ICT Investments and Growth Accounts for the European Union

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Final Report on « ICT and Growth Accounting » for the DG Economics and Finance of the European Commission, Brussels[1]

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Abstract

This report provides new series of ICT investment and ICT capital, estimates of the contribution of ICT capital to output and labour productivity growth, and the TFP contribution stemming from ICT production for the European Union from 1980 to 2000. The investment numbers are based on series from national statistical offices, complemented with new estimates which are specifically constructed for this study. The main findings are that even though real investment and capital service flows in the EU increased as rapidly as in the U.S., the shares of ICT in total investment and capital service flows in the EU have been approximately half to two thirds of the U.S. level throughout the period. In relative terms ICT capital in the EU was about half of the U.S. contribution to labour productivity growth up to the mid 1990s. Since the mid 1990s the relative contribution of ICT capital improved, but overall EU productivity growth collapsed. The study shows large variations in terms of ICT and TFP contributions to labour productivity growth between European countries, but no EU country (except Ireland) is ahead of the U.S. in terms of the total contribution from ICT. These findings might suggest that the EU is just lagging behind the U.S. in terms of ICT contributions to productivity growth. But the recent decline in aggregate productivity growth in Europe suggests that other factors, such as regulations and structural impediments in product and labour markets, may be standing in the way of a rapid catch-up of Europe on the U.S. as well.

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1. Introduction and Summary of Results

Until recently the explosive growth of investment in information and communication technology (ICT) has been at the centre of the "new economy" hype. The slowdown in GDP growth since 2000 has tempered the enthusiasm, and indeed investment in ICT has somewhat slowed in Europe and the United States alike. Nevertheless the contribution of ICT to output and productivity growth need not necessarily decline as a result of a slowdown in investment. On the contrary, following a period of ICT capital deepening, and a substitution of productive (ICT) assets for obsolete (non-ICT) assets, one may expect (or at least hope for) some benefits from this investment process in terms of spillovers or total factor productivity growth.

This report focuses on the growth contribution of ICT to output and productivity growth in the European Union between 1980 and 2000. So far most quantitative macro-based studies on the contribution of ICT to growth have been done for the United States.[2] ICT growth accounting studies for European countries are sparse and have relied heavily on private data sources that measure total expenditures on ICT (including household expenditures) which are used as a proxy to investment.[3] As yet official long term series on ICT investment and capital stock are available only for a few countries across the EU. Most EU countries have started to collect data on ICT asset types only recently, and for many countries these series are still unpublished. In the published series office and computing machinery and communication equipment are mostly included with overall "machinery and equipment". Since the introduction of the European System of Accounts (ESA 1995) most countries now have separate estimates on software but mostly for the most recent years only.

This report provides new series of ICT investment and ICT capital, estimates of the contribution of ICT capital to output and labour productivity growth, and the TFP contribution from ICT production for the European Union from 1980 to 2000. The investment numbers are partly based on series from national statistical offices, complemented with new estimates which are specifically constructed for this study. These complementary investment estimates were obtained with a "commodity-flow" method, tracing commodities from domestic

[2] See, for example, Oliner and Sichel (2000, 2002), Jorgenson and Stiroh (2000), Jorgenson (2001).

[3] See, for example, Schreyer (2000) and Daveri (2001, 2002) making use of IDC data sources. More recently Colecchia and Schreyer (2001) and Vijselaar and Albers (2002) make use of genuine ICT investment series for a limited number of countries. Goldman and Sachs (2000) combined private sources with national accounts. Country specific studies on Europe include Oulton (2001) for the UK, Jalava and Pohjola (2001) and Niiniinen (2001) for Finland, van der Wiel (2001) for the Netherlands, Cette, Mairesse and Kocuglu (2001) for France, De Arcangelis, Jona-Lasinio and Manzocchi (2001) for Italy, and RIW and Gordon (2002) for Germany. For a review, see also van Ark (2002).

production or imports to their final purchase. The ICT investment series are deflated using a procedure that uses the ratio of U.S. hedonic deflators for ICT investment relative to the deflator for non-ICT equipment (or the overall GDP deflator) applied to each country's own aggregate deflators (Schreyer, 2000; Colechia and Schreyer, 2001). The contribution of ICT capital to output and productivity growth is calculated on the basis of the services flows from three ICT asset types (office and computer machinery, communication equipment, and software) and three non-ICT asset types (machinery, transport equipment, and non-residential buildings), using calculations of rental prices to obtain the weights for each asset. Within this growth accounting framework the residual represents the contribution of total factor productivity growth. The contribution of ICT production (i.e., production of office and computer machinery, semiconductors, and communication equipment) to total factor productivity growth is calculated on the basis of the U.S. TFP growth rates for these industries. These are applied to each individual country using Domar-weights derived from the production shares of the industries for each country. Together the contribution of ICT capital and ICT production determine the total ICT contribution to labour productivity growth (see Table 1)

Our estimates cover the bulk of the European Union, i.e., 12 of the 15 EU member states.[4] Table 1 summarises the contributions from capital deepening and TFP growth to the growth of labour productivity for the periods 1990-1995 and 1995-2000. The estimates show that the productivity growth advantage in the European Union over the United States between 1990-1995 turned into a disadvantage from 1995-2000. This was partly due to much smaller contributions in the EU from ICT capital deepening as well as from lower TFP growth from ICT production. But for the other part the European advantage in capital deepening of non-ICT capital strongly slowed down as well, and the TFP contribution from non-ICT industries even fell well below that in the U.S. between 1995-2000. These results suggest that not only did ICT contribute less to growth in the EU than in the U.S., but the overall economic environment to generate spillovers from investment in ICT and non-ICT alike was much less favourable in Europe than in the United States as well.

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[4] Our estimates exclude Belgium, Luxembourg and Greece so that we cover 95 per cent of EU GDP in 2000.

Our main findings for the aggregate EU/U.S. comparison are as follows:

1) After appropriate corrections for the change in the prices of investment in ICT, the growth rates of real capital formation and capital services of ICT have quite similar between the EU and the U.S.

2) The pattern of ICT investment, reflected by the change in shares of ICT investment in total investment was also fairly similar between the EU and the U.S. Investment in office equipment grew very rapidly during the early 1980s and again since the mid 1990s, and was much faster than growth in communication equipment and software. Growth of the latter two investment categories accelerated as well since 1995, although somewhat more in the U.S. than in the EU.

3) However, the level of ICT investment was much lower in the European Union than in the U.S.. The ICT shares of ICT in total investment and in total capital service flows (excluding buildings) in the EU was at approximately half to two-thirds of the U.S. level throughout the period 1980-2000. Consequently the share of ICT in total equipment in 2000 was at about the same level as in the US in the 1980s.

4) In terms of its contribution to labour productivity growth, ICT capital in the EU contributed only at about half of the U.S. contribution in relative terms until the mid 1990s.

5) Since 1995 the *relative* contribution of ICT capital as a percentage of aggregate labour productivity growth in the EU has been almost as high as in the U.S., but EU labour productivity growth itself has strongly slowed; hence in *absolute* terms the percentage point contribution of ICT capital increased by half. In contrast, the contribution of ICT to labour productivity growth in the U.S. almost doubled in absolute terms.

6) Since 1995 the contribution of TFP growth to labour productivity growth has also strongly slowed in the EU which is in marked contrast to the U.S. TFP growth which accelerated. (See Table 19)

7) Between the first half of the 1990s and the second half of the 1990s, the contribution to TFP from ICT production (i.e., production of office and computer machinery, semiconductors, and communication equipment) increased both in the EU and in the US, but much more strongly in the latter (See Table 20).

These findings suggest that even though the growth and pattern of ICT investment and capital in the EU is not all that different from the U.S. (points 1 and 2), it is far behind the U.S. in terms of levels (point 3) and contributions to productivity growth (point 4). This can be interpreted as a case of the EU lagging behind the US, and may suggest the possibility a catching-up process of ICT investment rates and increased ICT contributions in the EU in the near future. However, this lagging hypothesis would have required a significant acceleration in the EU (beyond the U.S. acceleration) of the contributions of ICT capital to labour productivity growth and of ICT production to TFP growth during 1995-2000. The present study finds no evidence for this catching-up process (points 5 to 7).

The detailed results for individual EU member countries show the following:

1) The investment and capital services shares of ICT in total equipment vary a good deal between EU member countries. In the year 2000, countries like the United Kingdom and Sweden were characterised by particularly high shares of ICT in total capital services, whereas France, Ireland and Germany were characterised by relatively low shares.

2) There are also substantial differences in the distribution of office and computer machinery, communication equipment and software in total ICT capital. In 2000, the Nordic countries (Denmark, Finland and Sweden) are in particular characterised by relative high shares for software, whereas Ireland, the Netherlands, Spain and the UK have large shares in office and computer machinery, and Austria and Italy in communication equipment.

3) There is a large variation in terms of the contribution of ICT capital to labour productivity growth. For example, between 1995 and 2000, ICT capital contributed most to labour productivity in the UK, the Netherlands, and Ireland, and least in France, Portugal and Spain. Only Ireland showed a contribution of ICT capital to labour productivity growth about as large as in the U.S. during the second half of the decade.

4) The contribution of TFP growth to labour productivity growth from 1995-2000 is by far largest in Ireland, at some distance followed by Finland and Austria, and lowest in Italy, the Netherlands and Spain.

5) ICT production (i.e. the production of computers and office equipment, semiconductors and communication equipment) contributed most to TFP growth in Ireland, Finland, Portugal and the U.K., but less in Austria, Denmark and Spain.

These country findings suggest that the diffusion of ICT through large investments in ICT dominate the picture. Only in a limited number of cases (notably Ireland) does ICT production contribute significantly to TFP growth.

Section 2 of this study introduces an augmented growth accounting framework – based on Jorgenson, Gollop and Fraumeni (1987) and Jorgenson and Stiroh (2000) – which takes account of separate contributions of three types of ICT capital (office and computer machinery, communication equipment, and software) as distinguished from three other types of capital (other machinery and equipment, transport equipment and non-residential structures). Section 3 describes the investment in current prices. In Section 4 we present our method to deflate the investment series for each asset type with a common price deflator across countries. In Section 5 we present the derivation of the physical capital stock and the services flows that originate from it. In Section 6 shows the contribution of capital services to GDP growth in Europe and the U.S., and we compare the results with those from two other recent international comparative studies, i.e., Colecchia and Schreyer (2001) and Daveri (2002). This is followed by a discussion of the contribution of ICT capital, non-ICT capital and TFP to labour productivity growth and the breakdown of TFP growth into contributions from ICT production and non-ICT production. Finally, section 7 concludes and proposes further steps.

Most tables in the text of the paper refer to comparisons of the weighted averages for EU member countries with the United States.[5] The charts and appendix tables include detail for individual countries. Two appendices are added to this report, one explaining the sources on gross fixed capital formation for this study, and a second one on the estimation of the ICT contribution to TFP growth.

[5] Total EU results are obtained from the original country results. GDP, employment and investment levels are simple sommations of the corresponding figures of all 12 EU member countries included. For GDP and investment (expressed in 1995 constant prices) we use the official euro-conversion exchange rate (as of 1 January 1999) to convert national currencies to a euro basis. This clearly is not the most preferable method as it assumes fixed exchange rates between 1995 and 1999, and ignores price differentials between countries within the EU. The preferable method would have been to use 1995 PPPs for our purpose. Whereas this can be easily done for GDP and aggregate investment, specific PPPs for ICT investment categories are less reliable, and there are no PPPs for software. Further consideration of improvement of this summation method is therefore warranted.

2. The Growth Accounting Framework[6]

Measuring the Contributions of ICT to Growth

In a production function framework output (*Y*) can be perceived as a function of the service flows from capital (*K*) and labour (*L*):

$$Y = f(K, L) \qquad (1)$$

Using a flexible translog production function and assuming competitive product and factor markets and constant returns to scale, equation (1) can be transformed into an equation that accounts for the contributions of capital and labour to output growth:

$$\Delta Y = \bar{v}_k \Delta K + \bar{v}_l \Delta L + \Delta A \qquad (2)$$

where v_k and v_l denote the input shares in gross value added, with the hat representing averaging over periods t and t-1, and ΔA representing the rise in output over the growth in weighted factor inputs, or total factor productivity (TFP) growth.

The capital inputs *k* in equation (2) can be decomposed into the services flows from different types of physical capital. When we distinguish between three types of ICT capital goods *c* (office and computer machinery (*Ko*), communications equipment (*Km*), and software (*Ks*)) and three types of non-ICT capital *n* (other machinery (*Ke*), transport equipment (*Kt*), and nonresidential structures (*Kb*)), equation (2) can be rewritten as:[7]

$$\Delta Y = \sum_{i=o,m,s} \bar{v}_i^c \Delta K_i^c + \sum_{i=e,t,b} \bar{v}_i^n \Delta K_i^n + \bar{v}^l \Delta L + \Delta A \qquad (3)$$

Equation (3) can be redefined as the growth of labour productivity:

$$\Delta y = \sum_{i=o,m,s} \bar{v}_i^c \Delta k_i^c + \sum_{i=e,t,b} \bar{v}_i^n \Delta k_i^n + \Delta A \qquad (4)$$

where the lower-case variables *y* and *k* denote output (*Y*) per unit of labour input (*L*) and capital (*K*) per unit of labour input (*L*) respectively. Equation (4) decomposes labour productivity growth into three sources. The first is *capital deepening from ICT* defined as the contribution of ICT capital services per hour worked; the second is *capital deepening from*

[6] Much of this section is based on Jorgenson, Gollop and Fraumeni (1987) and – as far as the specific contribution of ICT capital is concerned – on Jorgenson and Stiroh (2000).

[7] Labour input may be further broken down into unskilled labour, intermediate skilled labour and high-skilled labour, with weights representing the relative wage level of each skill category. Skill data are available for EU countries from the EU Labour Force Survey from 1993 onwards, and wage levels can be obtained from the EU Wage Survey. As there are still substantial gaps in the data, even after 1993, the labour skill breakdown is not applied in this paper.

non-ICT defined as the contribution of non-ICT capital services per hour worked; and the third source is *total factor productivity* (TFP) growth.

The contribution of TFP growth to labour productivity growth may be further broken down into the TFP contributions from the ICT-producing industries (A^c) and TFP contribution from other industries (A^n). The first component of TFP growth represents technological change that stems from the production of ICT itself, whereas the second component includes effects from the adoption and diffusion of ICT in other industries as well as other sources of TFP growth[8]:

$$\Delta A = \sum_j \overline{u}_j^c \Delta A_j^c + \sum_j \overline{u}_j^n \Delta A_j^n \quad (5)$$

where u_j^c represents the output shares ICT-producing industries, DA_j^c TFP growth in ICT-producing industries, u_j^n the output share of other, non-ICT production industries, and $u_j^n DA_j^n$ the contribution to aggregate TFP growth from non-ICT production industries. Ideally one would require a disaggregated growth accounting study at industry level to back out these TFP growth rates. These are not available for European countries and instead we used TFP growth rates in the US, combined with national weights to arrive at the TFP contribution of ICT-producing industries in Europe.[9]

Finally, the combined contribution of ICT to labour productivity growth (Δy^c) can then be measured as the sum of the input-share weighted contributions of service flows from ICT assets *i* in the total economy (see equation 4) and the output-share weighted contributions of TFP in ICT producing industries *j* (see equation 5):

$$\Delta y^c = \sum_i \overline{v}_i^c \Delta k_i^c + \sum_j \overline{u}_j^c \Delta A_j^c \quad (7)$$

These final results are summarised for the European and the United States on the bottom line of Table 1, and for individual countries in Table 20.

[8] The second component also includes reallocation effects of labour and capital across industries.
[9] As will be shown in Section 6, the TFP contribution from software production is excluded from the overall TFP contribution of ICT production due to a lack of data on output from the software industry in most European countries. However, the independent contribution of the Electronic components and accessories industries (ISIC 321), which mostly produces semi-conductors, is included with the TFP contribution from ICT production.

Measuring Capital Stock and Capital Services

To construct the estimates of non-residential capital stock and capital services, six investment categories are distinguished, of which three are ICT assets.[10] To construct these estimates the most common approach is to apply the perpetual inventory method (PIM). According to the PIM, capital stock is defined as a weighted sum of past investments with weights given by the relative efficiencies of capital goods at different ages:

$$K_{i,T} = \sum_{t=0}^{\infty} \partial_{i,t} I_{i,T-t} \qquad (8)$$

with $K_{i,T}$ the capital stock (for a particular asset type i) at time T, $\partial_{i,t}$ the efficiency of a capital good i of age t relative to the efficiency of a new capital good, and $I_{i,T-t}$ the investments in period T-t.[11] As in the work of Jorgenson *et al.* a geometric depreciation pattern is applied. Hence with a given constant rate of depreciation ∂_i different for each asset type, $\partial_{i,t}$ is given by $\partial_{i,t} = (1-\partial_i)^{t-1}$, so that:

$$K_{i,T} = \sum_{t=0}^{\infty} (1-\partial_i)^t I_{i,T-t} = K_{i,T-1}(1-\partial_i) + I_{i,T} \qquad (9)$$

If one assumes that the flow of capital services from each asset type i (S_i) is proportional to the average of the stock available at the end of the current and the prior period ($K_{i,T}$ and $K_{i,T-1}$), one can aggregate capital service flows from these asset types as a translog quantity index to:[12]

$$\Delta K = \ln K_T - \ln K_{T-1} = \sum_i \bar{v}_i \, [\ln S_{i,T} - \ln S_{i,T-1}] \qquad (10)$$

where weights are given by the average shares of each component in the value of property compensation $\bar{v}_i = \frac{1}{2}[v_{i,T} + v_{i,T-1}]$ and $\bar{v}_i^T = \frac{p_{i,T} K_{i,T}}{\sum_i p_{i,T} K_{i,T}}$ with p_i the rental price of capital

[10] Residential capital is excluded from the analysis in this study. The markets for dwellings perform very differently across the European Union (and also relative to the U.S.), which implies that by including dwellings much of the findings on the differential impact of ICT on growth would be hidden from the results.
[11] An important implicit assumption made here is that the services by assets of different vintages are perfect substitutes for each other.
[12] Aggregation may also be carried out for any subgroup of assets, such as ICT capital (K^c) and non-ICT capital (K^n) (see equation 3). One may also distinguish between a direct summation over S_i and one using the shares in capital compensation, $\bar{v}_i$. The difference then represents the change in the quality of the capital stock (Jorgenson, *et al*., 1987)

services from asset type *i*. The rental price, which measures the price of an asset good at which the investor is indifferent between buying or renting the capital good, is defined as:

$$p_{i,T} = r_T + \partial_i - p_{i,T} \quad (11)$$

with r_T representing the nominal rate of return, ∂_i the depreciation rate of asset type *I*, and $p_{i,T}$, the rate of inflation in the price of asset type *i*. Hence equation (11) shows that the rental price represents the cost of capital, which is an annualisation factor that transforms the acquisition price of investment goods into the price of capital input.[13] The exact derivation of the rental price, and the capital service estimates are discussed in Section 5.

[13] The logic for using the rental price is as follows. In equilibrium, an investor is indifferent between two alternatives: earning a nominal rate of return *r* on an investment *q*, or buying a unit of capital collecting a rental *p* and then selling it at the depreciated asset price *(1-¶)q* in the next period. Assuming no taxation the equilibrium condition is: $(1+r_T)q_{i,T-1} = P_{i,T} + (1-\partial_i)q_{i,T}$, with *P* as the rental fee and q_i the acquisition price of investment good *i* (Jorgenson and Stiroh, 2000, p.192). Rearranging yields a variation of the familiar cost-of-capital equation: $P_{i,T} = q_{i,T-1}r_T + \partial_i q_{i,T-1} - [q_{i,T} - q_{i,T-1}]$, which when dividing the rental fee by the acquistion price of the previous period transforms into equation (11).

3. ICT investment series for EU Member Countries

Data sources for investment used in previous studies

Because of the lack of consistent and long term series on investment, most previous growth accounting studies used private data sources on expenditure on ICT, such as the World Information Technology and Services Alliance (WITSA), the International Data Corporation (IDC) and the European Information Technology Observatory (EITO). For example, WITSA provides time series of total expenditures on hardware, software and communication equipment in each EU country, without making a distinction on purchases by households, government and enterprises. As the expenditure by households is not part of investment, assumptions have to be made on its shares in total expenditure.

To break out household expenditure Schreyer (2000) uses U.S. data from the Bureau of Economic Analysis, which he applied to the G-7 countries to derive average investment shares in expenditure. For telecommunication equipment he estimated the investment share in total expenditure at 30 per cent, whereas for hardware he assumed that the WITSA expenditure figures equalled investment.[14] Schreyer excluded software from his analysis. Daveri (2001) also assumed that the U.S. investment shares in total expenditure could be used for all European countries, i.e., 58.6 per cent for hardware, 31.6 per cent for communication equipment and 212.5 per cent for software.[15]

Fortunately separate publication of ICT investment series in national accounts of individual countries has been extended in recent years, although they still cover relatively short periods. Following the implementation of SNA 1993, the national accounts of almost all European countries also provide investment data for software. In a recent OECD study, Colecchia and Schreyer (2001) extended their G-7 group of countries with estimates for Australia and Finland, basing themselves almost entirely on investment data from national sources. Vijselaar and Albers (2002) constructed average estimates for the euro area based on

[14] According to Schreyer, the WITSA data overstate IT investment in hardware due to the inclusion of household expenditure, but on the other hand the U.S. national income and product accounts understate IT investment as they exclude unincorporated enterprises. Schreyer assumed that these two effects cancel out and that the WITSA data therefore fully reflect hardware investment.

[15] Daveri's numbers in his 2002 publication are slightly different at 59 per cent for hardware, 33 per cent for telecommunication and 205 per cent for software.

national data for four countries (France, Germany, Italy and the Netherlands, together comprising 77% of the euro area) for 1991-1999.[16]

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Table 2 provides an overview of previous studies on ICT and growth accounting, including country-specific studies for Finland (Jalava and Pohjola, 2001), France (Mairesse, Cette and Kocoglu, 2001), Italy (De Arcangelis, Jona-Lasinio and Manzocchi, 2001), the Netherlands (van der Wiel, 2001) and the United Kingdom (Oulton, 2001).

Methodology to obtain ICT investment series in this study

An important source of differences between the various national growth accounting studies, as well as between this study and other international comparative studies concerns the precise definition of ICT investment. Table 3 shows that this study uses a particularly broad definition for ICT investment, which comprises the whole category of office and computer equipment (equal to products included in NACE 30) –including peripheral equipment such as printers, etc., but also photocopiers and related equipment –, radio, TV and communication equipment (equal to products included in NACE 32), and software (including pre-packaged, own account and customised software). The main items that we exclude here are measurement instruments and wire and cable that are part of larger industry groups that could not be separately distinguished.[17]

[TA BLE 3 about here]

The use of a broad ICT investment definition has important implications for the measurement of prices and the contribution of ICT to growth. Prices of the broad "office and machinery and equipment" category decline at much slower rates than the prices of computers only. However, the effect this slower price decline has on a smaller impact of ICT on labour productivity growth is to some extent offset by the larger share of office and machinery equipment in total investment. The use of this broader IT investment category should be kept

[16] In a study of 12 EU countries, Goldman and Sachs (2000) combine national accounts with expenditure data, but the exact sources for each country are unclear.

[17] It might have been preferable to break out Computer and Other Information Equipment (NACE 30.02) from Office Machinery (NACE 30.01), but this appeared not possible for most countries except France, the Netherlands and the UK. Moreover, even within NACE 30.02 it is not always clear whether the IT investment

in mind in particular when comparing the results for the European countries with those for the United States, where most studies use a narrower IT hardware definition.[18] For the purpose of a proper comparison the US is also included in this study.

To obtain sufficiently long series of ICT investment for individual EU countries we applied a three-step procedure:

1) First, we scrutinised existing series on ICT investment series from national statistical offices on their consistency in international comparative perspective and, where possible, used these as a starting point for our series.

2) We then extended the official investment series by constructing our own estimates of current investment in ICT back to 1980 using a commodity flow method.

3) In order to be able to construct ICT capital stock series, we then extrapolated the ICT investment series further backwards on the basis of assumptions concerning the relative growth of ICT investment to non-ICT investment, which were derived for two countries, namely France and the U.S.

Ad 1) ICT investment from national statistical offices

Data on ICT investment from national statistical offices, although often partial and for a few years only, are available for all EU member countries except Greece and Luxembourg. Table 4 provides an overview of data that were available from national statistical offices in the first part of 2001. For only five countries (Denmark, France, Italy, Netherlands and the United Kingdom), separate data series were available on all three ICT investment categories for at least a few years. For Germany and Spain separate estimates for software were unavailable. In most other countries (Austria, Finland, Ireland, and Sweden) published data on ICT investment are in fact limited to software.

[TA BLE 4 about here]

series that we obtained from the statistical offices for these countries only include computers, or also peripheral equipment such as printer, monitors, etc..

[18] See also Triplett and Bosworth (2002) who argue in favour of using a broader ICT category, called "ICOT" (Information, Communication and Other information Technology equipment), which also includes the photocopiers, etc., included under NACE 30.01 in Table 3.

Only France and the UK have detailed series on ICT investment going back several decades, and Italy's series go back to 1982. Germany has series back to 1991 for office and computer equipment, communication equipment, and intangible investment (of which software is part). Spain has only data on office and computer equipment back to 1980 and up to 1997. Even though it was not always possible to get precise descriptions of all items in each investment category, one can be confident that these series for office and computer machinery and for communication equipment are well comparable across countries.

Unfortunately this cannot be said of software. Software in principle includes pre-packaged, customised and own-account software, but coverage and estimation practices differ strongly between countries. Italy and the Netherlands are the only countries with a distinction between pre-packaged and customised software on the one hand and own account software on the other. In Austria and Germany, software is included in intangible investment. For Finland, France, Italy, the UK and the USA, data are available for both software and for total intangible investment. Despite these sources of inconsistency, we had to rely heavily on national investment series for software for almost all countries,

It is clear from the discussion above that we could not always rely on the ICT investment series from the national statistical offices. From the perspective of an aggregate estimate for the European Union, it is fortunate that official investment series could be used at least for the largest countries in the Union, including France, Germany, Italy, Spain and the United Kingdom. In particular for the smaller countries we had to resort to constructing our own estimates as described below.[19]

Ad 2) Estimating Investment Series on the Basis of the Commodity Flow Method

To fill gaps in the published series on ICT investment and to extrapolate these series back in time, various methods can be applied in addition to the "proxy expenditure" method that was applied by Schreyer (2000) and Daveri (2001, 2002).[20] For example, one can apply the

[19] See Appendix A for a source description of ICT investment series that were used in this study. There are large differences in composition of the three ICT categories in investment for those countries for which we have complete data. For example, the Netherlands has the highest share of office and computer equipment in total ICT investment, i.e., at 55 per cent. Software is the most important investment category in ICT in Denmark, i.e., at 76 per cent. Communication equipment is relatively most important in Italy, where it represented 46 per of total ICT investment. The share of software in intangible investment also differs substantially between France, Finland and Italy (around 80 per cent), on the one hand, and the UK (45 per cent) on the other in 1997. See also Appendix Table 1.

[20] Colecchia and Schreyer (2001) used a variation on this procedure for their ICT estimates for Finland (for which they had no national investment series, except for software) by applying the share of office and computer

ICT/non-ICT distributions of investment for countries for which all data were available, and apply these to countries that only have more aggregate investment data. However, this procedure assumes that investment patterns are the same across countries, which is at odds with the evidence we have so far (see footnote 20).[21]

Our preferred method, the "commodity flow method", resembles what many statistical offices in fact use themselves to develop their investment numbers. This supply side method traces commodities from their domestic production or importation to their final purchase.[22] To maintain consistency with the published investment series, input-output (I/O) tables (or, more precisely, the supply-and-use tables) are combined with production, export and import data for office and computer equipment and communication equipment.[23] The I/O tables show the shares of domestic production (from which exports have to be excluded) and imports (excluding re-exports) destined to investment. These shares were combined with data on the production, exports and imports for office and computer equipment (NACE 30) and radio, TV and communication equipment (NACE 32) from national accounts, production and trade statistics to estimate investment series as follows:

$$I_{i,t} = (Q_{i,t} - E^d_{i,t})\left(\frac{I(Q)^{IO}_{i,t}}{(Q-E^d)^{IO}_{i,t}}\right) + (M_{i,t} - E^r_{i,t})\left(\frac{I(M)^{IO}_{i,t}}{(M-E^r)^{IO}_{i,t}}\right) \qquad (12)$$

where $I_{i,t}$ is investment in item i in year t, $Q_{i,t}$ is domestic production, $E^d_{i,t}$ is exports from domestic production, $(Q-E^d)^{IO}_{i,t}$ is domestic production for domestic use as from I/O tables, $I(Q)^{IO}_{i,t}$ is investment originating from domestic production for domestic use as from I/O tables, $M_{i,t}$ are imports in year t, $E^r_{i,t}$ is re-exports in t, $(M-E^r)^{IO}_{i,t}$ are imports excluding re-exports as from I/O tables, and $I(M)^{IO}_{i,t}$ is investment originating from imports as from I/O tables.[24]

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equipment in total expenditure on machinery excluding transport equipment (i.e. production plus imports less exports) to total investment in machinery excluding transport equipment.

[21] Another alternative is to use the ratio of ICT investment to GDP, which is also quite different for countries for which we have data.

[22] An alternative estimation method that is used by some countries is a "demand-side" approach, which collects capital expenditure data directly from purchasers. Other countries, such as France and Italy, use both methods to provide a crosscheck.

[23] The procedure outlined above could not be applied for software, as there is usually no separate software group in the I/O tables. See below.

[24] The national accounts and trade statistics do not directly provide a split-up of exports from domestic production ($E^d_{i,t}$) and re-exports ($E^r_{i,t}$). These shares were therefore obtained from the I/O tables and applied to the total export series for each item i. For some countries no separate estimates could be provided for domestic

As supply-and-use tables with sufficient detail are mostly not available on an annual basis, the shares of investment in production and imports were estimated through geometric interpolation for intermediate years, and kept constant for years before (or after) the first (or the latest) year with an I/O table. When I/O tables were available from several sources, we relied on the tables from the national statistical offices as a benchmark. In addition, I/O tables were available from Eurostat for all individual EU member states for 1995, and from OECD which recently released a test-version of a new set of I/O tables for various European countries.[25] OECD tables were privileged above the Eurostat tables, as the former are directly based on national tables for the same year, whereas the latter are updates from older national tables.

The investment/production and investment/import ratios were applied to time series on production, exports and imports to obtain annual investment series. These production, export and import time series were mostly obtained from either the OECD STAN database on National Accounts or the previous OECD STAN database on Industrial Statistics.

For communication equipment, the supply-and-use table often only provided information on investment/production and investment/import shares for the broader group of "electrical equipment" (NACE 31-33) rather than for NACE 32 separately. In most cases we assumed the shares for the broader category as representative for the narrower category of communication equipment.[26]

As mentioned above investment series for software are mostly based on those provided by the national statistical offices. For Germany, where software was included with intangible investment, we made use of the average ratio of software to total intangible investment for Finland, France and Italy (the only countries with official data for both intangible and software investments). For some other countries (including Ireland before 1990, Portugal, Spain and Sweden), the average ratio software to office and computer equipment investments of France, Italy, Netherlands and UK was used, which was applied to the country-specific investments in office and computer equipment.

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production for domestic use and imports, and were estimated together combining the two right hand terms in equation (12), i.e., Q-E+M.

[25] OECD, Directorate for Science, Industry and Technology (2002), 'Input-Output Tables', (see http://www.oecd.org/EN/about/0,,EN-about-435-15-no-no-no-435--no-,00.html)

[26] For countries for which both the aggregate (electrical equipment) and the more detailed category (communication equipment) are available, the investment/production and investment/import ratios were in fact relatively close.

Ad 3) Backward Extrapolation of ICT Investment Series into the 1970s

In order to be able to build up an estimate for the ICT capital stock from 1980 onwards, the ICT investment series needed to be extrapolated further backwards. To do this current price series for investment in office and computer equipment, communication equipment and software were compared to the investment growth rates of total equipment in France and the U.S. before 1980. For both countries growth of investment in communications equipment was about the same as that for total equipment. Hence for all other countries annual growth of investment in communication equipment in current prices was estimated by using the annual growth rate of total equipment.

Investment in office and computer equipment and software investment in current prices in France and the U.S. appeared to grow faster than for total equipment, and we used the surplus growth rate over the growth rate of total equipment to estimate these series for other countries. For office and computer equipment, the additional growth over equipment investment was based on the quinquennial growth rate pattern for the United States, and for software the growth rate pattern for France was applied.[27]

It should be noted that the impact of these admittedly somewhat rough backward extrapolations of ICT investment on the estimates of the ICT capital stock from 1980 onwards is not large. Since 1980 the growth rates of ICT investment have been very rapid, so that impact of ICT investment flows during the pre-1980 period on current stock is not large. Secondly, as will be discussed in more detail below, the depreciation rates of most ICT assets are quite high so that the impact of any mismeasurement of investment in these assets before 1980 would only affect the estimates for the early 1980s.

Measures of ICT Investment Shares

Table 5 shows the shares of six asset categories in total non-residential gross fixed capital formation (GFCF) in current prices for the European Union and the United States from 1980-2000. These include estimates for the three ICT categories (office and computer equipment,

[27] For U.S. ICT equipment the additional growth over total equipment was 4, 2, 1 and 4 per cent per year for the periods 1960-65, 1965-70, 1970-75 and 1975-80 respectively. For French software it was 9, 9, 1 and 9 per cent per year for the periods 1960-65, 1965-70, 1970-75 and 1975-80 respectively. The additional growth rates for investment in ICT may seem small, but is should be noted that investment in IT hardware refers to office and computer machinery and not to computers only. Moreover the estimates here are in current prices, and therefore reflect very rapid price declines of computers over non-ICT equipment (see also Section 4). For France the additional growth rates for office and computer machinery over total equipment was even negative. Additional growth rates for U.S. software were much faster than in France, but in this case the growth rates for France seemed to be more plausible for the rest of Europe.

communication equipment, and software) described above, as well as three additional categories (non-ICT equipment, transport equipment and non-residential structures).[28] Transport equipment was directly derived from the *OECD National Accounts* (various issues). "Non-ICT equipment" was derived as the residual of the sum of GFCF in "Metal products and Machinery" and "Products of Agriculture, Forestry, Fisheries and Aquaculture" (from the *OECD National Accounts*) minus the investment series for office and machinery equipment and communication equipment derived above. "Nonresidential structures" are derived as the residual of the sum of "Other Construction" and "Other Products" from the *OECD National Accounts* minus the investment in software derived above. [29]

Table 5 shows that on average, the EU share of ICT investment in total nonresidential investment has been at about half to two-thirds of the U.S. share. In 2000 the ICT share was at 17.1 per cent of nonresidential GFCF in the EU against 29.6 per cent in the U.S.. Without nonresidential structures, ICT accounted for 28.2 per cent of GFCF in equipment in the EU compared to 42.7 per cent in the U.S. in 2000. The distribution of ICT asset types is quite similar between the EU and the U.S.. In 2000 about 30 per cent of ICT investment is made up by office and computer machinery and another 30 per cent by communication equipment in both the EU and the U.S.. The software share increased from less than 20 per cent in 1980 to 40 per cent in 2000 in both Europe and the U.S..

[TA BLE 5 about here]

[FIGURE 1 about here]

At the bottom of Table 5 current investment is expressed as a percentage of GDP.[30] The investment/output ratio for ICT is 2.9 per cent for the EU compared to 5.3 per cent for the U.S. in 2000. This figure looks particularly low for Europe given that the overall non-residential GFCF/GDP ratio is about the same for the EU and the U.S.. However, the latter

[28] Dwellings are excluded from the study here, but have been taken into account for the total database.

[29] In particular the category "Other Products" in the *OECD National Accounts* has become somewhat of a "mixed bag" since the introduction of the new SNA93/ESA95. The coverage of this category is now broader compared to the previous SNA68/ESA79 as software (as well as copyrights, royalties, and expenditure on mineral exploitation, entertainment, and literacy or artistic originals) is included together with "Other Construction" and "Land Improvement", which were separately identified in SNA68/ESA79. Moreover, SNA93/ESA95 now also includes military expenditures on structures and equipment. As we were not able to distinguish between these items, they ware all lumped together in our category of "Nonresidential Structures". See also Appendix A.

[30] As dwellings are not included with investment here, GDP is also excluding imputed and actual rents.

appears mainly dominated by the relative high share of current price investment in nonresidential structures in Europe.

Figure 1 shows the share of ICT investment in total equipment (i.e., excluding non-residential buildings) for individual countries.[31] The Figure shows that these shares vary between 19 per cent (for Portugal) and 37 per cent (for the Netherlands). However, within ICT there are fairly large differences in terms of distribution of ICT assets. Ireland in particular, but also Germany, the Netherlands, Spain and the United Kingdom are characterised by relatively large investment shares in office and computer machinery. Austria, Italy and Portugal have relatively large investments in communication equipment, and the Nordic countries (Denmark, Finland and Sweden) show particularly large software shares.

4. Deflation and Real Investment of ICT Investment in EU Member Countries

Price measurement practices

For ICT assets, and in particular for computer equipment, the computation of price indices is seriously hampered by huge quality changes over time. Depending on the methodology used, changes in computer equipment deflators among OECD countries ranged from +80 per cent to –72 per cent for the 1980s (Wyckoff, 1995). A Eurostat Task Force, reviewing ICT price indexes for the early 1990s, found that computer deflators in the national accounts of EU member countries ranged from -10 per cent to -47 per cent (Eurostat, 1999, Graph 2). The major source of difference in magnitudes of these deflators is of a methodological nature. For some countries ICT deflators explicitly take account of quality changes by applying a hedonic price index method. In most EU countries, however, price indexes are based on a matched model method, and the incidence of quality adjustments differs highly between countries

Matched model techniques, on the basis of which price indices are obtained by matching "identical" models in adjacent periods, comprise various methods which do explicitly recognise quality changes, for example the overlapping link method, direct

[31] Nonresidential buildings are excluded, because the estimates on the relative importance of ICT is clouded by large differences across countries in those shares in the aggregate. See Appendix Table 1 for country shares in total nonresidential GFCF.

comparison method, the link-to-show-no-price-change method, the imputed price change or the implicit quality adjustment (IP-IQ) method.[32]

The hedonic regression approach estimates price changes for a product (e.g., a personal computer), for which specific models cannot be directly compared, by estimating an implicit price on the basis of the coefficients of particular characteristics of a product (e.g., in the case of computers: speed, memory size, etc.) from a hedonic regression. At least three different methods can be distinguished, namely the dummy method (where the price series are derived by exponentiating the coefficients of the country dummies in the pooled regression), the imputation method (which fills holes for data of non-existing products in the price indices), and a hedonic quality adjustment, in which case a "true" price differential is distinguished from a price differential that is due to differences in characteristics.[33]

Whatever adjustments are made for quality changes in the matched model approach, in general the hedonic approach shows much stronger price declines. In the EU, expenditure price indices for personal computers are constructed on the basis of hedonic method for three countries (Denmark, France and Sweden), but there is widespread experimentation with these methods for Germany, the Netherlands and the UK as well.[34] Table 6 shows that the national accounts in none of the EU countries (except Sweden) makes use of independent hedonic price indexes for investment in ICT equipment. Some countries, including France and Denmark make (some) use of the U.S. price indices corrected for exchange rate movements.[35] In contrast, in the U.S. National Income and Product Accounts (NIPA), hedonic deflators are not only used for computers and peripheral equipment, but also for pre-packaged software, telephone switching equipment and local area network (LAN) equipment.

[TABLE 6 about here]

Although most studies indicate that the hedonic method is the preferred technique to capture rapid quality changes in high technology goods, Aizcorbe, Corrado and Doms (2000) show that matched model indexes can be equally precise in picking up quality changes in

[32] See OECD (2000a) and van Mulligen (2002) for an overview of methods to deal with quality changes. It should be noted that computers are part of the broader category Office and Computer Equipment. Price indices for most other items in this category are almost always based on matched model techniques.
[33] OECD (2000a) and van Mulligen (2002).
[34] See, e.g., Moch (2001), Moch and Triplett (2001), van Mulligen (2002a).
[35] In the case of France, the French hedonic price index for personal computers is used for the deflation of output but not for investment.

computer price indexes, provided that items are matched on a high-frequency basis, i.e. on the basis of quarterly or monthly data.[36]

ICT Investment Deflators

As the ICT price deflators from national statistics strongly differ across countries largely because of methodological reasons, a harmonisation method is required to obtain internationally consistent price index series. For this purpose we adopted the "price index harmonisation" method that was proposed by Schreyer (2000), and applied it to develop new deflators for office and machinery equipment and for communication equipment. The harmonisation method starts from the assumption that the U.S. investment price index for ICT assets, which is largely based on hedonic price measures, most adequately reflects "constant quality" price changes. Following Schreyer we made an adjustment for general inflation before applying the U.S. price index to other countries. Hence it is assumed that either the ratio of the U.S. price index for ICT capital goods relative to non-ICT capital goods, or – when a price index for non-ICT capital goods cannot be obtained – the ratio of the ICT price index to the overall GDP deflator, can be applied to the price index for non-ICT capital goods or the GDP deflator for each specific country.[37]

For office and computer equipment, the U.S. price index was constructed on the basis of price indexes for three asset types (computer and peripheral, office and accounting equipment, and photocopying and related equipment), on the basis of which a Tornquist aggregated price index was constructed. For France, Germany and Italy the ratio of the U.S. ICT index to the non-ICT index was applied to each country's own non-ICT price index. In all other cases the ratio to the overall GDP deflator was used as a correction factor. A similar procedure was applied for communication equipment and software.[38]

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[36] See van Mulligen (2000a) for a study of computer price indices in the Netherlands based on scanner data, which applies various index number techniques, including high-frequency matched models.

[37] Some statistical offices and analytical studies (e.g. Daveri, 2001, 2002) use the U.S. deflators for ICT equipment with an adjustment for exchange rate movements. This is done under the assumption that most of the ICT investment goods are imported and that exchange rate movements are fully reflected in changes in import prices, and/or that there is a competitive domestic market for ICT products. However, there is little evidence for both points of view. Schreyer (2002) provides a sensitivity analysis of various alternative procedures.

[38] In the case of software, there is only a U.S. hedonic price index for prepackaged software, but the total software price index relative to the GDP deflator was used and applied to the GDP deflator of all EU countries. For own-account and customised software, BEA computes indirect price indexes. For own-account software, the index is based on the development of real wages of programmers and system analysts and the costs of intermediate inputs. For customised software, price indexes are a weighted average of indices for pre-packaged and own-account software. See Grimm, Moulton and Wasshausen (2002) for a review. GDP deflators are not heavily influenced by the price index of ICT investment itself as the latter is still too small as a percentage of GDP to have a sizeable impact on the aggregate GDP deflator (see Van Ark, Inklaar and McGuckin, 2002). In

It should be noted that the harmonised deflation procedure applied here is not the perfect method to deflate ICT investment in EU countries. First, it implicitly assumes that there is a global (U.S.) hedonic model on the basis of which the "predicted" price of a model can be estimated across the OECD. The evidence for the validity of such a model is still thin.[39] Indeed differences in market structures or even customer preferences may affect the specification of the hedonic model between countries. Second, as the U.S. price index for office and computer equipment is constructed from three detailed indices by using U.S. weights, it does not allow for differences in composition of investment within that asset group, and much the same can be said of the communication and software price indices. Third, a substantial part of ICT investment goods in Europe is imported rather than domestically produced, and it is not obvious that these price indices of domestically produced investment goods and imported items develop in the same way. The ultimate solution to the problems raised here is the development of appropriate ICT deflators for individual EU countries. However, the solution proposed here is probably the best approximation of the actual price declines of ICT investment goods in Europe.

Table 7 shows the changes in price indices for investment of the six asset types for the EU and the U.S. from 1980 to 2000. Given the procedures outlined above, it should come as no surprise that the price changes for office and computer machinery and for communication equipment are quite similar between the EU and the U.S.. The average prices of computer and office equipment declined by about 90 per cent between 1980 and 2000. For communication equipment, the price index only began to fall as of 1990, and showed a decline of 20-25 percentage points during the 1990s. For software the price rise in the EU is somewhat faster than in the U.S.. For other asset types price indices were obtained from the ratio of the changes in current and constant price series from the *OECD National Accounts*. The aggregate investment price index for GFCF was reconstructed on the basis of a Tornquist aggregation. Table 7 shows a somewhat faster price increase for "Transport Equipment" and "Nonresidential Structures" in the EU than in the U.S., but slower price rises for non-ICT equipment.

[TABLE 7 about here]

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both cases – either using the non-ICT price index or the GDP deflator as the adjustment factor for general inflation – a three years average has been taken in order to smoothen fluctuations in the series. Schreyer (2000) uses a more advanced filter, but this does not matter much for the outcome.

[39] See, for example, Moch and Triplett (2001), confirming a common hedonic model for PC's in France and Germany.

The price indices for ICT (and non-ICT) asset categories show a large variation across countries as can be observed in some detail from Appendix Table 2. Given the procedure applied these differences are only due to a variation in general inflation as measured by the price index for non-ICT investment goods or the GDP deflator. Even though all countries showed a rapid decline in the price index of office and computer machinery, the picture was much more mixed for communication equipment and in particular for software. For example, the substantial price increase in overall ICT investment in Portugal is mainly due to a rapid price rise before 1990. However, since 1995 the decline in price of office and computer machinery has dominated price changes in the other two ICT categories, resulting in a fall of ICT prices across the board.

Real ICT investment

Table 8 shows the average annual growth rates of real investment for the six asset types as well as for total ICT investment and total gross fixed non-residential capital formation. The table shows that once adequate deflators have been adopted for the European countries, reflecting similar (although not identical) price changes to the U.S., growth rates of real investment in office and computer equipment and communication equipment for the total period 1980-2000 are not very different between the EU and the U.S.. For office and computer equipment, real investment in the EU has been even somewhat faster than in the U.S.. It should be noted that these faster growth rates are related to lower investment levels in Europe relative to the U.S. (see also Section 5). Investment in communication equipment also increased faster in the E.U. until 1995, but the U.S. showed faster growth since 1995. During the 1990s real investment in software in the EU has increased more slowly than in the U.S..

[TABLE 8 about here]
[TABLE 9 about here]

The variation in growth of real investment in ICT across EU member countries is quite substantial. Table 9 shows the growth rates real investment in ICT by country from 1990-1995 and 1995-2000.[40] Growth was fastest in Ireland, but it should be noted that this country started from a relatively low level investment level at the beginning of the 1990s. Otherwise growth

[40] See Appendix Table 3 for growth rates for 1980-1985 and 1985-1990, and for those of non-ICT asset types.

of real ICT investment was relatively high in Denmark and Sweden (in particular due to software) and in the U.K. and the Netherlands (in particular due to office and computer equipment).

5. Capital Service Measures and the Contribution to Growth

To compute the contribution of ICT capital to economic growth, it is necessary to construct measures of the stock of assets and the annual service flows that emerge from the stock. The switch from stock to flows is important because the former is likely to lead to a considerable understatement of the contribution of ICT capital to growth. Service flows are calculated by estimating the user cost for each type of capital. These are relatively high for ICT capital compared to non-ICT capital in particular because of high rates of depreciation for ICT goods. Hence the service flow per unit of ICT capital is substantially higher than the stock estimates suggest. Below we first discuss the construction of the capital stock, which is followed by our procedure to obtain capital service flows.

Measuring Capital Stock and Depreciation Rates

The implementation of the Perpetual Inventory Method (PIM) essentially requires measures of gross fixed capital formation – as obtained in the previous section – and an estimate of the asset-specific depreciation rates (see Equations 8 and 9 in Section 2). The geometric depreciation rate (∂) depends on the declining balance rate (R) and the service life of each asset (T), i.e. $\partial = R/T$. The overview below shows the depreciation rates used for this study.

Geometric Depreciation rates used in this study (¶)	
Office and Computer Machinery[a]	
1980	0.222
1985	0.235
1990	0.243
1995	0.254
2000	0.295
Communication equipment	0.115
Software	0.315
Non-ICT equipment	0.132
Transport equipment	0.191
Non-residential buildings and other structure	0.028

a) Office and Computer Machinery is a weighted average for the U.S. stock of computers and peripheral, office and accounting, and photocopying and related equipment.

Depreciation rates for non-ICT equipment and transport equipment (vehicles) are derived from Hulten and Wykoff (1981) using detailed investment data by sector and asset type for the U.S.[41] For nonresidential structures, depreciation rates are obtained from O'Mahony (1999) who derived her estimate by aggregating BEA estimates for detailed categories of structures in the U.S. from 1950-1994. Following Jorgenson and Stiroh (2000) and Oulton (2001), depreciation rates for software and communications equipment were set constant 0.315 and 0.115 respectively. For office and computer equipment, however, we applied a changing depreciation rate, as this asset type consists of the BEA categories "computer and peripheral", "office and accounting" and "photocopying and related equipment". As these asset types show very different depreciation rates and as their shares change rapidly over time (from slowly depreciating photocopying machines to rapidly depreciating computers), we weighted the depreciation rates for each category with their share in the U.S. capital stock.

Using the PIM and the geometric depreciation rates, the capital stock for 1980-2000 was constructed on the basis of the long run GFCF series. The gross fixed capital stock series were adjusted from end-year to mid-year basis.

Measuring Capital Services

To obtain a measure of capital services, the stock estimates for each asset type were weighted by their share in the total capital revenue (see Equations 10 and 11 in Section 2).[42] The rental prices, that were used to compute the capital revenue shares, consist of the depreciation rates (estimated above) plus the internal rate of return, and minus an asset revaluation term. The rate of inflation in the price of asset type *i* can be easily obtained from the investment deflators obtained above.

The estimation of the internal rate of return is less straightforward, however. Following Jorgenson *et al.* (1987) the ex-post approach was applied to obtain the internal rate of return, which is based of the following assumptions: 1) there is perfect competition and zero profits; 2) the nominal rate of return is equal for all assets in an industry; and 3) the sum of rental payments for all assets is equal to total property compensation. Using these assumptions, the rate of return in each country was obtained by first estimating the capital

[41] These rates were reproduced by Fraumeni (1997). See also O'Mahony (1999).

[42] As indicated by Equation 10, it is assumed that the average change in the stock within each asset category is representative of the service flow.

revenue (CR) on the basis of the gross operating surplus as reported in the *OECD National Accounts*, from which the imputed income of self-employed persons was deducted.

$$CR^T = \sum_i p_{i,T} K_{i,T} \qquad (13)$$

with p_i the rental price of capital services from asset type *i*. Given that for each asset type

$$p_{i,T} = r_T + \partial_i - \pi_{i,T} \qquad (14)$$

with r_T representing the nominal internal rate of return, ∂_i the depreciation rate and $\pi_{i,T}$ the rate of inflation, r_T can be derived as follows. Combining (13) and (14)

$$CR^T = r_T \sum_i K_{i,T} + \sum_i (\partial_i - \pi_{i,T}) K_{i,T} \qquad (15)$$

rearranging solves for the internal rate of return (pre taxation[43])

$$r_T = \frac{CR^T - \sum_i (\partial_i - \pi_{i,T}) K_{i,T}}{\sum_i K_{i,T}} \qquad (15)$$

Table 10 shows the average (pre-taxation) internal rates of return for five-year periods for each country. The estimates show that the U.S. and the EU have experienced almost the same rate of return for total non-residential capital throughout the period. The variation across countries is limited, although relatively low income countries such as Ireland and Portugal showed somewhat higher rates of return than the other countries. The very high rate of return for Ireland between 1995-2000 is due to rapid rise in capital revenue relative to the current value of the capital stock.

[TABLE 10 about here]

[TABLE 11 about here]

Table 11 shows the average five-year shares of capital and labour compensation in total GDP for the European Union and the United States. Capital compensation shares are somewhat higher in the EU than in the United States, but this is mainly due higher compensation for non-ICT equipment, not for ICT-capital. In particular since 1995 the EU experienced a rather high capital compensation share for non-residential building.

[43] Ideally taxes should be included to account for differences in tax treatment of the different asset types and different legal forms (household, corporate and non-corporate). The formulas should then be adjusted to take into

Table 12 shows the shares of ICT capital services in total services from non-residential capital. Similar to the share of ICT in investment (see Table 5), ICT shares in capital services from total equipment in the EU are about half to two thirds of the U.S. level throughout the period. This is confirmed by the time series of the ICT shares in capital services from total equipment in Figure 2. The composition of ICT by subcategory was similar between the EU and the U.S.. The share of Office and Computing machinery services showed a declining trend. Despite its high rental price, since the early 1990s the share of IT equipment in the nominal capital stock has fallen because of the rapid price declines. The share of capital services from communication equipment remained fairly constant. Only the software share in total capital services increased steadily in both the US and the EU. In 2000, the software contribution to capital service flows was higher than for either one of the other ICT-categories (see Table 12).

[TABLE 12 about here]

[FIGURE 2 about here]

Table 13 and Figure 3 shows the ICT share in capital services from total equipment by country for the year 2000, with additional country detail in Appendix Table 4. Table 13 shows that there is a large variance in the share of ICT. The United Kingdom, the Netherlands and Sweden are at the higher end of the distribution scale, whereas Finland, Portugal and Austria are at the lower end.

[TABLE 13 about here]

[FIGURE 3 about here]

Table 14 shows the average growth rates of the real service flows from each asset types for the EU and the U.S. The estimates shows that the growth in service flows from ICT are substantially higher than for other asset types. For the period as a whole the growth of capital services in office and computer machinery and communication equipment is very similar between the EU and the U.S., although there are some important differences for subperiods. But for total ICT, U.S. growth in capital service flows has been much faster than in the EU during the period as a whole because of the larger share of ICT in total capital. Table 15 shows the growth rates of the service flows from ICT on a country-by-country basis

account these tax rates (see Jorgenson and Yun, 1991). Unfortunately the data for this were not available for the present study.

for 1990-1995 and 1995-2000, which again shows large difference across countries, although the overall picture is not very different from that for real investment.

[TABLE 14 about here]

[TABLE 15 about here]

6. The Contribution of ICT to Output and Productivity Growth

The Contribution of Capital Services to Real GDP Growth

Having obtained the service flows from ICT and non-ICT capital, one can begin to determine the impact of both types of capital on economic growth since 1980. Table 16 shows the average quinquennial %-contribution to real GDP growth of service flows from ICT asset types weighted at capital revenue shares based on rental prices for the EU and the U.S.. The Table shows that the contribution to real GDP growth from all ICT investment categories in Europe has trailed behind the U.S., although not in relative terms.

[TABLE 16 about here]

[FIGURE 4 about here]

Figure 4 focuses on the relative contributions from ICT to real GDP growth on a country-by-country basis for the latest period 1995-2000, which is the period during which the output growth differential between the U.S. and the EU widened substantially.[44] The Figure shows large differences between countries. For example, in relative terms, the contribution of ICT capital to GDP growth in the U.K. and Germany was even larger than in the United States, followed by similar contributions as in the U.S. for Italy. Italy was characterised by a relatively large contribution of communication equipment, while Sweden and Denmark show a large contribution from investment in software.

The estimates in Table 16 and Figure 4 can be compared to the results from the two other recent studies on international comparisons. Firstly, Daveri (2002) makes use of expenditure data from a private data source, WITSA, which he adjusts to investment using U.S. investment/expenditure shares. As explained above, this is quite different from the way

[44] See Appendix Table 6 for details for other periods and the GDP contributions from non-ICT assets.

in which the ICT investment series for this study have been derived. But as Daveri's methodology to obtain capital services resembles ours, it is useful to make a comparison. Table 17 compares the %-point contribution of ICT capital services to GDP growth for the period 1995-2000. Countries are ranked according to the absolute contribution of ICT services to GDP growth, so that the ranking differs somewhat from the relative ranking in Figure 4 which uses a relative ranking. In terms of the absolute contribution of ICT capital to GDP, Daveri's estimates show substantially larger contributions (except for Italy), which suggest that his proxy numbers for investment, in particular for software, are probably too high. There are also some important differences in the ranking of countries, for example the higher positions of Denmark, Italy and the Netherlands according to this study, and the lower positions of Portugal, Finland and Sweden.

[TABLE 17 about here]

Compared to Daveri's study, a recent OECD study by Colecchia and Schreyer (2001) is better comparable with the present study as it also largely uses national investment data as well as a similar methodology to obtain capital services and to compute the contribution of ICT to output growth. Even though data and methodological details still differ slightly between the two studies, the results should largely point in the same direction. Table 18 shows that the GDP growth rates between both studies differ because the OECD study refers to the business sector only, whereas the present study covers the whole economy but excludes imputed and actual rents. Nevertheless, on the whole the capital contributions to GDP are not very different between the countries, with the exception of the contribution of IT and Communication Equipment for Finland, for which the present study does not find as big an improvement in the contribution than was found by Colecchia and Schreyer.[45]

[TABLE 18 about here]

The Contribution of ICT Capital to Labour Productivity Growth

As has been well established in earlier work, aggregate labour productivity growth has slowed down substantially in Europe since the mid 1990s, whereas it has accelerated in the United

[45] Finland is the weakest case in terms of data and methodology in the study of Colecchia and Schreyer, as IT & Communication data were estimated in a rather rough manner (see also footnote 21).

States.[46] When focusing on the contributions of ICT capital to labour productivity growth, it is important therefore to express this contribution not only in relative terms (as a percentage of labour productivity growth) but also in absolute terms in order to fully grasp the differences in the dynamics between the EU and the U.S.

Table 19 shows the contributions to labour productivity growth for the EU and the U.S. from 1980 to 2000 on a quinquennial basis. The table shows that until the mid 1990s the contribution of ICT capital to labour productivity growth was higher in the U.S. than in Europe in both absolute and relative terms. But from 1995-2000 the ICT capital contribution in the EU caught with that in the U.S. in relative terms, i.e., from 12 to 28 per cent of labour productivity growth in the EU compared to an increase from 33 to 34 per cent of labour productivity growth in the U.S.. This improvement in Europe was particularly due to the rapidly increased contribution from office and computer machinery. In absolute terms, however, the percentage point contribution of ICT capital to labour productivity in the U.S. has zoomed ahead of the EU since 1995, and was almost double the EU contribution, i.e, at 0.75 percentage points in the U.S. compared to 0.40 percentage points in the EU. The absolute increases in the contributions of ICT capital in the U.S. have been particularly strong for software.

[TABLE 19 about here]
[FIGURE 5 about here]

Figure 5 shows the absolute contributions to labour productivity growth from ICT capital as well as its distribution among the three ICT asset types for individual countries for 1995-2000, which shows a large variation.[47] In Ireland and the U.K. the contribution of ICT capital approaches the level in the U.S., in particular because of the high contribution from office and computer machinery. All other countries score well below the U.S. contribution of ICT capital, although the Netherlands show much higher contributions from office and computer machinery than the other countries.

[46] See, for example, McGuckin and van Ark (2002).

The Contribution of Total Factor Productivity Growth

Figure 6 summarises the contribution of ICT capital, non-ICT capital and total factor productivity growth to labour productivity growth from 1995-2000. This figure shows that despite differences in contributions of capital, the main impact on differences in labour productivity growth rates between countries are due to differences in contributions of TFP growth. TFP growth has contributed strongly to labour productivity in Finland and Ireland (which were both big producers of ICT), but much less so in countries like the United Kingdom and the Netherlands (both big ICT investors) and Italy and Spain.

[FIGURE 6 about here]

A key question that arises in this context is the extent to which the contribution of TFP growth is related to ICT production. As shown in Section 2 (Equation 5), TFP growth may be broken down into contributions from the ICT-producing industries and contributions from elsewhere in the economy. The first component represents technological change that stems from the production of ICT itself, whereas the second component includes effects from the adoption and diffusion of ICT in other industries, as well as other sources of TFP growth.[48] Together the contributions of ICT capital, derived in Section 5, and TFP growth from ICT production account for the total contribution of ICT to labour productivity growth.

We consider TFP growth in three ICT industries, namely Computer and Office Equipment (ISIC 30), the Electronic Components and Accessories Industries (ISIC 321), and Communications Equipment (ISIC 322).[49] As it is not possible to make detailed TFP computations for these three ICT industries for individual European countries, the calculation of the TFP contribution of ICT producing industries is done in two steps. First, TFP estimates for these industries in the U.S. are derived from a detailed study by Jorgenson, Ho and Stiroh (2002). We assume that the TFP growth rates for these three industries in the U.S. also hold true for the European countries (see Appendix B for a discussion of possible alternatives). As a second step we use Domar final output weights to obtain the contribution of each of these industries to aggregate TFP growth. These Domar weights are country specific and based on a

[47] See Appendix Table 7 for details for other periods and the labour productivity contributions from non-ICT assets.

[48] For example, efficiency gains, technological progress, scale economies, reallocation effects and measurement errors that allow more measured gross output to be produced from the same set of measured inputs.

[49] Due to a lack of data in most European countries we exclude the TFP contribution of software production. Although TFP growth in the software industry is only small, its contribution can be significant as its production share is large. For example, in the US its contribution is similar to that of communication equipment (Jorgenson 2001, Table 7).

combination of national accounts, production statistics and input-output tables. These two steps are explained in further detail below in Appendix B.

Table 20 and 21 show the contributions of the three ICT-producing industries to TFP growth for individual EU countries and the United States from 1990-1995 and 1995-2000. Figure 7 summarises the TFP contributions from ICT-producers as well as from other producers for 1995-2000. Between the first half of the 1990s and the second half of the 1990s, the contribution to TFP from ICT production (i.e., production of office and computer machinery, semiconductors, and communication equipment) rose with about 40% in the EU and with 75% in the United States.[50] In relative terms ICT-producers in both the EU and the U.S. accounted for one third of TFP growth from 1995-2000.

[TABLE 20 about here]
[TABLE 21 about here]
[FIGURE 7 about here]

In Ireland producers of office and computer machinery as well as those of semiconductors accounted for the lion share of TFP growth.[51] Office and computer machinery also accounts for a substantial share of TFP growth in the United Kingdom (Table 21). In Finland and Sweden the TFP contributions from the communication equipment industry were relatively large, but did not dominate the overall picture as is sometimes suggested. But for most EU countries the overriding contribution to TFP growth still comes from non-ICT producers, and in several cases (Finland, Austria, Ireland and Sweden) this non-ICT TFP contribution is higher than in the U.S.. In other countries, however, the TFP contribution from non-ICT production falls behind the U.S. (e.g., for Italy, UK, Netherlands; and for Spain, where it is negative).

[50] The contributions for the US are quite similar to those found by Oliner and Sichel (2002) which indicates that our method of deriving gross final output shares is a reliable alternative for the expenditure approach they apply. See Appendix B.
[51] The estimates for Ireland need some qualifications, however. The production shares from the production statistics, used for the Domar weighting in Ireland are strikingly high, and do not match data from the IO-table, which in turn does not show enough detail to separate 321 and 322 and to single out re-exports of especially computers.

7. Conclusions and Further Research

The main conclusion that can be derived from this study is that although investment rates and capital services flows from ICT have increased at fairly similar rates in Europe and in the U.S., the combined contributions to labour productivity form ICT capital and total factor productivity from ICT production have been much lower in Europe than in the U.S.. Moreover the EU/U.S. gap has significantly widened since 1995.

Since 1980, the pattern of ICT diffusion in Europe has not been all that different from that in the U.S., beginning with a rapid increase in office and computing equipment (which even accelerated after 1995), followed by a surge in communication equipment, and backed up by increased investment in software. However, the EU started from much lower levels and consequently it is still lagging behind the U.S. in terms of ICT intensity as well as in terms of its contribution of ICT capital to productivity growth. The contribution of ICT-production to TFP growth is also somewhat lower in the EU than in the U.S., mainly because of Europe's lower production share in ICT.

This study also finds very different country performance within the EU. Ireland, the Netherlands and the UK are characterized by a strong growth of ICT capital and a large contribution from ICT service flows to productivity growth. In contrast Ireland and Finland (which are among the major ICT producers in the EU) show the largest contributions from TFP growth. Countries like Spain and Portugal often tend to be at the lower end, and France and Germany are mostly in the middle group of both ICT capital and productivity contributions. In particular the Nordic countries (Denmark, Finland and Sweden) are characterized by relative high shares for software, which suggests substantial diffusion although this does not appear to be translated in substantial acceleration of productivity growth in these countries yet.

The European story might just be a case of it lagging behind the U.S., and catching up would then be a likely scenario. However, because of continuous growth of ICT investment and productivity in the US, with even an acceleration in the latest period, no signs of catch up by the EU have been found over the past years. Whereas the combined contribution to labour productivity growth from ICT capital and ICT production related TFP growth has increased in Europe, in absolute terms the EU/U.S. gap has widened very substantially since 1995.

In fact not all differences between the EU and the U.S. in terms of ICT and TFP contributions to labour productivity growth can be brought under the hypothesis of lagging

ICT diffusion. A striking development since the mid 1990s is the slowdown in productivity growth in the European Union (from 2.5 per cent from 1990-95 to 1.4 percent from 1995-2001 in per hour terms), which sharply contrasts with the rapid acceleration in productivity growth in the United States (from 1.2 per cent from 1990-1995 to 2.2 per cent from 1995-2001).[52] Van Ark, Inklaar and McGuckin (2002) show that this slowdown has been very widespread across the economy, in particular across service industries. But in contrast to "non-ICT" industries, intensive ICT-using services industries in Europe have in fact kept up their productivity growth rates relatively (although without the acceleration shown in the United States). This evidence suggest that ICT is not the only factor explaining differences in productivity growth between Europe and the U.S.

A broad literature has addressed a wide range of causes for Europe's slowdown in productivity growth during the 1990s, including a fall in capital/labour ratios, lower skill levels, and inflexible markets. In turn, these same factors may be behind the slower diffusion of ICT in Europe compared to the U.S.[53] Business organisation and the opportunities to exploit technologies depend on the constraints and restrictions that firms face. For example, McGuckin and van Ark (2001) argue that in many European industries the opportunities to invest in ICT are limited by regulations and structural impediments in product and labour markets. Examples of product market restrictions include limits on shop opening hours, and transport regulations that make it difficult for manufacturers and wholesalers to supply customers frequently. Restrictive labour rules and procedures limit flexibility in organising the workplace and hiring and firing of workers. Furthermore barriers to entry and restrictions on the free flow of capital are still an issue in many countries. We note that such queries would not just focus on European rigidities, but are also of continuous concern in the U.S. even though reforms have mostly begun earlier.

Finally, even though this study improves upon earlier work in looking at the contribution of ICT to output and productivity growth in Europe, through its broader coverage of countries and the use of genuine investment series for ICT, there are clearly areas for further improvement. First, there is a strong need for better and longer series of ICT investment data for individual countries to check upon the procedures applied here to construct our own investment data where necessary. Second, the use of U.S. price indices for ICT remains a second best option compared to the construction of country-specific ICT price

[52] See McGuckin and van Ark (2002).
[53] A useful summary can be found in Scarpetta et al. (2000, 2002).

indices which probably require application of hedonic pricing techniques. Third, the summation of numbers for the individual countries to an EU total using 1999 euro exchange rates needs to be improved upon by the use of purchasing power parities. For this study, however, this requires not only output and aggregate investment PPPs but also PPPs for individual ICT categories which are not available at this moment. Fourth, GDP output measures can be improved. Hedonic deflators should be used not only to revalue ICT investment but also ICT production. Similarly, high depreciation rates of ICT equipment can drive a wedge between gross and net measures of domestic production. And measures of output in services industries, which are among the most intensive users of ICT, need to be improved. Finally, it is crucial to combine the macro approach undertaken in this study with the industry focus as applied in Van Ark, Inklaar and McGuckin (2002), and extend this into a full scale growth acocunting study at industry level. This would, for example, greatly help to improve the TFP growth measures from ICT producing and ICT using industries. Some first steps in this direction have been made by O'Mahony and de Boer (2002) for France, Germany, UK and the U.S., and individual country studies are available as well. As a next step data on output, employment, investment, employment, prices and PPPs need to be further harmonized across countries to further this research.

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Table 1 Contributions to Growth in Average Annual Labour Productivity (in percentage points)

	1990-1995			1995-2000		
	EU	US	EU-US difference	EU	US	EU-US difference
Growth of labour productivity (a)	2.45	1.19	1.26	1.43	2.21	-0.78
Contributions from						
Capital deepening (b), *of which from*	1.34	0.58	0.75	0.80	1.00	-0.20
ICT capital	0.28	0.40	-0.11	0.40	0.75	-0.34
Office and computer equipment	0.13	0.19	-0.07	0.22	0.38	-0.16
Communication equipment	0.06	0.04	0.03	0.07	0.11	-0.04
Software	0.09	0.16	-0.07	0.11	0.26	-0.14
Other Non-Residential capital	1.05	0.19	0.86	0.40	0.25	0.15
Contributions from						
Total factor productivity (c), *of which from*	1.12	0.61	0.51	0.62	1.21	-0.58
Production of ICT, excluding software	0.14	0.23	-0.08	0.20	0.40	-0.20
Office and computer equipment	0.09	0.10	0.00	0.13	0.16	-0.03
Semiconductors	0.03	0.11	-0.08	0.07	0.24	-0.17
Communication equipment	0.01	0.02	-0.01	0.00	0.00	0.00
Other producers	0.97	0.38	0.59	0.42	0.81	-0.39
Total ICT contribution (d)	0.43	0.62	-0.20	0.61	1.15	-0.54

(a) GDP per hour worked in total economy; GDP excluding imputed and actual rents
(b) capital service per hour worked
(c) including changes in the quality of labour
(d) equals contribution of ICT capital and ICT production

Table2: Data Sources Used in Studies on Contribution of ICT to Economic Growth in EU[a]

Author	Country studied	Period	Data source
Schreyer (2000)	France, Germany, Italy, UK[b]	1990-96	WITSA
Goldman and Sachs (2000)	Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, UK	1990-99	National accounts for Finland, France, Germany, Ireland, Sweden, and UK. WITSA data for Italy, Spain, Belgium, Denmark.
Daveri (2001)	European Union	1992-99	WITSA / IDC
Vijselaar and Albers (2002)	France, Germany, Italy, Netherlands	1991-99	Authors' calculations from national accounts data
Colecchia and Schreyer (2001)	France, Finland, Germany, Italy, UK[c]	1980-2000	Author's calculations from national accounts data
Jalava et Pohjola (2001)	Finland	1975-99	National accounts for software, WITSA/IDC for hardware and communi-cation equipment.
Mairesse, Cette and Kocoglu (2001)	France	1980-2000	National accounts.
Van der Wiel (2001)	Netherlands	1980-2000	Author's calculations from National accounts and investment data
Oulton (2001)	United Kingdom	1974-98	Author's calculations from National accounts
De Arcangelis, Jona-Lasinio and Manzocchi (2001)	Italy	1992-2000	Authors' calculations from National accounts

a) excluding studies based on firm level data, e.g. Crépon and Heckel (2002).
b) also Canada, Japan and United States.
c) also Norway and Switzerland.
d) also Australia, Canada, Japan and United States.

Table 3: ICT Investment Goods and Services included in this Study

NACE	Description
30	***Office machinery and computers***
30.01	***Office machinery, of which***
	Word-processors (incl. automatic typewriters), Electronic, electrical and manual typewriters (excl. tot typewriters)
	Calculating and accounting machines, cash registers
	Postage-franking machines, ticket-issuing machines and similar machines incorporating a calculating device
	Electrostatic photocopiers, Blueprinters, diazocopiers and other photocopying apparatus of the contact type
	Photocopiers incorporating an optical system, thermocopiers (excl. electrostatic photocopiers and thermo-printers)
	Sheet fed office type offset printing machinery, for sheet size <= 22x36 cm
	Hectograph or stencil duplicating machines; addressing machines and address plate embossing machines, mailing machines
	Coin-sorting, counting or wrapping machines, automatic banknote dispensers, banknote counting and paying-out machines
	Digital customer self-service devices : cash, money exchange
	Parts and accessories of the above machines
30.02	***Computer and other information equipment, of which***
	Manufacture of computers and other information, analogue or hybrid automatic data processing machines
	Desk top and Laptop PCs and palm-top organisers, digital data processing machines: presented in the form of systems
	Other digital automatic data processing machines whether or not containing in the same housing 1 or 2 of the following units: storage units, input/output units
	Printers, keyboards, magnetic tape storage units
	Input or output units whether or not containing storage units in the same housing (incl. mouses)
	Monitors (visual display units), digital customer self-service devices
	Other input, output units (incl. mouses, plotters and scanners)
	Central and other storage units, CD-ROM drives, hard and floppy disk drives
	Parts and accessories for computers and other data processing machines
32	***Radio, television and communication equipment and apparatus***
32.1	***Electronic valves and tubes and other electronic components, of which***
	Thermionic, cold cathode or photocathode valves or tubes
	Diodes, transistors and similar semiconductor devices
	Photosensitive semiconductor devices, including photovoltaic cells
	Mounted piezoelectric crystals
	Electronic integrated circuits and microassemblies
	Printed circuits, electrical capacitors, including power capacitors, resistors, including rheostats and potentiometers
32.2	***Television and radio transmitters and apparatus for line telephony and line telegraphy, of which***
	Apparatus for television transmission, including relay transmitters and television transmitters for industrial use
	Television cameras, transmission apparatus for radio-broadcasting
	Transmission apparatus for radio-telephony: fixed transmitters and transmitter-receivers, radio-telephony apparatus for transport equipment, radio-telephones, other transponders, etc.
	Apparatus for line telephony: telephone sets, fax machines, automatic and non-automatic switchboards and exchanges, telex and teleprinter apparatus, etc.
32.3	***Television and radio receivers, sound or video recording or reproducing apparatus and associated goods, of which***
	Television receivers, incl. video monitors and video projectors, video recording or reproducing apparatus (camcorders)
	Radio-broadcasting receivers
	Magnetic tape recorders and other sound recording apparatus, incl. telephone answering machines, cassette-type recorders
	Turntables (record decks), record players, cassette players, CD players, etc.
	Microphones, loudspeakers, headphones, earphones, amplifiers and sound amplifier sets
	Pick-ups, tone arms, sound-heads, tables for turntables, record cutters, aerials, aerial reflectors and aerial rotors, cable converters, TV decoders
	Sound electroacoustic apparatus, including door intercoms, command transmitter intercoms, simultaneous interpretation apparatus, electronic voting systems, conference systems, paging devices, portable sound systems
	Software:
	Prepackaged
	Customised
	Own-account

Sources: Eurostat: NACE and PRODCOM.

Table 4: Survey of Publicly Available ICT Investment Data for Countries of the European Union as of first half of 2001

Country	Source	Period	Broad Categories[a]		Detail data by type of investment goods					
							software			
			Intangible investment (including software)	Office and computer equipment	Hardware + software	Hardware	Total	Pre-packaged and customised	Own Accounts	Commu-nication equipment
Austria	Nat. Acc.	1995-99	ν							
		1995,1997, 1998					ν			
Belgium	Nat. Acc.[b]	1995-97			νσ	νσ	νσ			νσ
Denmark	Nat. Acc.	1993-97		νσ						νσ
	Nat. Acc.	1966-2000					νσ			
Finland	Nat. Acc.	1991-99	νσ							
		1975-2000					νσ			
France	Nat. Acc.	1959-00			νσ	νσ	νσ			νσ
Germany	Nat. Acc.	1960-00	νσ	νσ						νσ
Greece	--		-	-		-	-	-	-	-
Ireland	Stocks/Asset Stat. (CSO)	1996-2000			ν					
		1990-99					νσ			
Italy	ISTAT	1990-94						ν	ν	
	ISTAT	1970-2000	νσ							
	ISTAT	1982-2000		νσ			νσ			νσ
Netherlands	CPB	1986-97			νσ		ν	ν	ν	
	CBS	1995-00	ν			ν				
	CBS (ICT Markt)	1995-98		ν	ν	ν	ν			ν
Portugal	Nat. Acc.	1999	-	-	ν	ν	ν	-	-	-
Spain	Nat. Acc.	1980-97[c]		ν						
	European Innovation survey	1996&1998					ν			
Sweden	Nat. Acc.	1993-2000					νσ			
UK	O'Mahony	1949-99			νσ	νσ	νσ			νσ
	Oulton	1974-98			ν	ν	ν			ν
	Nat.Acc.	1989-97	νσ							
		1992-98		ν						

ν: data at current prices. σ: data at constant prices.

(a) Refers to investment categories including other assets alongside ICT.

(b) Obtained via OECD.

(c) Data before 1994 include instruments and other professional equipment.

Table 5: Gross Fixed Capital Formation by Category (current prices) as %-share of Total Non-Residential GFCF and of Total Equipment, and as % of GDP (excluding rents)

	1980	1985	1990	1995	2000
Office and Computer Equipment					
European Union	2.9	5.0	4.7	4.8	5.5
United States	6.2	9.3	8.2	9.6	8.0
Communication Equipment					
European Union	3.0	3.7	3.5	4.0	4.6
United States	6.6	7.3	7.1	6.7	8.4
Software					
European Union	1.2	2.9	3.9	5.3	7.0
United States	2.7	4.7	7.5	9.3	13.2
Total ICT					
European Union	7.1	11.6	12.2	14.1	17.1
United States	15.5	21.3	22.8	25.6	29.6
Non-ICT Equipment					
European Union	34.1	34.2	32.3	30.7	30.1
United States	31.8	28.2	31.0	30.3	27.3
Transport Equipment					
European Union	10.8	11.1	11.6	11.7	13.6
United States	10.8	10.7	8.9	12.4	12.3
Non-Residential Buildings					
European Union	47.9	43.0	43.9	43.5	39.2
United States	41.9	39.8	37.3	31.7	30.7
Total Non-Residential GFCF					
European Union	100.0	100.0	100.0	100.0	100.0
United States	100.0	100.0	100.0	100.0	100.0
Total ICT Investments % of GFCF in Total Equipment*					
European Union	13.6	20.4	21.8	24.9	28.2
United States	26.7	35.4	36.4	37.5	42.7
Total ICT Investment as % of GDP, excluding rents					
European Union	1.3	1.9	2.3	2.2	2.9
United States	2.8	3.8	3.7	4.1	5.3
Total Non-Residential GFCF as % of GDP, excluding rents					
European Union	17.7	16.3	18.6	15.6	17.0
United States	17.9	17.9	16.0	15.8	17.9

European Union average is a weighted average for all member countries, excluding Belgium Luxembourg and Greece
* Total nonresidential GFCF excluding Nonresidential Buildings
See Appendix Table 1 for figures by individual country.

Table 6: Producer and Investment Price Indices for Hardware, Software and Communication Equipment

Country	Source	Software	Hardware	Communication equipment
Belgium	OECD (2000)	NA	Industrial production price index. No hedonic adjustment	NA
Denmark	OECD (Pilat, 2000)	NA	Application of the US hedonic price index, adjusted for exchange rate variations, for computers.	NA
Finland	OECD (Colecchia, 2000)	Weighted (50/50) average of industry computer and related activities average earnings index and the exchange rate corrected BLS' PPI pre-packaged software index.	NA	NA
France	Cette and al. (2000) "Les technologies de l'information et de la communication en France : diffusion et contribution à la croissance".	Price indexes for hardware and software of the US Bureau of Economic Analysis (BEA), corrected for the fluctuations of the FF/US$ exchange rate.		Factor costs methodology.
	INSEE (source : Brihault, 2000)	Using price indexes of the BEA corrected for the fluctuations of the exchange rate. French price index = BEA index multiplied by (1 + francs per dollar)/2. This method reflects the fact that half of the investment in computer equipment is of French origin and the other half imported and mostly invoiced in US dollars.		Factor costs methodology.
Germany	Bundesbank (2000)	Estimating the monetary value of the quality change on a case-by-case according to rules laid down by the Federal Statistical Office. The main methods used were the overlapping periods, direct comparison and linking with a fixed adjustment factor of 50 per cent or 100 per cent of price difference according to the difference in price between the old and the new model.		
Ireland	CSO	Earnings index.	NA	NA
Italy	OECD (2000)	NA	Industrial production price index. No hedonic adjustment	NA
Spain	OECD (2000)	NA	Index of industrial prices and unit value index. No hedonic adjustment.	NA
Sweden	OECD (2000)	NA	Producer price index with hedonic adjustment.	NA
UK	ONS ("ICT deflation and growth: a sensitivity analysis", 2001). Option cost is a variant of the overlapping link method.	No specific price indices, only more general investment deflators based on producers price indices (PPI).	Matched models. ONS uses a combination of two methods: option costing and manufacturer costing to evaluate changes in products.	NA
USA	OECD (Colecchia, 2001).	*Pre-packaged software*: hedonic method. *Own account software*: factor cost approach (i.e. salaries of programmers) ; *Customised software:* average or pre-packaged software and own account indices (25 per cent and 75 per cent fixed weights respectively).	Hedonic method applied since 1986 and retropolation until 1958.	Hedonic method applied only to telephone switching equipment and local area network (LAN) equipment; factor cost method applied to other communication equipment.

Table 7: Price Indices of Gross Fixed Non-Residential Capital Formation by Asset Type, 1980=100

	1980	1985	1990	1995	2000
Office and Computer Equipment					
European Union	100.0	65.4	51.1	31.7	10.1
United States	100.0	64.7	51.1	31.8	10.3
Communication Equipment					
European Union	100.0	128.7	132.4	126.7	107.1
United States	100.0	124.1	130.9	126.4	109.7
Software					
European Union	100.0	117.6	115.2	112.6	108.5
United States	100.0	113.4	107.0	100.8	97.2
Total ICT					
European Union	100.0	94.9	86.1	71.6	46.5
United States	100.0	92.0	83.8	68.4	45.5
Non-ICT Equipment					
European Union	100.0	133.3	146.6	157.4	157.2
United States	100.0	123.6	146.2	165.6	181.1
Transport Equipment					
European Union	100.0	139.9	174.7	199.0	210.7
United States	100.0	128.9	144.2	172.6	177.8
Non-Residential Buildings					
European Union	100.0	129.8	161.6	181.1	201.3
United States	100.0	123.6	144.1	162.5	192.0
Total Non-Residential GFCF					
European Union	100.0	128.2	147.1	156.5	153.3
United States	100.0	117.6	129.6	136.0	131.7

a) European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

Price indices for Office and Computer Equipment, Communication Equipment and Software are U.S. Price indices for all countries, adjusted for differences in general inflation.

See Appendix Table 2 for figures by individual country.

Table 8: Average Annual Growth Rates of Real Gross Fixed Non-Residential Capital Formation by Asset Type, 1980-2000 (in %)

	1980-1985	1985-1990	1990-1995	1995-2000	1980-2000
Office and Computer Equipment					
European Union	25.5	13.8	10.7	31.6	20.4
United States	24.8	6.3	17.4	27.0	18.9
Communication Equipment					
European Union	5.7	8.4	4.6	11.9	7.6
United States	5.8	2.6	4.1	15.7	7.1
Software					
European Union	20.6	16.0	7.6	12.3	14.1
United States	16.4	14.8	10.1	16.0	14.3
Total ICT					
European Union	17.2	12.8	7.7	18.5	14.0
United States	16.1	7.4	11.0	19.3	13.4
Non-ICT Equipment					
European Union	0.6	6.7	-1.3	5.5	2.9
United States	1.4	2.7	1.7	4.4	2.6
Transport Equipment					
European Union	0.0	6.2	-1.3	7.8	3.2
United States	2.8	-1.9	7.8	7.6	4.1
Non-Residential Buildings					
European Union	-1.1	5.8	-1.3	1.7	1.3
United States	2.8	-0.2	-1.0	4.3	1.5
Total Non-Residential GFCF					
European Union	1.3	7.0	-0.1	6.3	3.6
United States	4.8	2.2	3.7	8.9	4.9

a) European Union average is a weighted average for all member countries, excluding Belgium Luxembourg and Greece

See Appendix Table 3 for figures by individual country.

Table 9: Average Annual Growth Rates of Real Gross Fixed Non-Residential Capital Formation by Asset Type and Country, 1990-2000 (in %)

	Office and Computer Equipment	Commu-nication Equipment	Software	Total ICT	Total GFCF
1990-1995					
Austria	11.2	2.6	8.1	5.9	0.7
Denmark	14.8	-0.5	16.6	13.6	2.3
Finland	16.9	25.2	4.8	9.2	-8.5
France	12.9	3.9	6.7	7.9	-1.1
Germany	8.8	1.9	7.4	5.9	0.3
Ireland	38.7	6.2	8.4	21.4	1.3
Italy	7.7	5.5	4.2	5.6	-0.7
Netherlands	13.1	1.8	4.5	7.4	0.8
Portugal	10.4	2.7	8.7	6.1	2.6
Spain	1.6	-0.2	-2.3	-0.2	-0.2
Sweden	15.8	15.8	10.9	12.6	0.4
United Kingdom	13.5	15.6	11.5	12.8	0.7
European Union	10.7	4.6	7.6	7.7	-0.1
United States	17.4	4.1	10.1	11.0	3.7
1995-2000					
Austria	32.9	10.0	17.8	17.9	5.5
Denmark	26.0	8.2	14.5	16.7	7.8
Finland	28.6	26.1	13.0	18.4	8.0
France	30.2	10.2	17.7	19.0	4.9
Germany	33.9	12.0	11.4	19.4	4.2
Ireland	34.6	19.4	22.3	27.1	16.1
Italy	33.1	11.9	11.4	16.6	6.9
Netherlands	30.5	15.3	19.1	22.3	8.8
Portugal	31.9	12.2	13.2	17.2	10.3
Spain	30.1	13.5	11.1	18.2	6.8
Sweden	26.8	13.8	16.5	17.6	6.5
United Kingdom	30.4	10.4	7.7	17.3	8.6
European Union	31.6	11.9	12.3	18.5	6.3
United States	27.0	15.7	16.0	19.3	8.9

a) European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

See Appendix Table 3 for figures for all asset types

Table 10: Average Internal Rates of Return of Total Non-Residential Capital, 1980-2000, in %

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	0.15	0.14	0.14	0.13
Denmark	0.16	0.14	0.13	0.16
Finland	0.13	0.14	0.07	0.15
France	0.14	0.15	0.12	0.13
Germany	0.10	0.13	0.12	0.10
Ireland	0.15	0.19	0.22	0.38
Italy	0.14	0.15	0.15	0.17
Netherlands	0.12	0.12	0.13	0.15
Portugal	0.15	0.24	0.22	0.19
Spain	0.09	0.12	0.11	0.13
Sweden	0.13	0.14	0.07	0.10
United Kingdom	0.16	0.19	0.13	0.18
European Union	0.13	0.14	0.13	0.14
United States	0.12	0.13	0.13	0.15

a) European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

For derivation, see section 5 of main text.

Table 11: Share of Labour and Capital Compensation in GDP 1980-2000 (in %)

	1980-1985	1985-1990	1990-1995	1995-2000
European Union				
Labour Share in GDP	71.2	68.5	68.6	66.2
Capital Share in GDP	28.8	31.5	31.4	33.8
of which:				
Office and Computer Equipment	0.9	1.0	1.1	1.0
Communication Equipment	0.6	0.9	0.9	1.0
Software	0.9	1.0	1.1	1.0
Non-ICT Equipment	8.0	8.7	8.1	8.3
Transport Equipment	2.6	2.7	2.7	2.8
Non-Residential Buildings	16.4	17.7	17.6	19.5
United States				
Labour Share in GDP	71.4	71.0	70.5	68.7
Capital Share in GDP	28.6	29.0	29.5	31.3
of which:				
Office and Computer Equipment	1.9	2.0	1.9	1.8
Communication Equipment	1.2	1.6	1.7	1.8
Software	1.9	2.0	1.9	1.8
Non-ICT Equipment	7.9	7.4	7.4	7.8
Transport Equipment	2.6	2.4	2.3	2.8
Non-Residential Buildings	14.5	14.6	14.7	15.0

a) European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

See also Methodology and Sources Guide.

Table 12: Share in Capital Compensation by Asset Type, 1980-2000

	1980	1985	1990	1995	2000
Office and Computer Equipment					
European Union	3.5	3.2	3.6	3.2	2.7
United States	6.3	7.2	6.8	6.5	5.0
Communication Equipment					
European Union	2.4	2.4	2.9	3.3	3.5
United States	4.0	5.0	5.9	6.4	6.2
Software					
European Union	0.8	1.4	2.5	2.9	3.9
United States	1.6	2.7	4.3	5.5	8.1
Total ICT					
European Union	6.7	7.0	8.9	9.4	10.0
United States	11.9	14.9	16.9	18.4	19.3
Non-ICT Equipment					
European Union	30.5	27.7	28.3	24.2	24.2
United States	28.0	26.3	25.1	25.1	22.9
Transport Equipment					
European Union	9.7	8.4	8.9	8.2	8.9
United States	10.2	8.6	7.8	8.5	9.8
Non-Residential Buildings					
European Union	53.1	56.9	53.9	58.2	56.9
United States	49.9	50.2	50.2	48.0	48.0
Total Non-Residential GFCF					
European Union	100.0	100.0	100.0	100.0	100.0
United States	100.0	100.0	100.0	100.0	100.0
ICT as % of Total Equipment*					
European Union	14.3	16.2	19.4	22.4	23.2
United States	23.8	30.0	34.0	35.4	37.2

a) European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

* Total nonresidential GFCF excluding Nonresidential Buildings

See Appendix Table 4 for figures by individual country.

Table 13: Share in Total Capital Compensation*
by Asset Type and Country, 2000

	Office and Computer Equipment	Commu-nication Equipment	Software	Total ICT
Austria	4.2	10.9	4.5	19.5
Denmark	2.1	2.9	15.8	20.8
Finland	2.9	3.5	12.1	18.5
France	5.3	7.7	8.3	21.3
Germany	6.2	8.3	8.0	22.5
Ireland	8.6	9.8	2.7	21.1
Italy	3.8	11.8	5.8	21.4
Netherlands	9.7	8.7	11.9	30.4
Portugal	3.4	10.4	5.1	18.8
Spain	6.5	7.3	8.8	22.7
Sweden	3.7	4.0	17.3	25.0
United Kingdom	9.5	5.2	12.1	26.8
European Union	6.2	8.0	9.0	23.2
United States	9.7	11.9	15.6	37.2

a) European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

* Total nonresidential GFCF excluding Nonresidential Buildings

See Appendix Table 4 for figures for all asset types

Table 14: Growth of Capital Service Flows by Asset Type, 1980-2000
(Average Annual Growth Rates in %)

	1980-1985	1985-1990	1990-1995	1995-2000	1980-2000
Office and Computer Equipment					
European Union	22.4	17.5	10.2	25.0	18.8
United States	24.4	12.1	12.3	23.5	18.1
Communication Equipment					
European Union	6.2	7.1	6.0	8.5	6.9
United States	8.7	6.0	3.6	8.9	6.8
Software					
European Union	18.4	18.2	9.4	11.5	14.4
United States	16.1	15.1	11.9	14.8	14.5
Total ICT (a)					
European Union	15.6	14.7	8.8	13.9	13.2
United States	18.0	11.5	9.0	15.2	16.7
Non-ICT Equipment					
European Union	2.0	4.2	2.2	3.2	2.9
United States	1.8	2.6	1.7	3.3	2.3
Transport Equipment					
European Union	0.9	3.5	1.3	4.3	2.5
United States	0.5	0.9	4.2	6.4	3.0
Non-Residential Buildings					
European Union	3.0	3.2	2.7	2.1	2.7
United States	3.2	2.7	1.9	2.3	2.5
Total Gross Fixed Non-Residential Capital Services (a)					
European Union	3.4	4.2	3.2	3.5	3.6
United States	4.4	4.0	3.2	5.2	4.2

a) (Sub)totals are Tornqvist aggregated
European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece
See Appendix Table 5 for figures by individual country.

Table 15: Growth of Capital Service Flows by Asset Type and Country, 1990-2000 (Average Annual Growth Rates in %)

	Office and Computer Equipment	Commu-nication Equipment	Software	Total ICT (a)
1990-1995				
Austria	11.7	5.1	10.5	7.9
Denmark	12.3	2.7	14.7	11.0
Finland	12.5	12.0	7.5	9.1
France	12.5	6.3	7.1	8.9
Germany	9.3	5.8	9.8	8.6
Ireland	21.3	7.1	4.6	10.5
Italy	7.5	7.5	5.8	7.3
Netherlands	11.7	4.1	8.8	8.9
Portugal	11.1	5.4	11.1	8.3
Spain	6.5	2.7	5.0	6.4
Sweden	11.7	6.3	10.6	9.9
United Kingdom	11.4	6.9	12.9	11.2
European Union	10.2	6.0	9.4	8.8
United States	12.3	3.6	11.9	9.0
1995-2000				
Austria	25.7	6.5	16.8	12.1
Denmark	24.0	4.0	15.4	14.7
Finland	25.9	24.2	10.5	14.7
France	24.4	8.6	15.7	14.9
Germany	25.0	5.2	9.7	11.7
Ireland	34.8	17.2	16.8	24.9
Italy	25.3	9.7	9.7	12.2
Netherlands	25.6	9.4	16.1	16.9
Portugal	24.4	7.8	12.6	11.8
Spain	19.4	9.0	7.0	10.5
Sweden	23.5	14.6	15.5	16.6
United Kingdom	26.6	13.9	10.4	17.4
European Union	25.0	8.5	11.5	13.9
United States	23.5	8.9	14.8	15.2

a) (Sub)totals are Tornquist aggregated

b) European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

See Appendix Table 5 for figures for all asset types

Table 16: Percentage Contribution of ICT Capital Service Flows to Real GDP Growth (excluding rents), 1980-2000

	Office and Computer Equipment (%)	Commu-nication Equipment (%)	Software (%)	Total ICT (%)	Real GDP excl. rents
European Union					
1980-1985	0.20	0.04	0.05	0.29	1.5
in % of GDP growth	13	3	3	19	100
1985-1990	0.19	0.06	0.11	0.36	3.2
in % of GDP growth	6	2	4	12	100
1990-1995	0.11	0.06	0.09	0.25	1.4
in % of GDP growth	8	4	6	18	100
1995-2000	0.23	0.09	0.13	0.44	2.6
in % of GDP growth	9	3	5	17	100
United States					
1980-1985	0.46	0.11	0.10	0.66	3.1
in % of GDP growth	15	4	3	21	100
1985-1990	0.27	0.10	0.15	0.53	3.2
in % of GDP growth	8	3	5	16	100
1990-1995	0.22	0.06	0.18	0.46	2.4
in % of GDP growth	9	3	8	19	100
1995-2000	0.41	0.15	0.30	0.86	4.2
in % of GDP growth	10	4	7	20	100

European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

See Appendix Table 6 for figures for individual countries

Table 17: Differences in Contribution of ICT Capital to Real GDP Growth between Present Study and Daveri (%-point contribution to GDP)

	Present Study		Daveri (2002)	
	1995-2000	rank	1996-1999	rank
United States	0.86	1	1.45	1
Ireland	0.80	2	0.96	3
United Kingdom	0.69	3	1.17	2
Netherlands	0.68	4	0.72	6
Denmark	0.61	5	0.65	7
Sweden	0.53	6	0.85	4
Italy	0.41	7	0.35	12
Finland	0.37	8	0.74	5
Germany	0.37	9	0.45	9
Austria	0.36	10	0.43	11
France	0.35	11	0.44	10
Portugal	0.34	12	0.49	8
Spain	0.27	13	0.34	13

Present study: see Appendix Table 6; Daveri (2002), Table 2

Table 18: Differences in Contribution of IT, Software and non-ICT Capital to Real GDP Growth between Present Study and Colecchia and Schreyer (2001)

	GDP growth		Contribution of IT and Comm.				Contribution of Software				Contribution of non-ICT capital			
	This Study	C&S (2001)	This Study		C&S (2001)		This Study		C&S (2001)		This Study		C&S (2001)	
				%		%		%		%		%		%
United States														
90-95	2.42	2.64	0.28	12%	0.29	11%	0.18	8%	0.14	5%	0.49	20%	0.54	20%
95-00	4.21	4.40	0.56	13%	0.62	14%	0.30	7%	0.25	6%	0.77	18%	0.84	19%
Finland														
90-95	-1.14	-0.70	0.06	-6%	0.17	-24%	0.11	-10%	0.07	-10%	-0.03	3%	0.02	-3%
95-99	5.04	5.62	0.19	4%	0.46	8%	0.15	3%	0.16	3%	0.37	7%	-0.05	-1%
95-00	5.14		0.21	4%			0.17	3%			0.40	8%		
France														
90-95	0.97	0.97	0.16	16%	0.16	16%	0.04	4%	0.02	2%	0.98	101%	0.60	62%
95-00	2.52	2.81	0.23	9%	0.25	10%	0.12	5%	0.10	4%	0.72	29%	0.52	19%
Germany														
90-95	1.44	2.22	0.19	13%	0.24	11%	0.09	6%	0.06	3%	0.77	54%	0.78	35%
95-00	1.71	2.06	0.27	16%	0.30	15%	0.10	6%	0.07	3%	0.47	27%	0.61	30%
Italy														
90-95	1.20	1.44	0.18	15%	0.18	15%	0.05	4%	0.02	2%	0.58	49%	0.53	37%
95-99	1.70	1.93	0.31	18%	0.29	17%	0.07	4%	0.07	4%	0.72	42%	0.65	34%
95-00	1.97		0.33	17%			0.08	4%			0.78	39%		
UK														
90-95	1.78	2.12	0.19	11%	0.23	13%	0.15	9%	0.04	2%	0.67	37%	0.58	27%
95-00	2.89	3.55	0.50	17%	0.43	15%	0.19	7%	0.04	1%	0.94	33%	0.78	22%

C&S: Colecchia and Schreyer (2001), for which all numbers refer to the business sector only

Table 19: Contribution of ICT Capital, non-ICT Capital and TFP to Annual Average Labour Productivity Growth, 1980-2000, in %-point contribution and % of total Labour Productivity Growth

	Capital Deepening (Capital per Person Hour Worked)					Total Factor Prod'ty Growth	Labour Prod'ty Growth
	Office and Computer Equipment	Commu-nication Equipment	Software	Total ICT	Total non-ICT		
European Union							
1980-1985	0.20	0.05	0.05	0.30	0.97	1.26	2.53
in % of LP growth	8	2	2	12	38	50	100
1985-1990	0.18	0.05	0.11	0.33	0.64	1.02	2.00
in % of LP growth	9	3	5	17	32	51	100
1990-1995	0.13	0.06	0.09	0.28	1.05	1.12	2.45
in % of LP growth	5	3	4	12	43	46	100
1995-2000	0.22	0.07	0.11	0.40	0.40	0.62	1.43
in % of LP growth	15	5	8	28	28	44	100
United States							
1980-1985	0.43	0.09	0.09	0.60	0.24	0.84	1.69
in % of LP growth	25	5	5	36	14	50	100
1985-1990	0.23	0.07	0.13	0.43	0.14	0.66	1.23
in % of LP growth	19	6	11	35	12	53	100
1990-1995	0.19	0.04	0.16	0.40	0.19	0.61	1.19
in % of LP growth	16	3	14	33	16	51	100
1995-2000	0.38	0.11	0.26	0.75	0.25	1.21	2.21
in % of LP growth	17	5	12	34	11	55	100

European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

See Appendix Table 7 for figures for individual countries

Table 20: Average Contribution of ICT-Production to Average Annual TFP Growth, 1990-2000

	Aggregate TFP growth (%)		Contribution of ICT production to aggregate TFP (percentage points)		Contribution to aggregate TFP (% of aggregate TFP)	
	1990-1995	1995-2000	1990-1995	1995-2000	1990-1995	1995-2000
Austria	0.44	1.63	0.08	0.10	18%	6%
Denmark	1.61	0.72	0.05	0.06	3%	9%
Finland	1.23	3.18	0.16	0.17	13%	5%
France	0.06	0.70	0.17	0.22	277%	32%
Germany	1.36	0.91	0.14	0.16	10%	18%
Ireland	2.96	4.27	1.17	3.02	39%	71%
Italy	1.62	0.25	0.13	0.15	8%	61%
Netherlands	0.43	0.21	0.07	0.10	15%	49%
Portugal	1.36	0.92	0.02	0.03	2%	3%
Spain	0.98	-0.14	0.09	0.12	9%	-87%
Sweden	1.00	0.96	0.14	0.09	14%	10%
United Kingdom	1.41	0.49	0.21	0.32	15%	65%
European Union	1.12	0.62	0.14	0.19	12%	31%
United States	0.61	1.21	0.25	0.43	41%	36%

a) European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

Table 21: Domar weights and contributions to Average Annual TFP Growth, 1990-2000

	Domar weighted TFP (in percentage points)					
	NACE 30 1990-1995	NACE 30 1995-2000	NACE 321 1990-1995	NACE 321 1995-2000	NACE 322 1990-1995	NACE 322 1995-2000
Austria	0.00	0.02	0.04	0.08	0.04	0.00
Denmark	0.02	0.03	0.02	0.04	0.01	0.00
Finland	0.09	0.14	0.01	0.05	0.06	-0.03
France	0.09	0.11	0.06	0.12	0.02	0.00
Germany	0.09	0.10	0.03	0.07	0.01	0.00
Ireland	0.85	1.90	0.24	1.13	0.07	-0.01
Italy	0.05	0.06	0.05	0.10	0.03	0.00
Netherlands	0.05	0.09	0.01	0.01	0.01	0.00
Portugal	0.00	0.00	0.02	0.03	0.00	0.00
Spain	0.06	0.08	0.02	0.04	0.01	0.00
Sweden	0.05	0.06	0.02	0.06	0.07	-0.02
United Kingdom	0.17	0.25	0.03	0.07	0.01	0.00
European Union	0.09	0.13	0.03	0.07	0.01	0.00
United States	0.11	0.19	0.11	0.24	0.02	0.00
	Domar weights (gross final output over GDP in %)					
	30 *90-95*	30 *95-00*	321 *90-95*	321 *95-00*	322 *90-95*	322 *95-00*
Austria	0.04	0.12	0.37	0.45	1.14	1.31
Denmark	0.20	0.15	0.24	0.21	0.17	0.36
Finland	0.74	0.87	0.11	0.29	1.76	6.97
France	0.76	0.64	0.61	0.66	0.62	0.90
Germany	0.79	0.58	0.32	0.38	0.36	0.50
Ireland	7.20	11.34	2.24	6.27	2.29	2.61
Italy	0.42	0.35	0.44	0.54	1.03	1.00
Netherlands	0.41	0.53	0.10	0.07	0.24	0.17
Portugal	0.02	0.01	0.20	0.15	0.04	0.13
Spain	0.47	0.50	0.19	0.20	0.39	0.38
Sweden	0.46	0.36	0.17	0.31	2.05	5.48
United Kingdom	1.41	1.50	0.33	0.37	0.35	0.60
EU12	0.73	0.75	0.32	0.40	0.45	0.78
United States	0.95	1.16	1.05	1.33	0.63	0.81
TFP growth	0.12	0.17	0.11	0.18	0.03	0.00

a) European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

NACE 30: Office and Computer Machinery; NACE 321: Electronic Components and Accessories; NACE 322: Communication Equipment

Figure 1: ICT Investment share in Total Gross Fixed Capital Formation in Machinery and Equipment, current prices (%), 2000

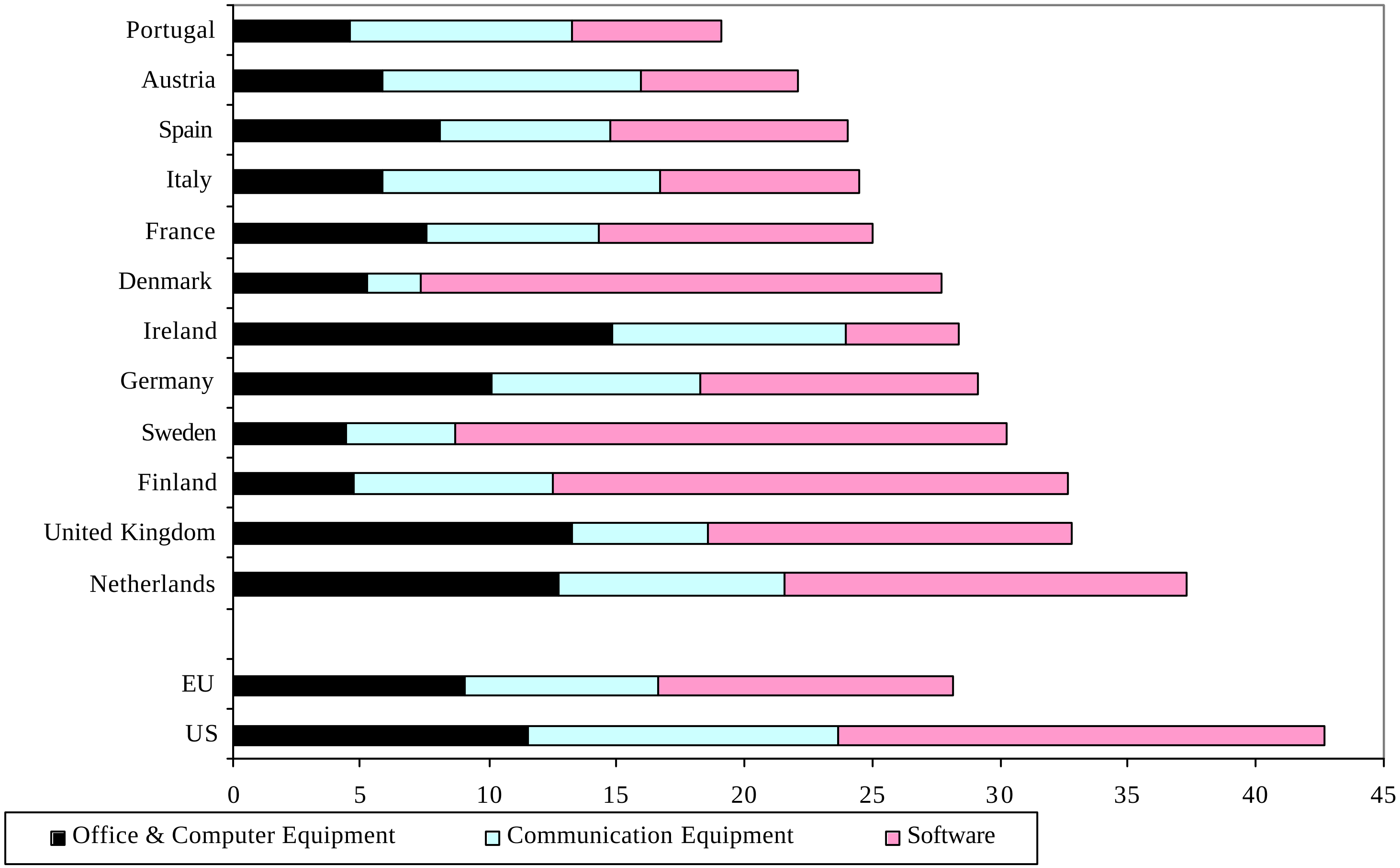


Figure 2: ICT share in Capital Service Flows of Total Equipment, EU and USA, 1980-2000 (in %)

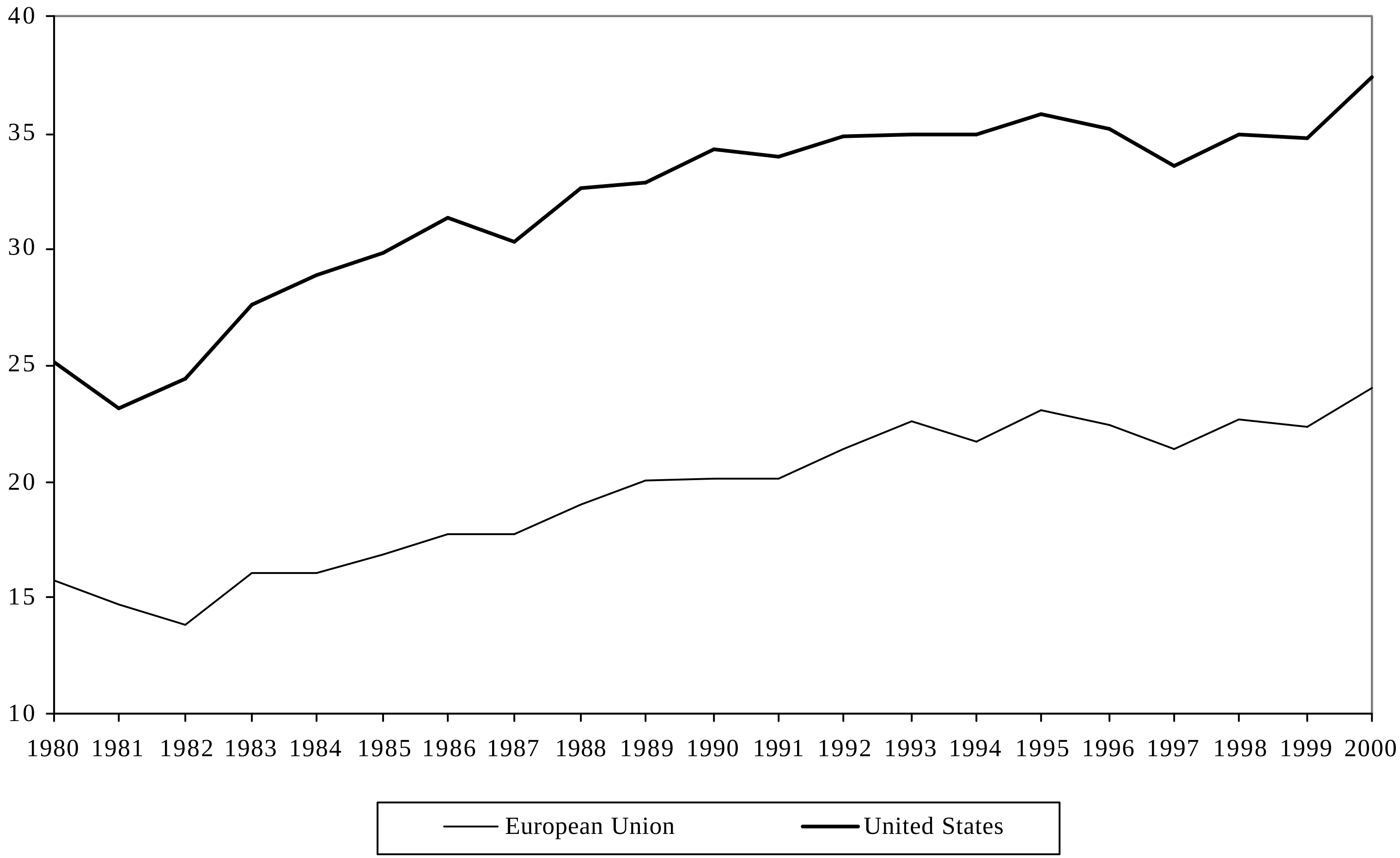


Figure 3: ICT Capital Services as % of Gross Fixed Capital Services of Equipment, 2000 (in %)

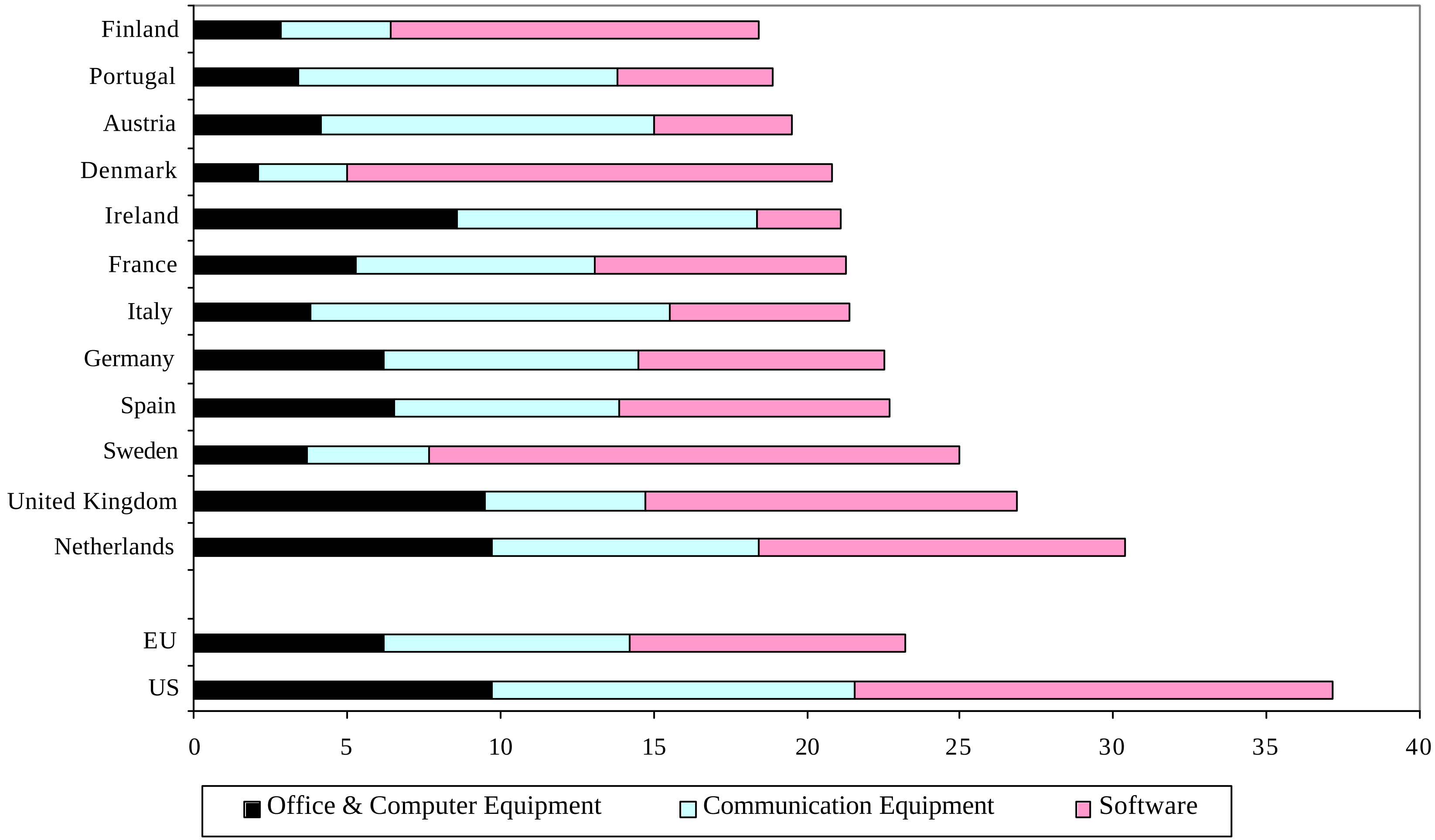


Figure 4: Contribution of ICT Capital to Growth in Real GDP, 1995-2000 (in percentage %)

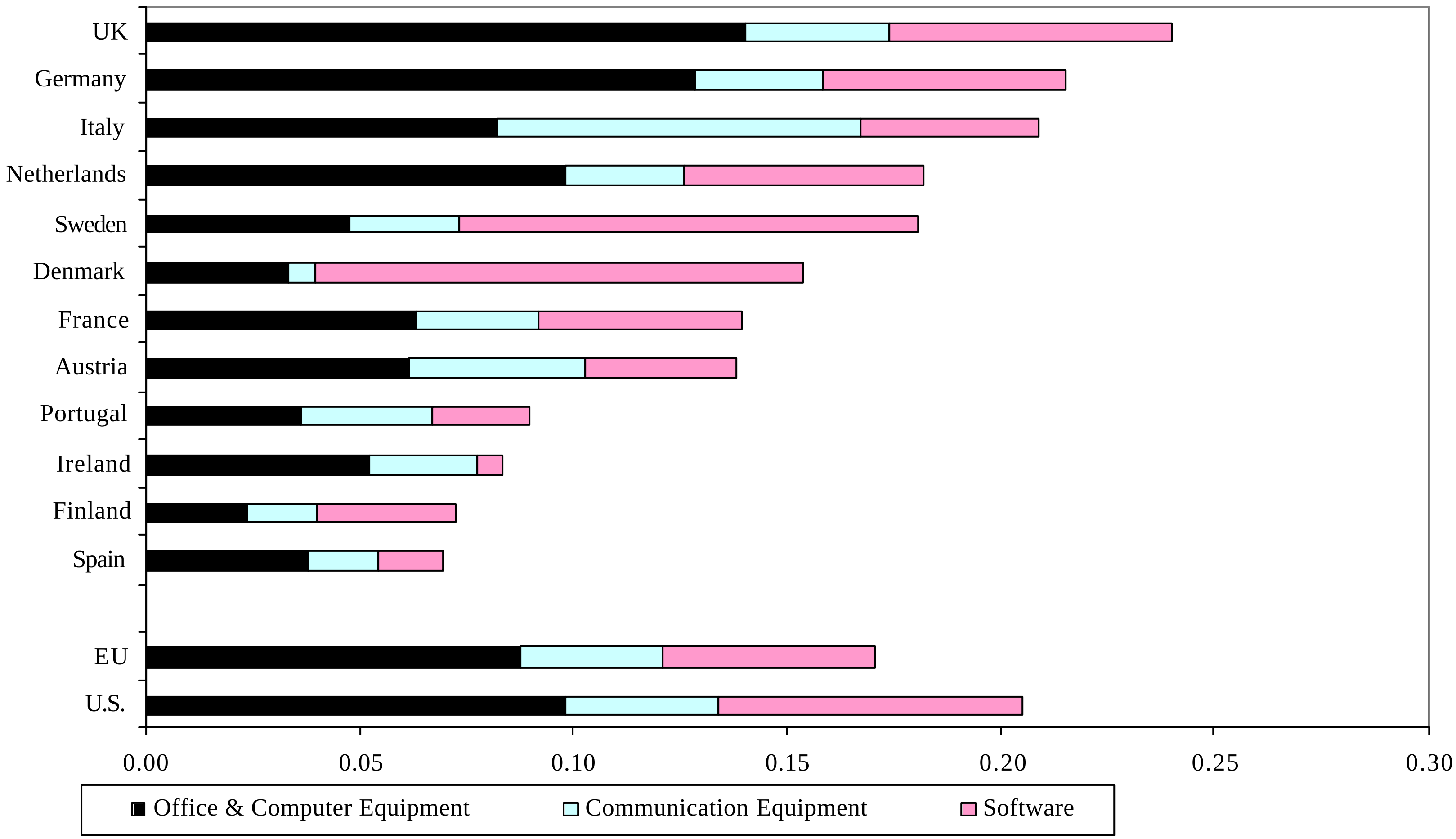


Figure 5: Absolute Contribution of ICT Capital to Labour Productivity Growth, 1995-2000 (in %-points)

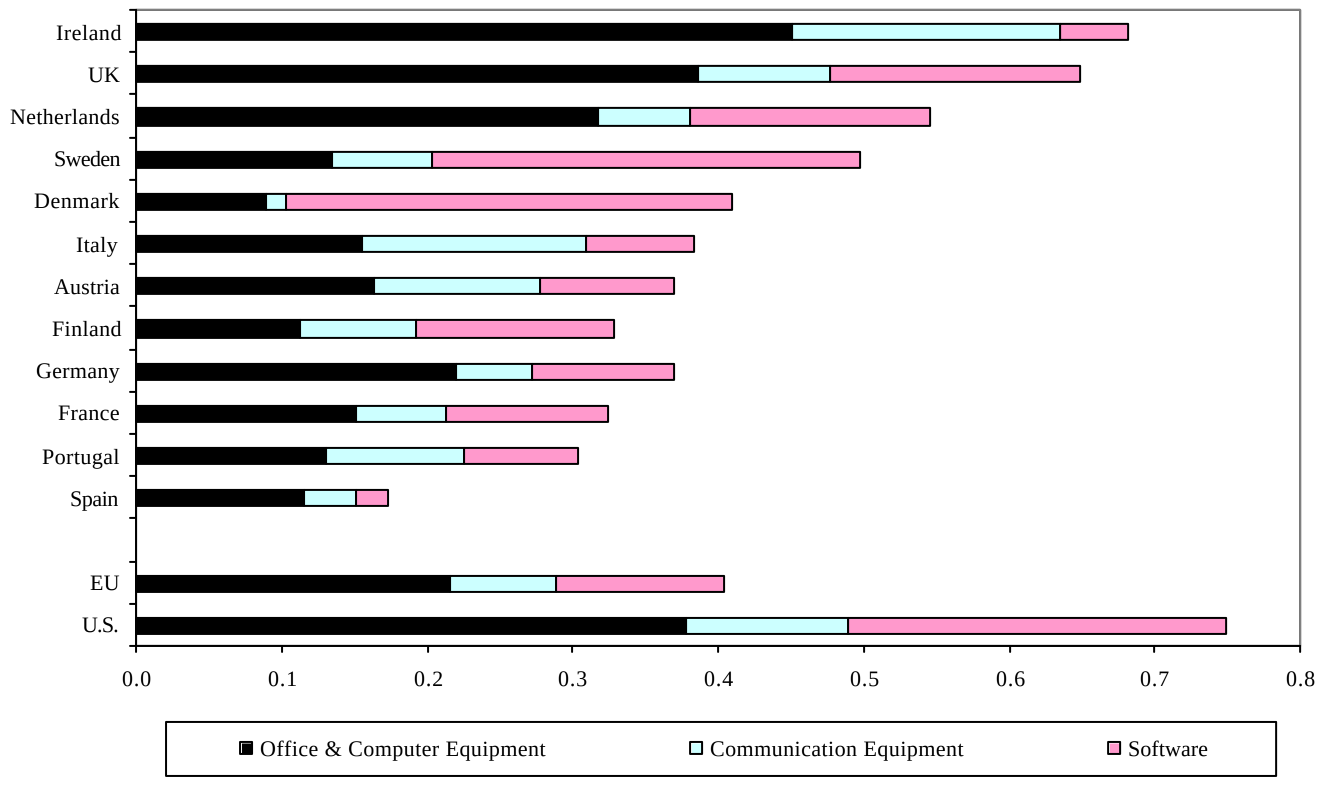


Figure 6: Absolute Contribution of Non-Residential Capital and TFP to Labour Productivity Growth, 1995-2000, (in %-points)

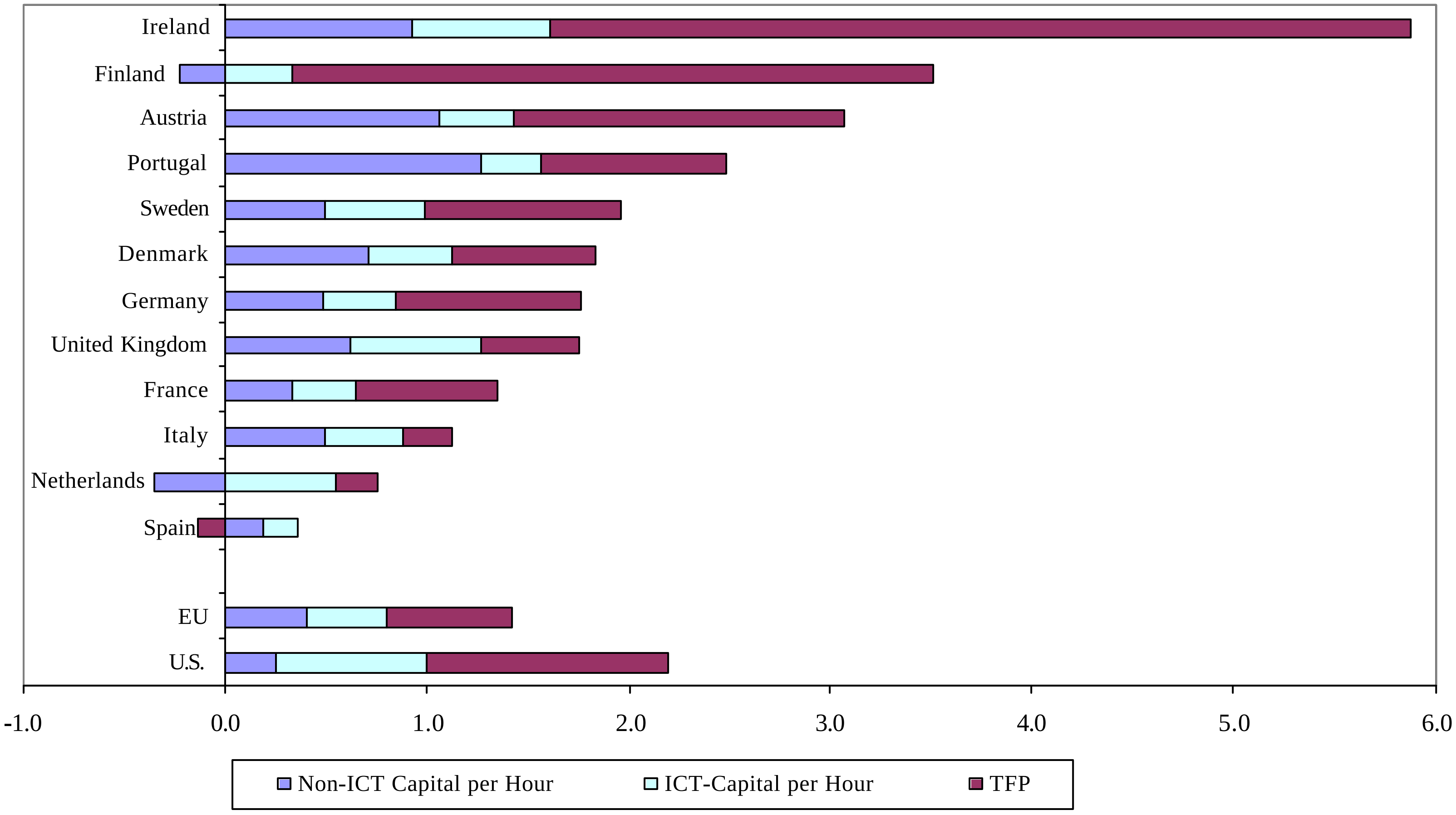
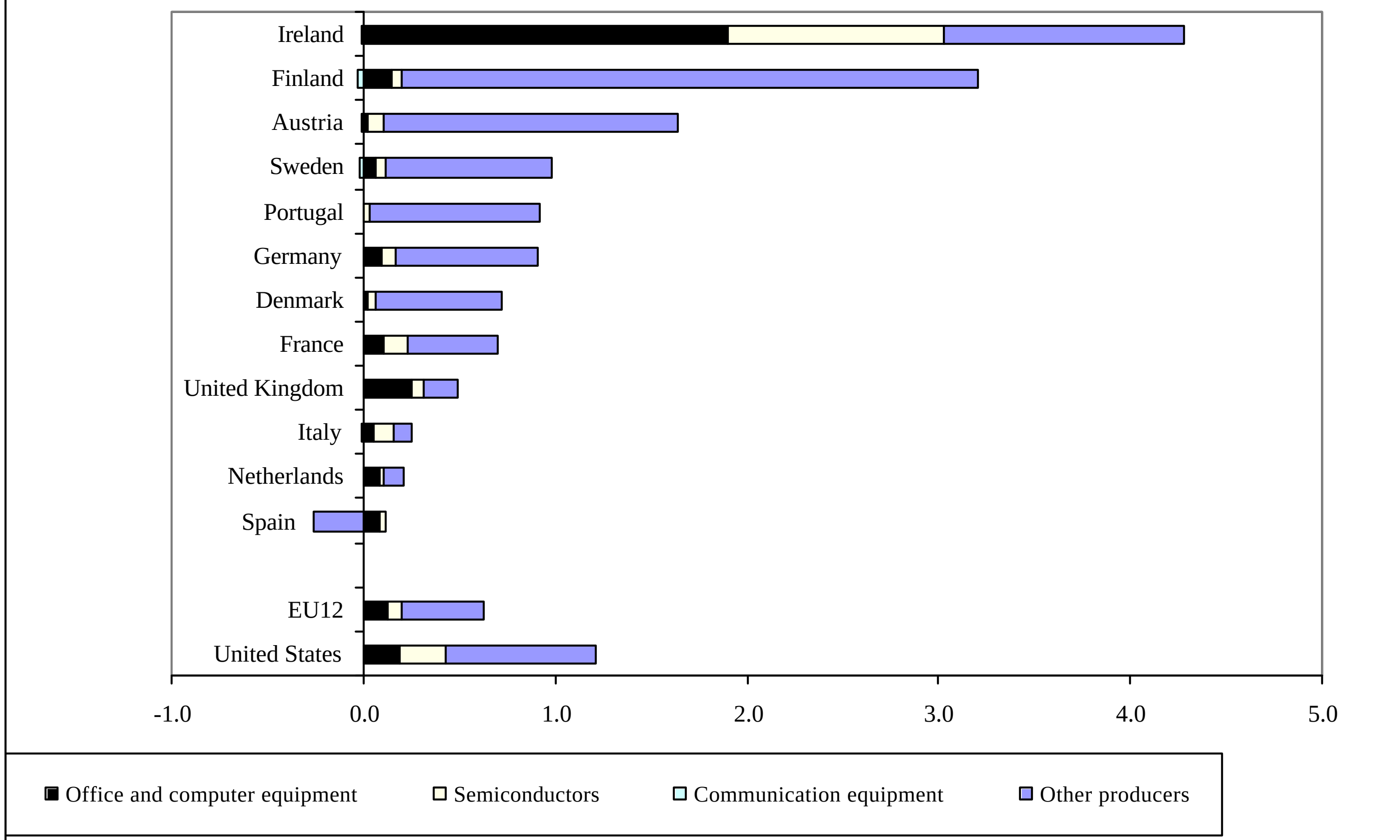


Figure 7: Contribution ICT Production and Other Production to Total Factor Productivity Growth, 1995-2000 (%-points)



Appendix Table 1.A: Gross Fixed Capital Formation in Office and Computer Equipment as share of Total Non-Residential GFCF in current prices

	1980	1985	1990	1995	2000
Austria	1.7	2.9	2.8	2.8	3.4
Denmark	2.9	4.0	3.8	4.4	3.6
Finland	0.9	1.3	1.4	2.9	2.5
France	2.3	3.7	3.2	3.5	4.0
Germany	3.1	6.0	5.4	4.6	6.7
Ireland	2.4	6.4	2.6	9.5	7.6
Italy	2.7	4.8	4.2	3.5	4.0
Netherlands	5.3	6.8	6.5	7.1	7.1
Portugal	1.7	4.0	2.9	2.8	2.7
Spain	2.3	4.5	5.2	3.4	3.4
Sweden	1.7	2.7	2.6	3.6	3.2
United Kingdom	3.2	5.7	6.7	8.2	8.9
European Union	2.9	5.0	4.7	4.8	5.5
United States	6.2	9.3	8.2	9.6	8.0

Appendix Table 1.B: Gross Fixed Capital Formation in Communication Equipment as share of Total Non-Residential GFCF in Current prices

	1980	1985	1990	1995	2000
Austria	4.9	5.6	5.6	5.6	5.9
Denmark	1.5	2.3	2.0	1.6	1.5
Finland	0.4	0.5	0.4	2.1	4.2
France	2.6	3.2	2.9	3.2	3.5
Germany	3.4	4.7	4.5	4.2	5.4
Ireland	1.4	3.3	4.2	4.7	4.7
Italy	4.5	5.5	6.1	7.0	7.4
Netherlands	3.3	4.4	4.1	4.0	5.0
Portugal	3.7	5.6	5.3	5.5	5.2
Spain	2.4	2.4	2.6	2.4	2.8
Sweden	1.3	1.6	1.2	2.5	3.1
United Kingdom	1.5	1.9	1.6	3.4	3.6
European Union	3.0	3.7	3.5	4.0	4.6
United States	6.6	7.3	7.1	6.7	8.4

Appendix Table 1.C: Gross Fixed Capital Formation in software as share of Total Non-Residential GFCF in current prices

	1980	1985	1990	1995	2000
Austria	0.5	1.2	1.6	2.1	3.5
Denmark	2.0	2.8	5.4	10.1	14.0
Finland	2.6	3.7	5.2	9.2	10.8
France	1.2	2.7	2.4	3.2	5.7
Germany	1.1	3.1	3.9	5.0	7.2
Ireland	0.8	2.6	1.5	1.8	2.3
Italy	0.8	2.2	3.8	4.3	5.3
Netherlands	2.7	3.4	4.9	5.3	8.8
Portugal	0.7	2.3	2.3	3.2	3.5
Spain	0.9	2.6	4.2	3.4	3.9
Sweden	2.0	4.5	6.0	9.8	15.4
United Kingdom	0.9	3.5	5.5	9.3	9.5
European Union	1.2	2.9	3.9	5.3	7.0
United States	2.7	4.7	7.5	9.3	13.2

Appendix Table 1.D: Gross Fixed Capital Formation in Total ICT as share of Total Non-Residential GFCF in current prices

	1980	1985	1990	1995	2000
Austria	7.1	9.6	10.0	10.4	12.8
Denmark	6.4	9.0	11.1	16.1	19.1
Finland	3.9	5.5	7.0	14.2	17.5
France	6.1	9.5	8.5	9.9	13.1
Germany	7.7	13.9	13.9	13.9	19.2
Ireland	4.6	12.3	8.3	16.0	14.6
Italy	8.0	12.5	14.2	14.8	16.7
Netherlands	11.2	14.6	15.5	16.4	20.9
Portugal	6.1	11.9	10.6	11.5	11.4
Spain	5.6	9.4	11.9	9.3	10.1
Sweden	5.0	8.7	9.7	15.8	21.6
United Kingdom	5.6	11.0	13.8	20.9	22.0
European Union	7.1	11.6	12.2	14.1	17.1
United States	15.5	21.3	22.8	25.6	29.6

Appendix Table 1.E: Gross Fixed Capital Formation in Non-ICT Equipment as share of Total Non-Residential GFCF in current prices

	1980	1985	1990	1995	2000
Austria	37.4	37.6	35.3	32.5	32.7
Denmark	36.4	40.6	36.5	34.8	35.4
Finland	38.2	38.8	37.0	37.0	28.4
France	29.9	30.7	28.8	28.1	26.8
Germany	34.2	33.6	35.1	29.5	31.7
Ireland	34.7	30.0	21.6	17.2	11.7
Italy	43.5	37.0	35.7	37.6	36.5
Netherlands	20.2	25.8	23.6	22.6	19.6
Portugal	50.8	42.9	44.6	32.3	30.6
Spain	26.3	26.2	21.3	19.8	21.8
Sweden	41.6	46.8	46.6	41.0	36.8
United Kingdom	39.6	39.1	32.3	35.3	32.7
European Union	34.1	34.2	32.3	30.7	30.1
United States	31.8	28.2	31.0	30.3	27.3

Appendix Table 1.F: Gross Fixed Capital Formation in Transport Equipment as share of Total Non-Residential GFCF in current prices

	1980	1985	1990	1995	2000
Austria	10.2	10.7	10.2	11.5	12.3
Denmark	11.2	13.1	13.1	15.0	14.4
Finland	9.0	7.0	8.1	7.3	7.5
France	10.1	9.7	10.9	11.3	12.6
Germany	9.8	10.6	12.4	11.1	15.1
Ireland	19.6	20.3	26.3	26.5	25.0
Italy	12.5	12.0	12.1	13.3	15.1
Netherlands	11.5	15.5	15.6	16.7	15.6
Portugal	12.6	11.8	11.3	13.1	17.7
Spain	11.3	9.5	9.7	9.3	10.2
Sweden	6.3	7.2	7.1	7.4	13.0
United Kingdom	13.7	12.9	11.4	11.7	12.2
European Union	10.8	11.1	11.6	11.7	13.6
United States	10.8	10.7	8.9	12.4	12.3

Appendix Table 1.G: Gross Fixed Capital Formation in Non-Residential Structures as share of Total Non-Residential GFCF in current prices

	1980	1985	1990	1995	2000
Austria	45.2	42.0	44.4	45.6	42.1
Denmark	46.0	37.3	39.2	34.1	31.2
Finland	48.9	48.7	47.9	41.5	46.6
France	53.9	50.1	51.8	50.7	47.4
Germany	48.3	42.0	38.6	45.5	34.0
Ireland	41.1	37.4	43.8	40.3	48.7
Italy	36.0	38.4	38.0	34.2	31.7
Netherlands	57.1	44.0	45.3	44.3	43.9
Portugal	30.4	33.4	33.5	43.1	40.3
Spain	56.7	54.9	57.1	61.6	58.0
Sweden	47.1	37.3	36.6	35.8	28.6
United Kingdom	41.1	37.1	42.6	32.1	33.1
European Union	47.9	43.0	43.9	43.5	39.2
United States	41.9	39.8	37.3	31.7	30.7

Appendix Table 2.A: Price Indices of Office and Computer Equipment 1980=100

	1980	1985	1990	1995	2000
Austria	100.0	62.4	47.7	30.3	9.4
Denmark	100.0	75.5	61.9	37.5	12.8
Finland	100.0	75.8	67.6	41.0	13.1
France	100.0	64.5	44.3	24.5	7.7
Germany	100.0	58.2	44.1	26.9	8.0
Ireland	100.0	104.7	81.4	51.1	18.3
Italy	100.0	90.9	71.6	45.2	14.2
Netherlands	100.0	59.0	41.2	25.1	8.3
Portugal	100.0	135.8	169.7	135.0	47.7
Spain	100.0	87.2	84.4	60.2	20.7
Sweden	100.0	74.8	69.9	43.7	13.8
United Kingdom	100.0	69.7	62.2	39.6	13.4
European Union	100.0	65.4	51.1	31.7	10.1
United States	100.0	64.7	51.1	31.8	10.3

Appendix Table 2.B: Price Indices of Communication equipment 1980=100

	1980	1985	1990	1995	2000
Austria	100.0	119.7	122.0	120.5	100.3
Denmark	100.0	144.8	158.3	148.8	135.6
Finland	100.0	145.2	173.1	163.0	139.6
France	100.0	123.6	113.3	97.4	81.9
Germany	100.0	111.6	112.9	106.7	85.0
Ireland	100.0	176.9	183.7	179.1	171.9
Italy	100.0	174.3	183.3	179.6	150.8
Netherlands	100.0	113.1	105.4	99.6	87.7
Portugal	100.0	260.2	434.5	536.0	507.2
Spain	100.0	167.1	216.0	239.3	219.6
Sweden	100.0	143.4	178.9	173.6	146.5
United Kingdom	100.0	133.6	159.1	157.5	142.4
European Union	100.0	128.7	132.4	126.7	107.1
United States	100.0	124.1	130.9	126.4	109.7

Appendix Table 2.C: Price Indices of Software 1980=100

	1980	1985	1990	1995	2000
Austria	100.0	109.4	99.7	96.1	88.8
Denmark	100.0	132.4	129.4	118.7	120.1
Finland	100.0	132.8	141.5	130.0	123.6
France	100.0	134.8	127.8	117.2	109.1
Germany	100.0	102.1	92.3	90.7	82.5
Ireland	100.0	150.1	139.4	132.5	141.3
Italy	100.0	172.3	195.5	203.3	205.6
Netherlands	100.0	103.4	86.2	79.4	77.7
Portugal	100.0	237.9	355.2	427.5	449.2
Spain	100.0	152.8	176.6	190.8	194.5
Sweden	100.0	131.1	146.3	138.5	129.8
United Kingdom	100.0	122.1	130.0	125.6	126.1
European Union	100.0	117.6	115.2	112.6	108.5
United States	100.0	113.4	107.0	100.8	97.2

Appendix Table 2.D: Price Indices of Total ICT 1980=100

	1980	1985	1990	1995	2000
Austria	100.0	100.5	92.7	80.8	53.2
Denmark	100.0	104.7	98.2	80.1	62.3
Finland	100.0	116.2	120.0	101.6	77.6
France	100.0	99.2	82.5	62.0	40.4
Germany	100.0	83.6	72.9	60.3	35.8
Ireland	100.0	128.3	115.6	91.1	54.3
Italy	100.0	133.8	130.8	117.1	83.0
Netherlands	100.0	81.6	64.9	50.6	32.0
Portugal	100.0	211.7	317.7	348.0	269.0
Spain	100.0	123.3	134.0	122.9	84.0
Sweden	100.0	112.5	121.2	104.6	80.4
United Kingdom	100.0	91.5	90.4	73.5	46.8
European Union	100.0	94.9	86.1	71.6	46.5
United States	100.0	92.0	83.8	68.4	45.5

Appendix Table 2.E: Price Indices of Non-ICT Equipment
1980=100

	1980	1985	1990	1995	2000
Austria	100.0	116.1	122.7	129.8	129.3
Denmark	100.0	152.1	151.6	148.7	155.6
Finland	100.0	134.8	167.9	182.6	179.8
France	100.0	123.1	126.6	127.6	135.1
Germany	100.0	121.9	129.4	140.8	141.4
Ireland	100.0	143.4	137.5	167.2	183.6
Italy	100.0	169.8	200.2	230.1	243.4
Netherlands	100.0	117.0	121.9	121.4	121.9
Portugal	100.0	277.0	443.8	506.1	573.2
Spain	100.0	172.4	201.9	247.9	271.6
Sweden	100.0	146.4	171.9	167.8	155.1
United Kingdom	100.0	127.6	147.9	156.7	136.3
European Union	100.0	133.3	146.6	157.4	157.2
United States	100.0	123.6	146.2	165.6	181.1

Appendix Table 2.F: Price Indices of Transport Equipment
1980=100

	1980	1985	1990	1995	2000
Austria	100.0	127.9	143.7	163.8	172.7
Denmark	100.0	167.4	236.4	241.9	256.0
Finland	100.0	147.4	179.3	225.4	243.4
France	100.0	143.1	176.2	180.6	170.6
Germany	100.0	120.2	139.2	158.6	171.5
Ireland	100.0	143.4	180.8	200.8	215.2
Italy	100.0	178.9	224.2	292.6	330.0
Netherlands	100.0	124.1	137.1	147.1	153.3
Portugal	100.0	277.0	442.1	544.4	583.2
Spain	100.0	188.3	230.1	259.7	292.4
Sweden	100.0	146.4	172.1	183.7	197.7
United Kingdom	100.0	138.3	202.9	239.4	254.0
European Union	100.0	139.9	174.7	199.0	210.7
United States	100.0	128.9	144.2	172.6	177.8

Appendix Table 2.G: Price Indices of Non-Residential Structures
1980=100

	1980	1985	1990	1995	2000
Austria	100.0	122.2	140.6	162.3	178.0
Denmark	100.0	147.1	174.5	186.6	208.2
Finland	100.0	151.8	213.7	205.0	246.0
France	100.0	146.8	176.6	186.9	201.5
Germany	100.0	108.7	125.5	148.9	143.4
Ireland	100.0	149.0	192.8	225.8	326.6
Italy	100.0	194.5	265.2	336.0	379.3
Netherlands	100.0	111.7	121.2	137.3	158.1
Portugal	100.0	261.7	426.6	561.2	669.8
Spain	100.0	175.4	230.4	284.2	342.3
Sweden	100.0	139.2	200.4	204.7	242.9
United Kingdom	100.0	115.0	161.4	156.1	196.7
European Union	100.0	129.8	161.6	181.1	201.3
United States	100.0	123.6	144.1	162.5	192.0

Appendix Table 2.H: Price Indices of Total Gross Fixed Non-Residential Capita
Formation, 1980=100

	1980	1985	1990	1995	2000
Austria	100.0	118.6	129.0	140.4	139.7
Denmark	100.0	147.1	163.7	162.6	165.9
Finland	100.0	142.9	186.0	186.7	194.8
France	100.0	134.9	150.1	151.5	150.4
Germany	100.0	111.1	119.8	130.6	119.6
Ireland	100.0	141.9	161.2	180.4	204.4
Italy	100.0	175.5	214.2	250.0	255.6
Netherlands	100.0	110.1	113.1	116.3	113.6
Portugal	100.0	266.0	425.7	514.4	565.2
Spain	100.0	171.6	212.5	251.1	277.1
Sweden	100.0	140.8	176.5	173.0	169.1
United Kingdom	100.0	119.7	151.8	149.2	139.7
European Union	100.0	128.2	147.1	156.5	153.3
United States	100.0	117.6	129.6	136.0	131.7

European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

Appendix Table 3.A: Average Annual Growth Rates of Real GFCF in Office and Computer Equipment

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	24.2	12.7	11.2	32.9
Denmark	23.6	8.4	14.8	26.0
Finland	24.1	13.5	16.9	28.6
France	25.9	14.7	12.9	30.2
Germany	26.1	11.0	8.8	33.9
Ireland	22.9	-2.9	38.7	34.6
Italy	25.5	12.7	7.7	33.1
Netherlands	18.7	12.3	13.1	30.5
Portugal	25.8	10.8	10.4	31.9
Spain	27.2	21.0	1.6	30.1
Sweden	24.9	10.9	15.8	26.8
United Kingdom	26.9	17.2	13.5	30.4
European Union	25.5	13.8	10.7	31.6
United States	24.8	6.3	17.4	27.0

Appendix Table 3.B: Average Annual Growth Rates of Real GFCF in Communication equipment

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	2.6	7.6	2.6	10.0
Denmark	13.6	0.4	-0.5	8.2
Finland	8.9	3.5	25.2	26.1
France	6.9	10.1	3.9	10.2
Germany	6.1	6.8	1.9	12.0
Ireland	10.5	14.1	6.2	19.4
Italy	4.7	11.5	5.5	11.9
Netherlands	6.3	6.0	1.8	15.3
Portugal	4.2	10.4	2.7	12.2
Spain	0.7	13.4	-0.2	13.5
Sweden	7.0	-0.2	15.8	13.8
United Kingdom	7.0	4.9	15.6	10.4
European Union	5.7	8.4	4.6	11.9
United States	5.8	2.6	4.1	15.7

Appendix Table 3.C: Average Annual Growth Rates of Real GFCF in Software

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	19.2	16.4	8.1	17.8
Denmark	12.9	18.9	16.6	14.5
Finland	12.0	16.2	4.8	13.0
France	18.0	8.7	6.7	17.7
Germany	21.9	14.1	7.4	11.4
Ireland	19.5	0.2	8.4	22.3
Italy	20.4	18.6	4.2	11.4
Netherlands	7.5	16.4	4.5	19.1
Portugal	21.6	13.8	8.7	13.2
Spain	23.0	24.1	-2.3	11.1
Sweden	20.7	13.9	10.9	16.5
United Kingdom	30.9	19.7	11.5	7.7
European Union	20.6	16.0	7.6	12.3
United States	16.4	14.8	10.1	16.0

Appendix Table 3.D: Average Annual Growth Rates of Real GFCF inTotal ICT

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	9.8	10.3	5.9	17.9
Denmark	18.0	10.7	13.6	16.7
Finland	14.8	14.7	9.2	18.4
France	16.6	11.4	7.9	19.0
Germany	17.4	10.4	5.9	19.4
Ireland	19.0	4.3	21.4	27.1
Italy	14.9	13.3	5.6	16.6
Netherlands	12.4	11.6	7.4	22.3
Portugal	13.4	11.1	6.1	17.2
Spain	17.2	20.3	-0.2	18.2
Sweden	18.9	11.0	12.6	17.6
United Kingdom	23.5	16.4	12.8	17.3
European Union	17.2	12.8	7.7	18.5
United States	16.1	7.4	11.0	19.3

Appendix Table 3.E: Average Annual Growth Rates of Real GFCF in Non-ICT Equipment

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	0.7	5.6	-0.4	5.7
Denmark	5.8	3.1	1.6	7.7
Finland	5.1	5.4	-10.2	3.9
France	3.8	8.2	-1.6	2.7
Germany	-2.2	7.3	-3.1	3.9
Ireland	-6.0	4.3	-4.8	9.0
Italy	-1.9	6.3	0.7	5.6
Netherlands	4.8	3.2	0.5	5.4
Portugal	-8.6	12.9	-2.7	8.6
Spain	0.3	10.0	-2.5	8.8
Sweden	4.8	6.9	-2.0	5.5
United Kingdom	3.1	4.8	1.0	8.5
European Union	0.6	6.7	-1.3	5.5
United States	1.4	2.7	1.7	4.4

Appendix Table 3.F: Average Annual Growth Rates of Real GFCF inTransport Equipment

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	-0.4	4.8	2.0	5.8
Denmark	4.8	-1.7	4.5	6.2
Finland	-2.0	9.8	-15.2	8.0
France	-0.6	8.1	-0.7	8.1
Germany	0.0	7.8	-2.7	7.0
Ireland	-2.4	10.7	1.6	16.1
Italy	-0.5	6.0	-0.9	7.4
Netherlands	4.7	3.9	1.4	6.0
Portugal	-6.6	11.4	5.1	16.9
Spain	-5.0	13.6	0.0	8.1
Sweden	5.3	6.7	-0.5	15.8
United Kingdom	0.5	1.4	-2.5	7.0
European Union	0.0	6.2	-1.3	7.8
United States	2.8	-1.9	7.8	7.6

Appendix Table 3.G: Average Annual Growth Rates of Real GFCF in Non-Residential Structures

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	-1.8	6.2	0.0	2.0
Denmark	0.1	2.8	-2.0	4.3
Finland	2.3	3.5	-10.5	7.5
France	-1.7	7.0	-2.5	1.9
Germany	-2.4	3.1	1.9	-2.6
Ireland	-5.7	8.2	-1.3	15.0
Italy	-0.1	4.0	-4.4	3.3
Netherlands	-4.4	4.8	-1.6	5.3
Portugal	-2.3	11.9	5.9	7.3
Spain	-0.7	12.6	0.4	3.9
Sweden	-1.1	2.5	-0.8	-1.8
United Kingdom	3.4	7.6	-4.6	3.3
European Union	-1.1	5.8	-1.3	1.7
United States	2.8	-0.2	-1.0	4.3

Appendix Table 3.H: Average Annual Growth Rates of Real GFCF in Total Gross Fixed Non-Residential Capital Formation

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	0.2	6.3	0.7	5.5
Denmark	4.3	3.0	2.3	7.8
Finland	3.6	5.5	-8.5	8.0
France	1.5	7.8	-1.1	4.9
Germany	0.0	6.1	0.3	4.2
Ireland	-2.9	7.6	1.3	16.1
Italy	0.6	6.4	-0.7	6.9
Netherlands	1.1	5.3	0.8	8.8
Portugal	-4.4	12.2	2.6	10.3
Spain	0.4	13.0	-0.2	6.8
Sweden	3.3	5.7	0.4	6.5
United Kingdom	4.7	6.8	0.7	8.6
European Union	1.3	7.0	-0.1	6.3
United States	4.8	2.2	3.7	8.9

European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

Appendix Table 4.A: Share of Office and Computer Equipment in total capital compensation

	1980	1985	1990	1995	2000
Austria	1.9	1.8	2.1	2.2	1.8
Denmark	4.0	1.3	1.2	1.2	0.9
Finland	0.9	1.1	1.3	1.3	1.2
France	3.6	2.7	2.6	2.2	1.8
Germany	4.6	3.9	4.1	3.6	2.7
Ireland	2.4	4.5	3.0	2.9	3.3
Italy	1.6	3.3	3.3	2.3	1.7
Netherlands	8.3	4.4	4.4	4.2	3.7
Portugal	1.0	1.5	1.8	2.5	1.8
Spain	3.1	3.2	4.8	4.1	2.4
Sweden	1.6	1.5	2.2	2.3	2.1
United Kingdom	1.9	3.3	4.9	5.1	4.8
European Union	3.5	3.2	3.6	3.2	2.7
United States	6.3	7.2	6.8	6.5	5.0

Appendix Table 4.B: Share of Communication equipment in total capital compensation

	1980	1985	1990	1995	2000
Austria	4.3	4.4	4.7	5.3	4.6
Denmark	1.1	1.2	1.6	1.6	1.3
Finland	0.3	0.3	0.4	0.6	1.4
France	2.2	2.1	2.5	2.5	2.6
Germany	2.9	3.0	3.5	4.0	3.7
Ireland	1.3	1.7	2.9	2.9	3.8
Italy	3.2	3.6	4.7	5.0	5.4
Netherlands	2.6	2.5	3.0	3.1	3.3
Portugal	3.2	3.9	4.2	6.2	5.5
Spain	3.2	2.7	2.4	2.5	2.7
Sweden	1.0	1.1	1.2	1.5	2.3
United Kingdom	0.9	1.2	1.5	1.9	2.7
European Union	2.4	2.4	2.9	3.3	3.5
United States	4.0	5.0	5.9	6.4	6.2

Appendix Table 4.C: Share of Software in total capital compensation

	1980	1985	1990	1995	2000
Austria	0.3	0.6	0.9	1.2	1.9
Denmark	1.0	1.5	3.4	4.3	7.2
Finland	1.6	2.4	4.0	4.2	4.9
France	0.7	1.3	1.7	1.7	2.8
Germany	0.7	1.4	2.4	2.9	3.5
Ireland	0.7	1.4	1.3	0.9	1.0
Italy	0.5	1.1	2.3	2.2	2.7
Netherlands	1.9	1.7	2.5	2.9	4.5
Portugal	0.5	0.9	1.3	2.2	2.7
Spain	1.0	1.5	3.5	3.4	3.2
Sweden	1.3	2.0	4.6	5.5	10.1
United Kingdom	0.4	1.4	3.2	4.7	6.1
European Union	0.8	1.4	2.5	2.9	3.9
United States	1.6	2.7	4.3	5.5	8.1

Appendix Table 4.D: Share of total ICT in total capital compensation

	1980	1985	1990	1995	2000
Austria	6.5	6.7	7.7	8.7	8.3
Denmark	6.2	4.0	6.3	7.1	9.5
Finland	2.8	3.8	5.8	6.1	7.6
France	6.6	6.2	6.8	6.4	7.2
Germany	8.2	8.3	10.0	10.4	10.0
Ireland	4.4	7.6	7.1	6.7	8.1
Italy	5.3	8.0	10.3	9.5	9.8
Netherlands	12.8	8.5	9.8	10.1	11.5
Portugal	4.7	6.3	7.3	10.8	10.0
Spain	7.3	7.4	10.8	9.9	8.3
Sweden	4.0	4.7	8.1	9.3	14.6
United Kingdom	3.3	5.8	9.6	11.8	13.6
European Union	6.7	7.0	8.9	9.4	10.0
United States	11.9	14.9	16.9	18.4	19.3

Appendix Table 4.E: Share of Non-ICT Equipment in total capital compensation

	1980	1985	1990	1995	2000
Austria	33.3	30.8	28.6	29.5	25.8
Denmark	30.9	30.0	28.7	27.7	26.3
Finland	36.4	34.9	33.2	36.1	27.6
France	25.2	24.0	22.9	20.1	18.9
Germany	31.3	27.1	29.0	25.5	25.9
Ireland	35.4	27.5	24.9	17.6	13.4
Italy	35.6	32.4	30.9	26.4	26.7
Netherlands	18.4	15.5	17.5	17.4	16.0
Portugal	55.3	49.3	45.3	40.7	30.4
Spain	33.5	27.5	24.2	18.1	20.0
Sweden	39.3	32.6	44.1	36.7	36.5
United Kingdom	39.3	32.5	34.6	26.4	26.8
European Union	30.5	27.7	28.3	24.2	24.2
United States	28.0	26.3	25.1	25.1	22.9

Appendix Table 4.F: Share of Transport equipment in total capital compensation

	1980	1985	1990	1995	2000
Austria	9.9	7.9	8.3	8.5	8.5
Denmark	13.1	9.1	11.1	9.4	9.7
Finland	8.6	7.4	7.6	6.7	5.7
France	9.0	7.9	8.0	7.4	7.6
Germany	8.4	7.6	8.3	8.4	8.5
Ireland	21.1	15.7	15.9	14.2	16.8
Italy	9.8	9.4	9.5	7.5	9.1
Netherlands	10.4	8.7	10.2	10.1	10.4
Portugal	13.0	11.2	9.7	11.1	12.6
Spain	16.2	11.1	9.8	8.4	8.1
Sweden	5.8	4.9	6.5	5.0	7.5
United Kingdom	12.9	9.7	10.1	9.3	10.1
European Union	9.7	8.4	8.9	8.2	8.9
United States	10.2	8.6	7.8	8.5	9.8

Appendix Table 4.G: Share of Non-residential Capital in total capital compensation

	1980	1985	1990	1995	2000
Austria	50.3	54.6	55.4	53.3	57.4
Denmark	49.8	56.8	53.9	55.8	54.5
Finland	52.2	53.8	53.4	51.2	59.1
France	59.3	61.9	62.4	66.2	66.3
Germany	52.0	57.0	52.6	55.7	55.6
Ireland	39.2	49.2	52.1	61.5	61.7
Italy	49.3	50.2	49.2	56.6	54.4
Netherlands	58.4	67.3	62.5	62.4	62.1
Portugal	27.0	33.1	37.7	37.4	47.0
Spain	43.0	54.1	55.1	63.6	63.6
Sweden	50.9	57.8	41.3	49.0	41.4
United Kingdom	44.6	52.0	45.7	52.5	49.5
European Union	53.1	56.9	53.9	58.2	56.9
United States	49.9	50.2	50.2	48.0	48.0

Appendix Table 5.A: Average Annual Growth Rates of Capital Services from Office and Computer Equipment

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	21.7	17.7	11.7	25.7
Denmark	23.9	12.5	12.3	24.0
Finland	23.7	17.0	12.5	25.9
France	23.3	17.9	12.5	24.4
Germany	22.3	16.0	9.3	25.0
Ireland	25.2	4.3	21.3	34.8
Italy	25.5	14.7	7.5	25.3
Netherlands	14.4	15.0	11.7	25.6
Portugal	25.0	13.9	11.1	24.4
Spain	22.6	24.8	6.5	19.4
Sweden	21.4	17.0	11.7	23.5
United Kingdom	23.4	20.4	11.4	26.6
European Union	22.4	17.5	10.2	25.0
United States	24.4	12.1	12.3	23.5

Appendix Table 5.B: Average Annual Growth Rates of Capital Services from Communication equipment

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	4.9	5.6	5.1	6.5
Denmark	9.0	6.7	2.7	4.0
Finland	6.4	6.9	12.0	24.2
France	7.7	9.4	6.3	8.6
Germany	6.0	6.0	5.8	5.2
Ireland	10.1	11.8	7.1	17.2
Italy	6.2	8.4	7.5	9.7
Netherlands	4.3	6.6	4.1	9.4
Portugal	7.8	6.7	5.4	7.8
Spain	3.0	6.1	2.7	9.0
Sweden	6.8	3.5	6.3	14.6
United Kingdom	8.4	7.5	6.9	13.9
European Union	6.2	7.1	6.0	8.5
United States	8.7	6.0	3.6	8.9

Appendix Table 5.C: Average Annual Growth Rates of Capital Services from Software

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	17.7	17.5	10.5	16.8
Denmark	14.5	19.9	14.7	15.4
Finland	12.8	15.6	7.5	10.5
France	18.1	11.4	7.1	15.7
Germany	19.3	17.2	9.8	9.7
Ireland	21.1	4.4	4.6	16.8
Italy	19.5	20.8	5.8	9.7
Netherlands	4.6	14.8	8.8	16.1
Portugal	21.2	15.0	11.1	12.6
Spain	19.2	26.4	5.0	7.0
Sweden	17.7	18.2	10.6	15.5
United Kingdom	27.3	21.9	12.9	10.4
European Union	18.4	18.2	9.4	11.5
United States	16.1	15.1	11.9	14.8

Appendix Table 5.D: Average Annual Growth Rates of Capital Services from Total ICT

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	10.2	10.3	7.9	12.1
Denmark	16.1	15.0	11.0	14.7
Finland	15.4	15.4	9.1	14.7
France	16.7	13.8	8.9	14.9
Germany	15.5	13.4	8.6	11.7
Ireland	21.5	7.7	10.5	24.9
Italy	15.0	13.0	7.3	12.2
Netherlands	9.5	12.8	8.9	16.9
Portugal	13.6	9.8	8.3	11.8
Spain	13.5	20.4	6.4	10.5
Sweden	15.6	16.2	9.9	16.6
United Kingdom	20.1	19.2	11.2	17.4
European Union	15.6	14.7	8.8	13.9
United States	18.0	11.5	9.0	15.2

Appendix Table 5.E: Average Annual Growth Rates of Capital Services from Non-ICT Equipment

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	2.6	4.1	2.7	2.9
Denmark	2.4	4.8	2.3	4.7
Finland	3.5	5.3	-3.1	0.9
France	5.0	6.3	2.9	2.1
Germany	1.0	3.1	2.2	1.3
Ireland	2.1	0.6	0.1	3.3
Italy	1.5	3.8	2.4	3.6
Netherlands	2.3	4.7	2.3	3.8
Portugal	-0.3	2.3	1.4	3.7
Spain	1.0	5.5	1.6	5.2
Sweden	3.2	6.2	0.9	4.4
United Kingdom	1.9	3.9	2.5	5.8
European Union	2.0	4.2	2.2	3.2
United States	1.8	2.6	1.7	3.3

Appendix Table 5.F: Average Annual Growth Rates of Capital Services from Transport Equipment

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	0.0	2.7	3.1	4.0
Denmark	-0.9	1.5	1.1	4.5
Finland	0.7	4.1	-6.0	1.4
France	1.2	4.2	2.0	4.4
Germany	1.7	3.9	2.8	2.9
Ireland	2.6	3.7	1.8	12.8
Italy	3.5	3.5	0.4	4.7
Netherlands	1.3	3.4	2.3	4.1
Portugal	-0.8	3.5	5.6	11.8
Spain	-0.8	5.3	2.2	5.8
Sweden	1.8	6.2	0.5	9.9
United Kingdom	-1.2	2.0	-1.3	3.9
European Union	0.9	3.5	1.3	4.3
United States	0.5	0.9	4.2	6.4

Appendix Table 5.G: Average Annual Growth Rates of Capital Servicesfrom Non-Residential Structures

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	3.7	3.5	3.7	2.7
Denmark	2.3	3.2	1.7	2.4
Finland	4.1	3.8	1.3	1.6
France	3.3	3.6	2.9	2.0
Germany	2.7	2.5	2.5	1.6
Ireland	4.8	2.9	3.2	5.7
Italy	2.8	2.7	1.9	1.5
Netherlands	1.7	1.9	1.7	1.8
Portugal	5.9	5.6	6.5	6.7
Spain	4.0	5.2	5.2	4.0
Sweden	2.9	2.7	1.7	1.3
United Kingdom	3.1	4.0	2.8	2.1
European Union	3.0	3.2	2.7	2.1
United States	3.2	2.7	1.9	2.3

Appendix Table 5.H: Average Annual Growth Rates of Capital Services from Total Gross Fixed Capital Formation

	1980-1985	1985-1990	1990-1995	1995-2000
Austria	3.3	3.7	3.6	3.4
Denmark	2.2	3.6	2.1	3.7
Finland	3.9	4.3	0.3	2.0
France	3.5	4.1	3.0	2.7
Germany	2.5	2.9	2.7	2.3
Ireland	4.2	2.7	2.8	7.6
Italy	2.7	3.2	2.1	2.9
Netherlands	1.8	2.5	2.0	3.2
Portugal	3.1	4.5	4.9	6.8
Spain	3.4	5.6	4.5	4.6
Sweden	3.0	3.8	1.7	3.3
United Kingdom	2.6	4.2	2.8	4.4
European Union	2.8	3.6	2.8	3.1
United States	3.1	3.0	2.4	4.3

European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

Appendix 6: Absolute Contribution of ICT Capital Service Flows to Real GDP Growth, 1980-2000

	Office and Computer Equipment (%)	Commu-nication Equipment (%)	Software (%)	Total ICT (%)	Total non-ICT (%)	Total Physical Capital (%)	Real GDP Growth Rate
Austria							
1980-1985	0.12	0.07	0.02	0.21	0.99	1.20	1.12
1985-1990	0.12	0.09	0.05	0.26	1.11	1.36	3.18
1990-1995	0.09	0.09	0.04	0.22	1.12	1.34	1.96
1995-2000	0.16	0.11	0.09	0.36	0.90	1.26	2.58
Denmark							
1980-1985	0.10	0.03	0.05	0.18	0.52	0.70	1.96
1985-1990	0.05	0.03	0.15	0.23	1.09	1.32	1.31
1990-1995	0.05	0.02	0.18	0.24	0.58	0.82	2.12
1995-2000	0.09	0.02	0.32	0.44	1.04	1.48	2.84
Finland							
1980-1985	0.06	0.01	0.08	0.15	1.08	1.23	2.81
1985-1990	0.06	0.01	0.15	0.22	1.31	1.52	3.24
1990-1995	0.05	0.02	0.11	0.17	-0.03	0.14	-1.14
1995-2000	0.12	0.09	0.17	0.37	0.40	0.78	5.14
France							
1980-1985	0.17	0.04	0.05	0.26	0.98	1.24	1.49
1985-1990	0.15	0.07	0.06	0.29	1.27	1.55	3.19
1990-1995	0.10	0.05	0.04	0.20	0.98	1.18	0.97
1995-2000	0.16	0.07	0.12	0.35	0.72	1.07	2.52
Germany							
1980-1985	0.24	0.05	0.05	0.34	0.60	0.94	1.30
1985-1990	0.21	0.06	0.11	0.38	0.75	1.13	2.86
1990-1995	0.12	0.07	0.09	0.28	0.77	1.05	1.44
1995-2000	0.22	0.05	0.10	0.37	0.47	0.83	1.71
Ireland							
1980-1985	0.23	0.03	0.05	0.31	0.98	1.29	2.30
1985-1990	0.06	0.09	0.02	0.18	0.62	0.80	4.85
1990-1995	0.15	0.07	0.01	0.24	0.80	1.03	4.68
1995-2000	0.50	0.24	0.06	0.80	2.43	3.23	9.61
Italy							
1980-1985	0.17	0.05	0.04	0.26	0.66	0.93	1.53
1985-1990	0.15	0.10	0.11	0.36	0.85	1.21	2.79
1990-1995	0.07	0.11	0.05	0.23	0.58	0.82	1.20
1995-2000	0.16	0.17	0.08	0.41	0.78	1.19	1.97

Appendix 6 (continued)

	Office and Computer Equipment (%)	Commu-nication Equipment (%)	Software (%)	Total ICT (%)	Total non-ICT (%)	Total Physical Capital (%)	Real GDP Growth Rate
Netherlands							
1980-1985	0.26	0.03	0.02	0.31	0.54	0.85	1.15
1985-1990	0.26	0.07	0.11	0.44	0.84	1.28	3.21
1990-1995	0.18	0.05	0.10	0.33	0.65	0.98	2.06
1995-2000	0.37	0.10	0.21	0.68	0.77	1.45	3.73
Portugal							
1980-1985	0.08	0.07	0.04	0.19	0.50	0.70	0.88
1985-1990	0.09	0.09	0.06	0.24	1.05	1.30	5.08
1990-1995	0.08	0.09	0.07	0.23	1.35	1.58	1.75
1995-2000	0.14	0.12	0.09	0.34	1.64	1.98	3.81
Spain							
1980-1985	0.11	0.01	0.04	0.16	0.42	0.58	1.34
1985-1990	0.23	0.03	0.16	0.41	1.10	1.52	4.58
1990-1995	0.09	0.02	0.06	0.18	0.93	1.10	1.32
1995-2000	0.15	0.06	0.06	0.27	1.19	1.46	3.85
Sweden							
1980-1985	0.08	0.02	0.07	0.18	0.76	0.94	1.95
1985-1990	0.10	0.01	0.18	0.29	1.16	1.45	2.69
1990-1995	0.07	0.02	0.14	0.22	0.34	0.57	0.57
1995-2000	0.14	0.07	0.32	0.53	0.73	1.26	2.95
United Kingdom							
1980-1985	0.20	0.03	0.07	0.30	0.67	0.97	2.08
1985-1990	0.25	0.03	0.16	0.45	1.06	1.51	3.42
1990-1995	0.16	0.03	0.15	0.34	0.67	1.01	1.78
1995-2000	0.40	0.10	0.19	0.69	0.94	1.63	2.89
European Union							
1980-1985	0.20	0.04	0.05	0.29	0.70	0.99	1.55
1985-1990	0.19	0.06	0.11	0.36	0.98	1.34	3.15
1990-1995	0.11	0.06	0.09	0.25	0.75	1.01	1.39
1995-2000	0.23	0.09	0.13	0.44	0.76	1.20	2.59
United States							
1980-1985	0.46	0.11	0.10	0.66	0.61	1.27	3.14
1985-1990	0.27	0.10	0.15	0.53	0.63	1.15	3.23
1990-1995	0.22	0.06	0.18	0.46	0.49	0.96	2.42
1995-2000	0.41	0.15	0.30	0.86	0.77	1.63	4.21

European Union average is a weighted average for all member countries, excluding Belgium, Luxembourg and Greece

Appendix Table 7: %-Point Growth Contribution of ICT and non-ICT Capital and TFP to Labour Productivity Growth, 1980-2000

	Capital Deepening (Capital per Person Hour Worked)					Total Factor Prod'ty Growth	Labour Prod'ty Growth
	Office and Computer Equipment	Commu-nication Equipment	Software	Total ICT	Total non-ICT		
Austria							
1980-1985	0.12	0.06	0.02	0.20	0.78	-0.52	0.46
in % of LP growth	26	13	5	44	171	-115	100
1985-1990	0.12	0.08	0.04	0.24	0.91	1.42	2.57
in % of LP growth	5	3	2	9	35	55	100
1990-1995	0.09	0.08	0.04	0.21	1.03	0.44	1.69
in % of LP growth	5	5	2	13	61	26	100
1995-2000	0.16	0.11	0.09	0.37	1.06	1.63	3.06
in % of LP growth	5	4	3	12	35	53	100
Denmark							
1980-1985	0.10	0.03	0.05	0.18	0.48	1.25	1.91
in % of LP growth	5	1	3	9	25	65	100
1985-1990	0.05	0.03	0.15	0.23	1.05	-0.06	1.21
in % of LP growth	4	3	12	19	87	-5	100
1990-1995	0.05	0.02	0.18	0.25	0.70	1.61	2.55
in % of LP growth	2	1	7	10	27	63	100
1995-2000	0.09	0.01	0.31	0.41	0.71	0.72	1.84
in % of LP growth	5	1	17	22	39	39	100
Finland							
1980-1985	0.06	0.01	0.08	0.14	0.94	1.26	2.35
in % of LP growth	3	0	3	6	40	54	100
1985-1990	0.06	0.01	0.15	0.22	1.37	1.86	3.45
in % of LP growth	2	0	4	6	40	54	100
1990-1995	0.06	0.02	0.15	0.23	0.84	1.23	2.29
in % of LP growth	3	1	7	10	36	53	100
1995-2000	0.11	0.08	0.14	0.33	-0.22	3.18	3.29
in % of LP growth	3	2	4	10	-7	97	100
France							
1980-1985	0.18	0.05	0.05	0.29	1.47	1.59	3.35
in % of LP growth	6	2	2	9	44	47	100
1985-1990	0.15	0.07	0.06	0.27	1.04	1.14	2.45
in % of LP growth	6	3	2	11	42	47	100
1990-1995	0.11	0.06	0.04	0.21	1.11	0.06	1.38
in % of LP growth	8	4	3	15	80	5	100
1995-2000	0.15	0.06	0.11	0.32	0.33	0.70	1.35
in % of LP growth	11	5	8	24	24	52	100

Appendix Table 7 (continued)

	Capital Deepening (Capital per Person Hour Worked)					Total Factor Prod'ty Growth	Labour Prod'ty Growth
	Office and Computer Equipment	Commu-nication Equipment	Software	Total ICT	Total non-ICT		
Germany							
1980-1985	0.25	0.05	0.05	0.36	0.85	1.04	2.24
in % of LP growth	11	2	2	16	38	46	100
1985-1990	0.20	0.06	0.11	0.37	0.66	1.51	2.55
in % of LP growth	8	2	4	15	26	59	100
1990-1995	0.14	0.09	0.10	0.33	1.18	1.36	2.87
in % of LP growth	5	3	4	12	41	47	100
1995-2000	0.22	0.05	0.10	0.37	0.48	0.91	1.76
in % of LP growth	12	3	6	21	27	52	100
Ireland							
1980-1985	0.24	0.04	0.06	0.34	1.49	2.53	4.36
in % of LP growth	6	1	1	8	34	58	100
1985-1990	0.05	0.08	0.02	0.15	0.24	3.26	3.66
in % of LP growth	1	2	0	4	7	89	100
1990-1995	0.14	0.06	0.01	0.21	0.43	2.96	3.61
in % of LP growth	4	2	0	6	12	82	100
1995-2000	0.45	0.18	0.05	0.68	0.93	4.27	5.88
in % of LP growth	8	3	1	12	16	73	100
Italy							
1980-1985	0.17	0.06	0.04	0.27	0.77	0.91	1.94
in % of LP growth	9	3	2	14	39	47	100
1985-1990	0.14	0.09	0.10	0.34	0.62	1.02	1.98
in % of LP growth	7	5	5	17	32	51	100
1990-1995	0.09	0.14	0.06	0.29	1.09	1.62	3.00
in % of LP growth	3	5	2	10	36	54	100
1995-2000	0.16	0.15	0.07	0.38	0.49	0.25	1.13
in % of LP growth	14	14	7	34	44	22	100
Netherlands							
1980-1985	0.27	0.04	0.03	0.34	0.81	0.90	2.05
in % of LP growth	13	2	1	16	40	44	100
1985-1990	0.20	0.03	0.09	0.32	-0.30	-0.28	-0.25
in % of LP growth	-79	-14	-34	-127	118	110	100
1990-1995	0.17	0.04	0.09	0.30	0.30	0.43	1.03
in % of LP growth	16	3	9	29	29	42	100
1995-2000	0.32	0.06	0.16	0.55	-0.35	0.21	0.41
in % of LP growth	78	16	40	134	-86	51	100

Appendix Table 7 (continued)

	Capital Deepening (Capital per Person Hour Worked)					Total Factor Prod'ty Growth	Labour Prod'ty Growth
	Office and Computer Equipment	Commu-nication Equipment	Software	Total ICT	Total non-ICT		
Portugal							
1980-1985	0.08	0.07	0.04	0.19	0.52	0.17	0.88
in % of LP growth	9	8	4	22	58	20	100
1985-1990	0.07	0.05	0.05	0.17	0.10	1.94	2.21
in % of LP growth	3	2	2	8	5	88	100
1990-1995	0.09	0.11	0.07	0.28	1.88	1.36	3.52
in % of LP growth	3	3	2	8	53	39	100
1995-2000	0.13	0.10	0.08	0.30	1.27	0.92	2.49
in % of LP growth	5	4	3	12	51	37	100
Spain							
1980-1985	0.12	0.03	0.04	0.19	0.94	3.40	4.53
in % of LP growth	3	1	1	4	21	75	100
1985-1990	0.20	0.02	0.14	0.35	0.42	0.79	1.56
in % of LP growth	13	1	9	22	27	50	100
1990-1995	0.11	0.02	0.07	0.20	1.11	0.98	2.29
in % of LP growth	5	1	3	9	48	43	100
1995-2000	0.12	0.04	0.02	0.17	0.19	-0.14	0.22
in % of LP growth	52	16	10	78	84	-62	100
Sweden							
1980-1985	0.08	0.02	0.07	0.17	0.59	0.59	1.36
in % of LP growth	6	1	5	13	44	44	100
1985-1990	0.09	0.01	0.17	0.26	0.81	0.33	1.40
in % of LP growth	6	1	12	19	58	23	100
1990-1995	0.07	0.02	0.15	0.25	0.61	1.00	1.86
in % of LP growth	4	1	8	13	33	54	100
1995-2000	0.13	0.07	0.29	0.50	0.50	0.96	1.96
in % of LP growth	7	4	15	25	25	49	100
United Kingdom							
1980-1985	0.20	0.03	0.07	0.30	0.86	1.52	2.68
in % of LP growth	8	1	3	11	32	57	100
1985-1990	0.24	0.03	0.15	0.41	0.62	0.87	1.90
in % of LP growth	12	1	8	22	33	46	100
1990-1995	0.17	0.03	0.16	0.36	0.88	1.41	2.65
in % of LP growth	6	1	6	13	33	53	100
1995-2000	0.39	0.09	0.17	0.65	0.62	0.49	1.76
in % of LP growth	22	5	10	37	35	28	100

Appendix A. Sources on Gross Fixed Capital Formation at Current Prices

This appendix describes the construction of the series for gross fixed capital formation at current prices, which are used to estimate the capital stock and services.

Basic Sources

The starting point for our investment database is the OECD *National Accounts*. This source is preferred above national sources, as some harmonization of the estimates has taken place at the OECD. However, the OECD data have been compared with national sources (when available) to identify differences and investigate the reasons for those differences.

In the most recent OECD National Accounts, the classification of GFCF is based on the SNA93/ESA95 (henceforth called OECD new series) whereas the old series were based on SNA68/ESA79 (OECD old series). Unfortunately these classifications are not fully compatible. Most importantly, under SNA93/ESA95 the coverage of GFCF has been widened, and now includes various intangible investments, such as mineral exploration, entertainment, literary and artistic originals and, most importantly, software. These new investments are included as part of "Other products", although practices appear to differ somewhat between countries.[54] In the old system only software acquired together with hardware was recorded in GFCF, whereas software that was separately purchased or self-produced was not capitalized (and therefore included in intermediate consumption). There are some other differences between the old and new SNA system concerning the classification of investment. GFCF also includes land improvement, and military expenditures on structures and equipment (except weapons).

These changes in coverage required us to splice the new and old OECD series by applying growth rates from the old series to the first year for which the new OECD data is available. In effect we therefore assume that the widened coverage in the new SNA also has implications for the past.

The OECD makes the following asset type distinctions in its newest publications based on SNA 1993:
- Products of agriculture, forestry, fisheries and aquaculture,
- Metal products and machinery
- Transport equipment
- Housing
- Other constructions
- Other products. The latter includes, amongst other things, software, land improvement, mineral exploration, entertainment, and literary or artistic originals.

In the old publications of the OECD based on SNA 1968, the following asset types are identified
- Residential buildings
- Non-residential buildings
- Other construction
- Land improvement
- Transport equipment
- Machinery and equipment
- Breeding stocks etc.

To link the old and new data, the following concordance has been used between the old and new OECD data:

[54] Personal communication with Seppo Varjonen (OECD).

Concordance Table for Gross Fixed Capital Formation from OECD

Our categories	OECD 1993 SNA	OECD 1968 SNA
RES(a)	- Housing	- Residential buildings
NON-RES	- Other constructions - Other products (EXCL Software)	- Non-residential buildings - Other construction - Land improvement
TRANS	- Transport equipment	- Transport equipment
NON-ICT ICT (OCM) ICT (COMM)	- Metal products and machinery - Products of agriculture, forestry, fisheries and aquaculture	- Machinery and equipment - Breeding stocks etc.
SOFT	- Other products (Software part)	

(a) residential investment is not included in this study but was collected to split it off from total GFCF.

The first two columns of the concordance table show the concordance between the OECD data and our asset 7 types. Two problems occur here. First, according to the OECD data software is included in "Other products". Data on software has therefore been collected separately by us (see below) and hence these are used to "clean" the "other products" part from the OECD database, which we included with non-residential GFCF. Second, in the OECD data ICT investment is included in "metal products and machinery". Separated data on Office and Computer Machinery (OCM) and Communication Equipment (ICT COMM) were generated (see below) to split off ICT from "metal products and machinery". Hence Industrial equipment and agriculture products (NON-ICT) are calculated as a residual: NON-ICT = "metal products and machinery" + "Products of agriculture, forestry, fisheries and aquaculture"– ICT (OCM) – ICT (COMM).

Sources on ICT Investment 1980-2000

This section reports the sources on investment in Office and Computer Machinery, Communication Equipment and Software. The source description focuses on the figures for the period 1980-2000. The details for the pre-1980 estimates are described in Section 2 of the report. The estimates for total GFCF, residential and non-residential structures, equipment and other products were obtained from *OECD National Accounts*, vols. 1 and 2 (various issues since 1960)

Austria

Office and Computer Machinery

Sources: 1980-2000: Estimated series based on the I/(Q+M-E) share from the national 1995 I/O table from Statistik Austria and with production, import and export series from OECD STAN Database 2002, release 02, converted to national currency at the official Euro-exchange rate.

Communication equipment

Sources: Estimated series based on the I/(Q+M-E) share from the national 1995 I/O table from Statistik Austria and production, import and export series from OECD STAN Database 2002, converted to national currency at the official Euro-exchange rate.

Software

Sources: Official series from Statistik Austria for 1976-2000.

Denmark

Office and Computer Machinery

Sources: 1980-2000: estimated series based on I/(Q+M-E) shares from the OECD 1997 I/O Tables of 1993 and production, import and export series from the OECD STAN Database 2002, release 02.

Communication equipment

Sources: 1972-2000: estimated series based on I/(Q+M-E) shares from the national 1993 I/O table and the OECD I/O tables for 1972, 1977, 1980, 1985 and 1990 and production, import and export series from the OECD STAN Database 2002, release 02.

Software
Sources: Official series from Danmarks Statistiken for 1966-2000.

Finland
Office and Computer Machinery
Sources: 1980-2000: Estimated series based on I/(Q+M-E) shares from the OECD 1995 I/O table and production, import and export series from the OECD STAN Database 2002, release 02, converted to national currency at the official Euro-exchange rate.

Communication equipment
Sources: 1980-2000: Estimated series based on I/(Q+M-E) shares from the OECD 1995 I/O table and production, import and export series from the OECD STAN Database 2002, release 02, converted to national currency at the official Euro-exchange rate.

Software
Sources: Official series from Statistics Finland for 1975-2000.

France:
Office and Computer Machinery
Sources: 1959-2000: Official series from INSEE.

Communication equipment
Sources: 1959-2000: Official series from INSEE.

Software
Sources: 1959-2000: Official series from INSEE.

Germany
Office and Computer Machinery
Sources: Official series from German National Accounts for 1991-2000, extrapolated with series for West Germany for 1970-1991.

Communication equipment
Sources: Official series from German National Accounts for 1991-2000; 1980-1990 extrapolated with the estimated series based on I/(Q+M-E) shares from OECD 1995 I/O table and production, import and export series from the OECD STAN Database 2002, release 02, converted to national currency at the official Euro-exchange rate (1991-2000) and West German trend from the OECD STAN Database 1995 (1976-1990).

Software
Sources: 1991-1999: Estimation based on average ratio of software to intangible investment for France, Finland Italy and UK, applied to intangible investment from German Statistical Office; extrapolated with ratio of software to office and computer equipment for other countries to investment in office and computer equipment for 1980-90 and 2000.

Ireland
Office and Computer Machinery
Sources: 1980-2000 Estimated series based on I/(Q+M-E) shares from CSO National tables of 1985 and 1990 and production and import series from the Industrial Census of Production from CSO, converted to national currency with the official Euro-exchange rate.

Communication equipment
Sources: 1980-2000: Estimated series based on I/(Q+M-E) shares from CSO National tables of 1985 and 1990 and production, import and export series from the Industrial Census of Production, converted to national currency at official Euro-exchange rate.

Software
Sources: Official series from CSO for 1990-2000, extrapolated application of ratio of software to office and computer equipment for other countries to investment in office and computer equipment for 1981-89.

Italy
Office and Computer Machinery
Sources: 1982-2000: series from *Istat Contabilità nazionale*; 1980-1981 extrapolated with estimated series based on I/(Q+M-E) shares from the OECD 1985 I/O table and production, import and export series from the OECD STAN Database 2002, release 02, converted to national currency at official Euro-exchange rate, (1990-2000) and OECD STAN Database 1995 (1980-1990).

Communication equipment
Sources: 1982-2000: series from *Istat Contabilità nazionale*; 1980-1981extrapolated with estimated series based on I/(Q+M-E) shares from the OECD 1985 I/O table and production, import and export series from the OECD STAN Database 2002, release 02, converted to national currency at official Euro-exchange rate (1990-2000) and OECD STAN Database 1995 (1980-1990).

Software
Sources: 1982-2000: series from *Istat Contabilità nazionale*, extrapolated with application of ratio of software to office and computer equipment for other countries to investment in office and computer equipment for 1980-1981.

Netherlands
Office and Computer Machinery
Sources: Official series for 1995-2000; 1977-1995 extrapolated with an investment series in computer equipment from ECB (2001); 1972-1977: extrapolated with estimated series based on I/(Q+M-E) shares from the OECD 1972 and 1977 I/O tables and production, import and export series from the OECD STAN Database 2002, release 02, converted to national currency at official Euro-exchange rate, (1976-1977) and OECD STAN Database 1995 (1972-1976).

Communication equipment
Sources: Estimates from ECB (2001). 2000 is estimated with the share of C in Total equipment of 1999.

Software
Sources: Official series for 1995-2000, extrapolated with series from OECD document for 1986-1994, and with ECB (2001) estimates for 1977-1985.
Notes: 1960-1976: extrapolated with extension method (see 2.4).

Portugal
Office and Computer Machinery
Sources: 1980-1994: Estimated series based on I/(Q+M-E) shares from the EUROSTAT 1995 I/O table and production, import and export series from the *OECD STAN Database for industrial analysis 1976-1995 (1997)*. 1995-2000: derived from total equipment with average shares of 1993 and 1994.

Communication equipment
Sources: 1980-94: Estimated series based on I/(Q+M-E) shares from the EUROSTAT 1995 I/O table and production, import and export series from the *OECD STAN Database for industrial analysis 1976-1995 (1997)*. 1995-2000: derived from total equipment with average shares of 1993 and 1994.

Software
Sources: 1980-94 estimated with application of ratio of software to office and computer equipment for other countries to investment in office and computer equipment, 1995-98 interpolation of 1994 and 1999 estimates.
Notes: 1960-1976: extrapolated with extension method (see 2.4). 2000 is estimated with the share of software in Total equipment of 1999.

Spain

Office and Computer Machinery

Sources: 1980-1997: Contabilidad Nacional de España; 1997-1999 extrapolated with estimated series based on I/(Q+M-E) shares from the OECD 1995 I/O tables and production, import and export series from the OECD STAN Database 2002, release 02, converted to national currency at official Euro-exchange rate. 2000 derived from total equipment with average shares of 1998 and 1999.

Communication equipment

Sources: 1980-1999: Estimated series based on I/(Q+M-E) shares from the National I/O tables of 1991-1994 and the OECD 1995 I/O table and production, import and export series from the OECD STAN Database 2002, release 02, converted to national currency at official Euro-exchange rate. 2000 derived from total equipment with average shares of 1998 and 1999.

Software

Sources: estimated by application of ratio of software to office and computer equipment for other countries to investment in office and computer equipment (see text) for 1980-1999. 2000 derived from total equipment with shares of 1998 and 1999.

Sweden

Office and Computer Machinery

Sources: estimated series based on I/(Q+M-E) shares from the EUROSTAT 1995 I/O table and production, import and export series from the OECD STAN Database 2002, release 02. 1999 and 2000 are estimated with the share of IT in Total equipment of 1997 and 1998.

Communication equipment

Sources: 1980-1998: Estimated series based on I/(Q+M-E) shares from the EUROSTAT 1995 I/O table and production, import and export series from the OECD STAN Database 2002, release 02. 1999 and 2000 are estimated with the share of C in Total equipment of 1997 and 1998.

Software

Sources: 1993-2000: SCB National Accounts, extrapolated by application of ratio of software to office and computer equipment for other countries to investment in office and computer equipment for 1980-1992.

UK

Office and Computer Machinery

Sources: Official series for 1974, 1979, 1984 and 1989-1999, linearly interpolated for the missing years in between; 1972-1974 extrapolated with estimated series based on I/(Q+M-E) shares from the OECD 1968 and 1979 I/O tables and production, import and export series from the OECD STAN Database 1995. 2000 is estimated with the shares of IT in Total equipment of 1998 and 1999.

Communication equipment

Sources: 1959-1999: Estimates from O'Mahony. 2000 is estimated with the shares of C in Total equipment of 1998 and 1999.

Software

Sources: Estimates from O'Mahony. 2000 is estimated with the share of software in Total equipment of 1999.

USA

Office and Computer Machinery

Sources: 1947-1999: Bureau of Economic Analysis (BEA), October 2001; 2000 from Bureau of Economic Analysis (BEA), August 2002 (update).

Communication equipment

Sources: 1947-2000: Bureau of Economic Analysis (BEA), October 2001.

Software
Sources: 1947-1999: Bureau of Economic Analysis (BEA), October 2001; 2000 from Bureau of Economic Analysis (BEA), August 2002.
Notes:

Appendix B. The Contribution of ICT Production to TFP Growth

For the purpose of this study we consider TFP growth in two of the three ICT industries used in our analysis above, namely Computer and office equipment (ISIC 30) and Communications equipment (ISIC 322). Due to a lack of data in most European countries we exclude the TFP contribution of software production.[55] In addition we also consider the independent contribution of the Electronic components and accessories industries (ISIC 321). This industry mainly produces intermediate inputs (semi-conductors) for the computer and communication equipment industries.[56] As a large part of intermediate semiconductor input into industries 30 and 322 in Europe is being imported, separate measurement of the production of the semi-conductor industry is crucial for a correct assessment of the contribution of ICT production in Europe.

The contribution of ICT producing industries is calculated in two steps. First, we derive TFP estimates for these industries for the U.S. from a detailed study by Jorgenson, Ho and Stiroh (2002) We assume that the TFP growth rates for these three industries in the U.S. also hold true for the European countries. As a second step we use Domar final output weights to obtain the contribution of each industry to aggregate TFP growth. These Domar weights are country specific and based on a combination of national accounts (from which we obtain gross output for industries 30 and 32), production statistics (to break out the contributions of industries 321 and 322) and input-output tables (to adjust gross output to final output, i.e., gross output excluding intermediate input deliveries within each industry). The two steps are explained in further detail below.

Productivity in US ICT producing industries

To date there are various estimates of productivity growth in US ICT producing industries. They differ in the growth accounting approach used (primal versus dual or price approach), the specific deflators used and in the weights of intermediate inputs, in particular semi-conductor input. The primal approach hasd been used by Jorgenson, Ho and Stiroh (2002) and the Bureau of Labour Statistics (Kask and Sieber, 2002), and has been expla ined in the main text. The dual approach has been used by the others, in particular Oliner and Sichel (2002).

In the price dual approach to growth accounting, the rate of productivity growth in each industry *j* (DA_j) is measured as the decline in the pric e of output, plus a weighted average of the growth rates of input prices with value shares of the inputs as weights (see e.g. Triplett 1996, Jorgenson 2001, and Oliner and Sichel 2002):

$$\Delta A_j = -\Delta P_{jY} + \bar{v}_{jl}\Delta P_{jl} + \bar{v}_{jk}\Delta P_{jk} + \bar{v}_{ji}\Delta P_{ji} \qquad \text{(B.1)}$$

where DP_{jY} stands for the price change of output in industry j, DP_{jl}, DP_{jk}, and DP_{ji} for the price change in labour, capital and intermediate inputs in industry j respectively, and v_{jl} , v_{jk} and v_{ji} denoting the input shares in gross value of output in each industry, with the hat representing averaging over periods t and t-1. The factor A_j, which represents industry productivity is conceptually analogous to the TFP concepts used above.[57]

The difference in results between the various studies are given in the top panel of Table B.1. An important outcome is that semiconductor productivity growth is much higher according to the O&S

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[55] Although TFP growth in the software industry is only small, its contribution can be significant as its production share is large. In the US its contribution is similar to that of communication equipment (Jorgenson 2001, Table 7).

[56] Alternatively, one can consider the combined contribution of these three industries as in Jorgenson (2001) and use only output prices of computer and communication equipment. The assumption is then that all domestically produced semi-conductors are used in these two industries only, and that the net imports of semi-conductors is negligible.This makes estimation easier as it abstains from measuring semi-conductor price declines and the problems in estimating the input share of semi-conductors in using industries (see Triplett 1996, Oliner and Sichel 2000 on this issue), but the assumption on zero net imports cannot be maintained in the case of Europe.

[57] Following Jorgenson and Stiroh (2000), we refer to this term as *industry productivity* to distinguish it from TFP, which is estimated from a value-added concept of output and based on factor inputs only.

study. Although the JHS study and the BLS study uses the primal approach while O&S study applies the dual approach, the main reason for the different TFP growth rate in semiconductors is that the price index of O&S, which is developed internally at the Federal Reserve Board, shows a much faster decline than the price index used in the BLS estimates. Consequently growth in the computer hardware and communication industry, which are the biggest users of semi-conductors, is lower than according to the BLS study.

As a check, we also calculated our own estimates of U.S. TFP growth in these industries using the price or "dual" approach to productivity measurement. For the computer industry (ISIC 30), the expression for industry productivity is dominated by two terms, namely the decline in the price of output of computers and the contribution of the decline in the price of intermediate (semi-conductor) input. The latter depends on the share and the actual price decline of semi-conductor inputs. The same holds true for communication equipment (ISIC 322). For the electronic component industry (ISIC 322), the expression is dominated by the decline in the output price of semi-conductors. Output and input prices for these industries were derived from PPIs from the BEA combined with input-output tables from the BLS. The change in the price of labour and capital services is approximated by the overall price change in gross domestic income.[58]

In the bottom panel of Table 1 we present our TFP estimates. We provide two alternatives to indicate the sensitivity of the results with respect to assumptions on the input structure of the ICT industries, in particular the share of semi-conductor input in total inputs. Triplett (1996) argues that the share of semi-conductors in total inputs of the computer industry as given in the manufacturing census (15%) is too low and shows alternative estimates of 30 and 45 %. Oliner and Sichel (2002, Table 3) use the 30% share in their calculations without further motivation. This assumption of a relatively high semi-conductor input share drives down productivity growth in computers production.

The problem to decide on the right semi-conductor input share is that there are no good estimates of the share of other electronic components which show a similar rapid price decline as semi-conductors. As an alternative we used the 1992 U.S. input-output table from BEA, which is the latest IO-table with sufficient detail on the input structure of the computer industry. According to this table the share of semi-conductors is about 11%. However, when the concept of semi-conductors is extended to include also other inputs from industry electronic components (SIC 367), namely "other electronic components" and "printed circuit boards", the share goes up to 36-39% which is close to the assumption of O&S. Unfortunately it is not clear whether the rapidly falling semi-conductor output price index is also applicable to these other categories. Implicitly O&S assume this is the case for the computer industry, but for the communication equipment industry they do not maintain this assumption as the semi-conductor input share in that industry is estimated to increase from only 5 to 9 % over the 1990s (Oliner and Sichel 2002, Table 3). The 1992 BEA tables shows an input share of 13% of semi-conductors proper and a staggering 47% of all electronic components in the communications equipment industries. The difference in TFP estimates for 30 and 322 using these extreme assumptions are given in Table B.1.

For our estimate of TFP growth in the ICT productivity industries we opted for the Jorgenson, Ho and Stiroh (2002) estimates as they appear to reflect the most up-to-date data in concordance with the NIPA. However, we stress the need for further research on the correct share of semi-conductors in inputs. From all estimates it is clear that TFP growth in the computer and semi-conductor industry was very high, and accelerating in the second half of the 1990s. In the communication equipment

[58] Here we follow Jorgenson (2001). The use of the GDP deflator as proxy for capital and labour input in each individual industry may introduce a bias in the TFP estimates for the ICT producing industries. When the share of computer equipment and software, which are capital inputs in these industries is much higher than on average, TFP growth in the ICT industries is overstated. Similarly, the price of capital in these industries might have gone down much faster due to declining rates of return on capital triggered by declining global demand and heightened competition in the aftermath of the Asian crisis in 1997-98. However, data on profits from the world's largest semiconductor producer, Intel, does not confirm that pattern (see Oliner and Sichel 2000, footnote 19)

producing sector TFP growth was relatively slow, but this might be due to a lack of suitable quality adjusted deflators for communication equipment.

Table B.1: Alternative estimates of multifactor productivity in ICT producing sectors, US

	1990-95 assumed shares of semi-conductors	1995-00 Assumed shares of semi-conductors	1990-95 TFP growth	1995-00 TFP growth
Jorgenson, Ho and Stiroh (2002)				
SIC 357 Computer and office equipment	n.a.	n.a.	11.9	16.8
SIC 366 Communications equipment	n.a.	n.a.	3.2	-0.4
SIC 367 Electronic components and accessories	n.a.	n.a.	10.6	18.0
Oliner and Sichel (2002) 1 (a)				
computer hardware	30.0	30.0	11.4	14.0
Communication equipment	4.5	8.9	3.3	2.2
semi conductors	-	-	22.0	45.1
BLS Productivity database(b)				
SIC 357 Computer and office equipment	n.a.	n.a.	14.9	27.9
SIC 366 Communications equipment	n.a.	n.a.	5.4	5.3
SIC 367 Electronic components and accessories	n.a.	n.a.	16.3	20.3
Our estimate using semi-conductor price index for inputs of semi-conductors proper				
ISIC 30 Computer and office equipment	11.3	12.2	13.1	20.2
ISIC 322 Communications equipment	12.8	13.9	1.3	0.9
ISIC 321 Electronic components and accessories	-	-	11.2	22.2
Our estimate using semi-conductor price index for input of all electronic components				
ISIC 30 Computer and office equipment	36.0	38.7	10.0	14.8
ISIC 322 Communications equipment	47.4	51.4	-1.4	-4.1
ISIC 321 Electronic components and accessories	-	-	10.8	21.3

(a) Data refers to period 1991-95 instead 1990-95 and 1995-01 instead 1995-00.
(b) Data refers to period 1995-99 instead 1995-00.
Source: Oliner and Sichel derived from Oliner and Sichel (2002) Table 1 and Table 3. BLS estimates based on primal approach. Taken from BLS productivity database at 9 aug 2002 at ftp://ftp.bls.gov/pub/special.requests/opt/dipts/indmfp.txt. Own estimates based on BEA gross output price indices and BLS input-output tables.

Domar weights

For weighting the industries' TFP growth a Domar weighting scheme is used. Domar (1961) showed that aggregate TFP can be expressed as a weighted average of industry productivity growth using industry gross output-GDP ratios as weights:[59]

$$\dot{A}_{GDP} = \sum_i \overline{w}_i \dot{A}_i$$

with $\overline{w}_i = \frac{1}{2}\left(\frac{GVO_{i,t}}{GDP_t} + \frac{GVO_{i,t-1}}{GDP_{t-1}}\right)$ and GVO the value of gross final output of industry i (which excludes intra-industry flows), A_i industry *i*'s productivity growth and A_{GDP} aggregate total factor productivity growth. Domar weights have the notable feature that they do not sum to unity. This reflects the different output concepts used at the aggregate and industry levels, i.e. final output and

[59] See Jorgenson, Gollop and Fraumeni (1987) for a more general statement of the Domar aggregation scheme.

value added respectively. At the aggregate level, only primary inputs (labour and capital) are considered, whereas both primary and intermediate inputs are included in the industry production functions. For the typical industry, gross output considerably exceeds value added, and therefore the sum of gross output across industries exceeds the sum of value added.[60]

Final output series, which represent gross output minus intermediate deliveries within the same industry, are not readily available for either the US or the European countries. Basically, there are two alternatives to obtain final output. The first is to collect data on final and intermediate demand categories for the domestically produced output in these industries. This method has been used by Oliner and Sichel (2002) but data requirements are very high as illustrated in their source description (appendix 2). Alternatively, gross output series, which are readily available from manufacturing census and survey material, can be adjusted for intra-industry deliveries using the share of intra-industry intermediate deliveries in industry gross output from input-output tables (see for full description of derivation of the series on gross final output in 30, 321 and 322 below).

Table 21 shows the Domar weights that we computed for each individual country. It is clear that these weights are somewhat higher for the United States than for the European Union, reflecting the large share of computers and communication equipment in industry output. However, within the European Union some large difference can be observed. The estimates for Ireland need some qualifications. The production shares in Ireland are strikingly high. Here we faced a measurement problem, as the Irish production statistics do not match data from the IO-table, which in turn does not show enough detail to separate 321 and 322 and to single out re-exports of especially computers. By weighting the TFP growth rates in each industry by its Domar weight, the contribution of ICT production to aggregate TFP growth can be calculated (see Table 20).

The estimates of the contribution of the ICT producing sector in the EU must be seen as a first rough indication of the differences relative to the United States, and further research is necessary. Firstly, software has been excluded in our study due to a lack of production data in the EU. O&S show that the contribution of software production is comparable to the contribution of communication equipment in the US, but in Jorgenson, Ho and Stiroh (2002) it was much smaller and even negative in the period 1977-1995. Secondly, obviously what is needed is country specific TFP estimates for ICT producing industries in European countries. For example, the input and output structure of the communication equipment industry in Sweden and Finland is quite different from that in the US leading to different aggregate input deflators, and as a result, different TFP growth rates. In countries like Ireland, where much of the ICT production represents assembly work, TFP growth rates from the U.S., which is characterized by a fully integrated computer industry, may not be correct. Finally, in come cases the production shares of ICT industries need further consideration, such as for Ireland.

Sources used for TFP decomposition

All countries, except Portugal, Ireland, Sweden and Austria:
Final output (which is gross output excluding intra-industry deliveries) in industries 30 and 32 for a recent benchmark year from input-output tables (from OECD, *New Input-output database*) extrapolated with annual gross output series from OECD, *STAN NEW database*. Portugal, Ireland, Sweden and Austria lack an input-output table with sufficient industry detail and hence annual gross output series from OECD, *STAN NEW database* are used, adjusted for intra-industry deliveries insofar possible. Industries 321 and 322 derived by splitting up the estimate of final output of 32 on the basis of shares in gross output from OECD, *Structural Statistics for Industry and Services* for all countries except the Netherlands which is based on Eurostat, *Panorama of European Business*. (NB hence assuming that the final output - gross output ratio is constant for all sub-industries in industry 32).

[60] This weighting methodology implies that economy-wide TFP growth can grow faster than productivity in any industry, since productivity gains are magnified as they work their way through the production process.

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