I_{k,m,j} \quad \text{(A1)}$$

TABLE A.1

Industries in the Growth-Accounting Database

Number	Industry	ISIC Rev3 Code	ICT Classification
1	Agriculture, forestry and fishing	01–05	N
2	Mining and quarrying	10–14	N
3	Food products	15–16	N
4	Textiles, clothing and leather	17–19	N
5	Wood products	20	N
6	Paper, printing and publishing	21–22	U
7	Petroleum and coal products	23	N
8	Chemical products	24	N
9	Rubber and plastics	25	N
10	Non-metalic mineral products	26	N
11	Metal products	27–28	N
12	Machinery	29	U
13	Electrical and electronic equipment & instruments	30–33	P
14	Transport equipment	34–35	N
15	Furniture and miscellaneous manufacturing	36–37	U
16	Electricity, gas and water	40–41	N
17	Construction	45	N
18	Wholesale trade	50–51	U
19	Retail trade	52	U
20	Hotels and restaurants	55	N
21	Transport & storage	60–63	N
22	Communications	64	P
23	Financial intermediation	65–67	U
24	Business services	71–74	U
25	Social and personal services	90–99	N
26	Non-market services	75–85	N

Notes: P: ICT-producing industries, U: ICT-using industries, N: Non-ICT industries.

Equation (A1) gives an expression for the rental price of asset j in countries k and m (since we use the same depreciation rate across countries, no country subscript is attached). Most elements of equation (A1) are readily available, since we could already calculate the rental price from equation (2). The only missing element is the investment PPP (PPP^I). For this, we rely on OECD (2002a) expenditure PPPs for 35 assets for 1999. The 35 assets are aggregated to the six assets in this study using a multilateral (EKS) aggregation procedure. The resulting capital service PPPs are used to convert capital compensation to U.S. dollars. EU-4 ICT (non-ICT) capital compensation in U.S. dollars is the sum of ICT (non-ICT) capital compensation of the four European countries.

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