# How much does IT Consumption matter for Growth? Evidence from National Accounts

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**Abstract**

An international comparison on the adoption of Information Technologies by households is carried out in this paper by employing a growth accounting approach. It is shown that home computers contributed to the recent output growth of the EU and the US more than some kinds of high-tech investment (communication equipment and software). This finding suggests that the literature on new economy has thus far left unexplored a sizeable part of IT-led growth.
Whereas the major continental countries in Europe exhibit a scarce propensity to adopt home computers, Denmark and the UK stand out for a large growth contribution of IT consumption, even superior to the US. Overall, the divergence between the EU and the US in the dynamic pattern of output growth is found to be widely dependent on a different application of ICT both for production and consumption aims.

**Keywords**: ICT, Consumption, Growth.
**JEL**: E21, E22, O47.

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# 1 Introduction

The policy agenda of the European Union has focused from the Lisbon Conference of 2000 on the construction of an information society. As part of a broader strategy to increase competitiveness, the EU leaders set of stimulating the spread of Information Technology across firms and households as a key operative goal to lead Europe towards a high growth track similar to the US one[1].

So far relatively little is known about the home possession of ICT goods and its effects on growth; by contrast, much has been said on the impact of the ICT uptake on the supply-side, being a topic of the literature on productivity from at least three decades.

At the economy-wide level, Information Technology is broadly acknowledged as the driving force behind the recent recovery in US labour productivity. The growth contribution of such technologies outside the United States has been smaller due to either a lesser degree of adoption or a minor specialization in the production of ICT goods.
Similarly to the US, Korea as well as Ireland and Finland are usually referred to as countries where the brilliant performance of the last years has foundation in a comparative advantage in ICT production[2]. Australia is instead indicated as a model where the disadvantage of the hi-tech de-specialization has been mitigated by a strong uptake of ICT. This was stimulated by the wide range of pro-competitive policies adopted during the 1990s. In Europe the contribution of IT capital to labour productivity growth is comparable to the United States only in Sweden and Ireland.
Aside from these notorious exceptions, the production and usage of new technologies in the EU are sensibly lower than in the US, especially across the major continental countries. The difference in ICT capital deepening and TFP growth in IT producing industries is found to entirely account for the EU-US gap in labour productivity growth of 1995-2001 (Timmer *et al.* (2003)).

At an industry level, the output-labour ratio in Europe is sluggish across non-ICT producing sectors as well (O'Mahony and van Ark (2003)). The delay is more significant in IT intensive using services which have driven the

[1] "*An information society for all.* The shift to a digital, knowledge-based economy, prompted by new goods and services, will be a powerful engine for growth, competitiveness and jobs. In addition, it will be capable of improving citizens' quality of life and the environment." Lisbon European Council, March 2000, Presidency Conclusions, par. 8; http://ue.eu.int/ueDocs/cms Data/docs/pressData/en/ec/00100-r1.en0.htm.

[2] See Pilat and Wolfl (2004) for an exhaustive description of the role played by ICT production and usage in aggregate productivity growth of OECD countries.

resurgence on the other Atlantic side (retail, wholesale and securities; van Ark *et al.* (2002a)).
The inner reason why the European countries have not been able to catch (or as much as the US) the growth opportunity supplied by the development of ICT may be identified in an institutional environment less favorable to the uptake of such technologies. The excessive markets regulation may have prevented IT investment from materializing in productivity gains. Few start-ups endowed with an IT-tailored business plan were able to enter the market (Bassanini and Scarpetta (2002)); on the other hand, business reorganizations took a long time as facing a strong opposition (Gordon (2004)). Both the wider commitment in R&D activities and the major competitiveness of markets reveal that in the United States there is an environment more prone to risk and experiment. This encourages the introduction of complementary innovations which enhance the return of ICT capital (co-invention; see Pilat (2004)).
Nevertheless, it is also argued that the ultimate source of Europe's productivity slowdown may be deeper and not strictly dependent on a delayed IT usage (Daveri (2004)); moreover, the main disease of the community economy seems to reside, rather, in the diffused weakness of non-durable manufacturing[3]. Indirectly, a confirmation of such explanation for the divergent growth pattern exhibited by the EU and the US comes from Timmer *et al.* (2003). By contrasting the inputs contribution to labour productivity growth between 1980-95 and 1995-2001, they find that the European slowdown is primarily determined by a slower traditional capital deepening and the fall in TFP growth of non-ICT manufacturing industries.

The literature on Information Technology and productivity growth at a firm level is rather rich (see for instance Dedrick *et al.* (2003) and Pilat (2004)). A lot of attention has been also deserved to the effects produced by the uptake of ICT on workers' attainment (wages, occupation, etc.) because of the skill-bias induced by the evolution of technical change[4]. However, this body of research examines exclusively the impact of computer introduction in the workplace.
Only more recently, the consolidation of the surveys on households' budgets at national statistical agencies has provided a mass of information on the home adoption of PCs and the main aspects affecting this choice (income, gender, education, etc.). For instance, Goolsbee and Klenox (2002) investigate on the environmental factors influencing the computer purchase: they

[3]An analysis focused on the sources of the Italian slowdown is carried out by Venturini (2004b).

[4]Acemoglu (2002) provides a very detailed survey on this topic.

find that the proximity of intensive users enhances the probability of buying a PC. Miniaci and Paradisi (2004) analyze instead the peers' effects on computer ability while Schmitt and Wadsworth (2004) examine how the domestic use of PCs affects the educational outcomes of British teenagers. Kawaguchi (2004) finds no effects of home possession of computer on labour market outcomes (employment, wages, etc.), suggesting that IT consumption may be a good opportunity to acquire skills only for marginal workers; however, such finding may be influenced by the short time span of the data employed.
All these studies share the belief that the home adoption of computers may virtually improve the individual ability, similarly to the usage on the workplace. High-tech consumption may then be a source of skill-enrichment, surely more than the traditional consuming activities.
Moreover, there is another reason at the basis of interest for households' propensity towards Information Technology.[5] Services industries firms can effectively take advantage of the introduction of new business practices (e-commerce, e-government, etc.) only in presence of a diffused familiarity with computers and the Internet on the demand side. In absence of a such propensity, the growth potential of ICT might remain partially unexploited. In this respect, IT consumption may influence the efficiency of the economic activity as well as the usage of IT equipment by firms. This explains the strong commitment of community authorities in raising the IT literacy and the connectivity of European citizens.[6]

This paper aims at shedding a first light on this nearly unexplored side of the new economy. It presents an international comparison on the growth contribution of IT consumption, by extending to a wide group of EU countries a growth accounting approach formerly adopted only for the US (Jorgenson and Stiroh (2000)). Therefore, the work is able to draw more in detail than in the past the European delay relative to the US in the digitalization process of the economy. Clearly, the framework employed does not allow to describe all the growth effects of ICT such as spillovers which, instead, requires an econometric investigation. Nevertheless, this paper is to interpret as a preliminary step towards that direction.

[5]It is also important to remind a statistical measurement problem related to IT consumption. The widespread adoption of home desktops (and notebooks) has increased the amount of hours worked outside the workplace which, consequently, are not picked up by official statistics. This implies that the labour contribution to growth may be underestimated and a fraction of output is erroneously attributed to the residual efficiency. This aspect is also discussed in Gordon (2004).

[6]For instance, see the section 5 of the opening address by the President of the European Commission to the conference on 'The e-Economy in Europe: its potential impact on EU enterprises and policies', Brussels, 1st March 2001; http://europa.eu.int/comm/stockholm council/speech1 en.htm.

The remainder is organized as follows. Section 2 describes the growth accounting methodology and data sources. The benchmark is the extended version of the production possibility frontier where consumer durables are treated as investment goods. Section 3 displays the results for the European Union and the United States; it shows that the uptake of home computer is diffusely sizeable in Europe with the notable exception of the major continental states. Nevertheless, the UK and Denmark are the sole countries with a contribution to the output growth from IT consumption close -and *even* larger- to the US. The comparison on the sources of the output growth between 1981-95 and 1995-2001 reveals, then, that the different application of ICT -both for production and consuming aims- entirely accounts for the diverging pace of development recently showed by the two Atlantic regions. Finally, section 4 concludes outlining a possible track for a future regression analysis.

# 2 Methodology and Data Description

## 2.1 Production possibility frontier

This growth accounting analysis relies upon the production possibility frontier approach originally introduced by Jorgenson (1966); it decomposes aggregate output into final purchases (consumption and investment goods; *output side*) and factor inputs utilized (capital and labour services; *input side*):

$$Y(C_t, I_t) = A_t f(K_t, L_t). \tag{1}$$

$A_t$ is the Hicks-neutral index of productivity; it measures the rise in output over the share-weighted growth of factor inputs (total factory productivity) and changes over time in response to (disembodied) technological change, economic shocks and managerial choices[7].

This work adopts the extended version of eq. (1), recently employed by Jorgenson and Stiroh (2000) and Jorgenson (2004). It is based on a concept of output broader than GDP, including a flow of services attributable to consumer durables. Such imputation guarantees a consistent treatment between (owner-occupied) residential buildings and (owner-utilized) consumer

[7]The US resurgence has greatly renewed the interest of researchers for total factory productivity. See Hulten (2000) for a description of the main features of such index while Stiroh (2002) for the interpretative problems due to the hypotheses at the basis of the method of computation. A brief survey of the dispute on the way to formulate the impact of technical change on growth (*embodiment controversy*) is provided by Venturini (2004a); with regard to this, Limpsey and Carlaw (2004) have recently raised the possibility that technical change and TFP may be uncorrelated.

durables. In National Accounts whereas dwellings are treated as investment goods and their annual rental is registered as consumption expenditure (and, at the same time, as capital income -imputed rentals), a similar procedure is not followed for consumer durable goods.
The extended version of eq. (1) fills this gap by including a flow of services for this kind of products, estimated through an user cost[8] (time sub-scripts are omitted to simplify notation):

$$Y(Y_{nICT}, C_{IT}, I_{ICT}, D_{IT}) = A\ f(H, K_{ICT}, K_{nICT}, D_{IT}, D_{nIT}).$$

The output side comprises households' purchases of computers ($C_{IT}$), firms' investment in IT equipment, communication and software ($I_{ICT}$) along with the flow of services provided by IT goods owned by consumers ($D_{IT}$). Residually, $Y_{nICT}$ collects any non-ICT output (consumption or investment goods) and the services of non-IT consumer durables ($D_{nIT}$).
The inputs side analysis offers a decomposition of output growth into the contribution of the services of ICT and non-ICT capital ($K_{ICT}$ and $K_{nICT}$) and consumer durables ($D_{IT}$ and $D_{nIT}$). Because of the lack of data, hours worked ($H$) are used in place of labour services; hence, the contribution of labour quality is included into the residual TFP (Jorgenson and Griliches (1967)).
If one hypothesizes perfectly competitive markets, goods are priced to their marginal costs and factor inputs remunerated at the value of marginal product. Therefore, output elasticities coincide with the income shares and sum to unity under the additional assumption of constant returns to scale ($\Sigma_i \omega_i = \Sigma_i \nu_i = 1$). Thus, the time log-differentiated version of the previous expression can be expressed as follows:

$$\begin{aligned}\bar{\omega}_{Y,nICT}\Delta \ln Y_{nICT} + \bar{\omega}_{C,IT}\Delta \ln C_{IT} + \bar{\omega}_{I,ICT}\Delta \ln I_{ICT} + \bar{\omega}_{D,IT}\Delta \ln D_{IT} = \\ = \bar{\nu}_H \Delta \ln H + \bar{\nu}_{K,ICT}\Delta \ln K_{ICT} + \bar{\nu}_{K,nICT}\Delta \ln K_{nICT} + \\ + \bar{\nu}_{D,IT}\Delta \ln D_{IT} + \bar{\nu}_{D,nIT}\Delta \ln D_{nIT} + \Delta \ln A. \qquad (2)\end{aligned}$$

[8] See Christensen *et al.* (1981), p. 72. The debate on the need to treat consumer durables as investment goods dates back to the seminal paper of Christensen and Jorgenson (1970). Recently, it has been revived by the rise of motor vehicles and IT goods in households' expenditure.
Fraumeni and Okubo (2001) propose to capitalize the services of motor vehicles through the fees paid to lease a car. They assume that leased and purchased cars are perfect substitute.
In order to calculate the services of consumer durables, Katz and Peskin (1980) propose a method alternative either to the *observed market rent* (Fraumeni and Okubo's one) or to the traditional *rental price* (used in this work): they build an user cost that includes the operative expenses to manage consumer durables (*opportunity cost measure*).

Table 1. **Expenditure variables and depreciation rates of stocks**

| **INVESTMENT GOODS** | | **CONSUMER DURABLES** | | |
|---|---|---|---|---|
| | **Depreciation Rate** | | **Depreciation Rate** | **COICOP categories** |
| IT equipment | variable | Furniture and furnishings | 0,1169 | 5.1 |
| Communication equipment | 0,1150 | Household appliances | 0,1500 | 5.3 |
| Non-IT equipment | 0,1320 | Other home furnishings | 0,1650 | 5.2 plus 5.5 |
| Transport equipment | 0,1910 | Vehicles | 0,2550 | 7.1 |
| Non-residential structures | 0,0280 | Audio-visual and photographic eq. | 0,1833 | 9.1 less 9.1.3 |
| Software | 0,3150 | Information processing equipment | 0,3150 | 9.1.3 |
| Residential Buildings | 0,0120 | Other major durables for | 0,1650 | 9.2 |
| Inventories | 0,0000 | recreation and culture | | |

Notes: Depreciations rates are taken from Timmer *et al.* (2003) for non-residential investment goods, from Oulton (2001) for residential buildings and Jorgenson and Stiroh (2000) for inventories and consumer durables.

$\bar{\omega}_i$ and $\bar{\nu}_i$ denote two-years means of the income shares; they derive from the Tornqvist's formula adopted in this work for volume and price indexes.

## 2.2 Data Characteristics

The analysis employs various sources of National Accounts. Data on investment and hours worked have been extracted from GGDC Total Economy Growth Accounting database[9].
It distinguishes between three kinds of non-ICT capital goods (non-IT equipment, transport equipment and non-residential structures) and three kinds of ICT capital (IT equipment, communication equipment and software). The former series mainly stem from OECD National Accounts; the latter come from national sources or, when missing, are estimated through the 'commodity flow' method. This technique consists in applying an expenditure coefficient extrapolated from OECD input-output tables to the final domestic sales of Office machinery and computer industry (cat. 30 ISIC Rev. 3, OECD STAN database).

In order to preserve the comparability among 'investment goods' of households (buildings and consumer durables), a measure of the dwellings stock has been built from the value of housing reported in OECD National Accounts. As in Jorgenson and Stiroh (2000), inventories have been also included while, by contrast, land is not taken into account due to the lack of data (see Table

[9]This database is downloadable at URL: http://www.ggdc.net/series/totecon.shtml#top. It is at the basis of the results reported by van Ark *et al.* (2002b) and Timmer *et al.* (2003). More recently, it has been also employed by OECD to estimate multi-factor productivity.

1).
Consumption series have been collected from national statistics offices and, whenever necessary, integrated with OECD National Accounts. Long-term series on households' purchases of computers are available only for Denmark, Finland, France, Netherlands, UK and US and, thus, the 'commodity flow' method has been employed to build or integrate data relative to Austria, Germany, Italy and Sweden[10].

The matching of different sources presented two main difficulties. Firstly, the US classification (NIPA) does not perfectly fit the international classification of consumption (COICOP) and, thus, the analysis has narrowed to those goods classified uniformly. This choice is dictated by the fact that the only depreciation rates available for consumer durables reflect the US categories[11].
Secondly, expenditure in Telephone and telefax equipment is not considered as available only for a handful of countries. For this reason, the outline presented in the following is likely to underestimate the propensity towards hi-tech goods of Finland and Italy. These countries present a share of communication equipment in consumption much larger than the other countries (respectively 0,2% and 0,6% against an average of 0,05% of France, Sweden and UK). TLC consumption in Italy is even superior to expenditure in home computers -by a factor of three times[12].
This lack clearly limits the scope of the analysis as it neglects a key factor of the new economy, widely acknowledged as potential source of network externalities. Recently, the technological convergency between Information and Communication Technology (cable modem for TV or GPRS and UMTS mobiles) has further enhanced the importance of TLC equipment that has diffusely become a tool for the access to the Internet[13].

[10]This approach is very close the one followed by statistical agencies. For instance, the US Bureau of Economic Analysis takes the values from benchmark I-O tables and, then, interpolates data for missing years (see BEA (1990)). In Italy, ISTAT follows a similar method (see Corea *et al.* (2000)).
Despite input-output tables follow a classification of production activities (ISIC Rev. 3), there is a satisfactory correspondence with the category of consumption relative to Information processing equipment (cat. 9.1.3 COICOP) because of the irrelevance of secondary productions from other industries for this kind of product. Details on data sources are provided in the Appendix.

[11]Notice that, in contrast to NIPA, COICOP does not strictly regard China and Glassware, Jewelry, Therapeutic appliances and equipment, Books and Maps as consumer durables. Hence, they are left out from the analysis.

[12]The commodity flow method provided unreliable estimates of consumption of TLC equipment for some countries and, consequently, they have been not taken into account.

[13]As formerly pointed out, the development of communication infrastructures is one of the operative goals pursued by the EU authorities. See in this respect the surveys on

All in all, the analysis takes into consideration the following durable goods: Furniture and furnishings, carpets and other floor coverings, Household appliances, Vehicles, Audio-visual and photographic equipment, Information processing equipment, Other major durables for recreation and culture. Finally, Textile and Tools and equipment for house and garden have been joined into an only one category very close to NIPA Other home furnishings (Table 1)[14].

## 2.3 From nominal expenditure to productive services of capital

### Price Harmonization

Since the mid-1990s the deflation of ICT goods has vertiginously accelerated because of the impressive rise in semiconductors efficiency and the resulting fall in prices. The miniaturization of chips has fuelled the rapid quality improvement of the high-tech goods embodying these intermediate inputs such as computers whose production costs are accounted for a half by semiconductors[15].

Increasingly, new PCs perform an amount of tasks larger than old models as better endowed in terms of speed of processing and storage capacity. This is the reason why computers are difficultly comparable over time, even between adjacent periods.

Such products need to be gauged in quality-adjusted units; it requires a deflation technique able to isolate the price change by holding product characteristics constant. Conventional methods (matched models) are unable to fully evaluate quality improvement as monitoring the price of the exactly

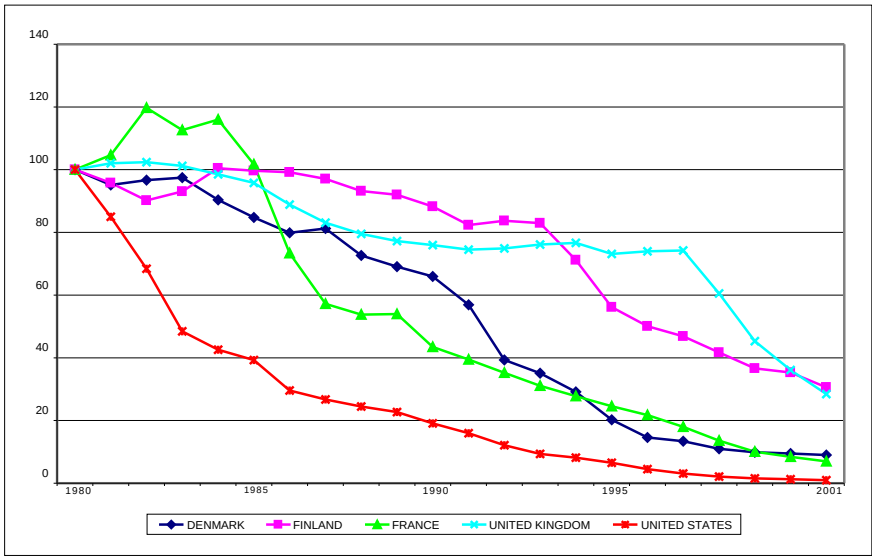
the penetration of ICT across households (INRA (2004)) commissioned by Directorate General for the Information Society as well as the e-Business W@tch program launched in 2001 by DG Enterprise to monitor the adoption, development and impact of electronic business practices. A synthetical outline on telecommunication trends in Europe is drawn in ESPON (2004) where the focus is restricted on regional disparities. A summary on the penetration rates of ICT across households emerging from these surveys is provided below in section 3.1.

[14]NIPA Other home furnishings durable collects such house furnishings as floor coverings, comforters, quilts, blankets, pillows, picture frames, mirrors, art products, portable lamps, and clocks. It also includes writing equipment and hand, power, and garden tools.

The matching between NIPA and COICOP is largely satisfactory even though some discrepancy remains. For instance, COICOP includes Photographic equipment and Musical instruments respectively into 9.1 and 9.2 categories while NIPA doing viceversa. Thus, it is hypothesized that these outlays perfectly balance in the US.

[15]See Jorgenson (2001) for one influential reassessment of the impact of semiconductors technology on US productivity growth.

Figure 1. **National deflators for households' expenditure in computers** (1980-2001), 1980=100




same good over time. Evidently, they fail when some characteristic significatively changes[16].

Hedonic pricing is the most consolidated technique allowing for the rapid growth in quality of ICT goods as it estimates the unit price as function of a bundle of product characteristics[17]. Accordingly, a PC is evaluated as computing power rather than physical box.

In international comparisons there is need to guarantee a similar treat-

[16]A price index is computed by comparing the average price of an array of product varieties in distinct times. Difficulties arise when a variety meaningfully changes or cannot be observed; the replacement of old model with a strict substitute imposes some assumption on the treatment of the quality disparity existing between these items.
Matched models include a plenty of methods to handle this adjustment (OECD (2004a)). For instance, overlapping link method exploits for non-adjacent periods information on prices of old product and item replacement for intermediate years (when they are both available).
Statistical agencies commonly use other methods like direct comparison (no quality distinction is assumed between the original variety and its replacement), the link-to-show-no-price-change (price change between old item and its replacement is fully attributed to quality change), the deletion technique (old items and replacements are simply dropped). Option pricing is another conventional technique to adjust quality: it subtracts from new goods price the value of extra characteristics measured at price they can be separately purchased on the market.

[17]However, by using a matched model with very detailed and high frequency data, Aizcorbe *et al.* (2002) find prices for high-tech goods very similar to the hedonic indexes.

ment to quality adjustment of hi-tech products; otherwise, the discrepancies in prices measurement may hide the real differences across countries. Figure 1 shows that the gap among national indexes for IT consumption may be very considerable; for instance, the US deflator was smaller than the Finnish one in 2001 by a factor of 30 times.
In order to avoid such problem, this work employs the price harmonization method proposed by Schreyer (2002) to deflate IT consumption, following a strategy closed to the one adopted at GGDC for ICT investment.
By assuming a global model of relative prices ($P^i_{ICT}/P^i_n = P^{US}_{ICT}/P^{US}_n$), one can use the US deflator for ICT ($P^{US}_{ICT}$) in place of national price indexes, after a small correction for the differential in consumer durables inflation ($P^{US}_n$ for the US and $P^i_n$ for EU countries):

$$\Delta \ln(P^i_{ICT}) = \Delta \ln(P^{US}_{ICT}) + \Delta \ln(P^i_n) - \Delta \ln(P^{US}_n)^{18}. \quad (3)$$

Two further adjustments have been implemented to make data comparable across countries. First, price harmonization has been also applied to consumption of audio-visual equipment[19] to avoid the understatement stemming from the fact that it is computed residually by subtracting harmonized expenditure in computers from aggregate 9.1 (see Table 1).
Second, as in Oulton (2001)[20], the official figures for GDP have been corrected in light of the new estimates of ICT volumes. The use of Tornqvist's index formula to handle this task determines a downward correction of output for those countries adopting base-year indexes (Laspeyres) in National Accounts as smaller weights are now attributed to ICT goods (Schreyer (2001)).

[18]For consumption the US Bureau of Economic Analysis employs a hedonic function to price kitchens, vehicles and audio-visual equipment along with computers.
In eq. (3) $P^i_{ICT}$ is estimated as a three years average of price changes. The procedure based on relative prices of consumer durables is nearly equivalent to the correction for general inflation (GDP) employed by van Ark *et al.* (2002b). Colecchia and Schreyer (2002) instead apply the predicted values from a regression of a polynomial trend on the relative change of US ICT prices to the non-ICT price index of the other countries.
An alternative method to the global model of relative prices consists in using the US prices corrected for the oscillations in exchange rate. As most of ICT investment goods are imported from the US, it imposes that import prices fully reflect the movements in exchange rate (see for instance Daveri (2002)).

[19]The adoption of a global hedonic model understands the assumption of identical market structure, competition and preferences across countries that may seem excessive for audio-visual equipment. Moreover, this kind of goods show a less pronounced quality growth than computers.

[20]Oulton (2001), p. 17, re-calculates the GDP growth rate of the UK by re-aggregating its sub-components once provided with the quality-adjusted series of ICT expenditure. Inventories are proportionally imputed to other expenditure aggregates as being small, erratic and sometimes with negative values.

Table 2. **Effect of price harmonization and Tornqvist's index formula on GDP**, annual average growth rates (%)

| | GDP 1 | INV 2 | P&S 3 | A&V 4 | GDP* 1+4 | GDP 1 | INV 2 | P&S 3 | A&V 4 | GDP* 1+4 |
|---|---|---|---|---|---|---|---|---|---|---|
| | AUSTRIA | | | | | ITALY | | | | |
| **1981-1995** | 2,25 | 0,20 | 0,20 | 0,24 | 2,48 | 1,91 | 0,19 | 0,19 | 0,21 | 2,12 |
| **1995-2001** | 2,38 | 0,22 | 0,22 | 0,25 | 2,63 | 1,90 | 0,38 | 0,38 | 0,40 | 2,30 |
| **Δ** ***post-95*** | ***0,13*** | | | | ***0,14*** | ***-0,01*** | | | | ***0,18*** |
| | DENMARK | | | | | NETHERLANDS$^{\circ +}$ | | | | |
| **1981-1995** | 1,69 | 0,08 | 0,08 | 0,11 | 1,80 | 2,65 | 0,07 | 0,07 | 0,12 | 2,77 |
| **1995-2001** | 2,45 | 0,34 | 0,41 | 0,41 | 2,86 | 3,24 | 0,38 | 0,38 | 0,43 | 3,68 |
| **Δ** ***post-95*** | ***0,77*** | | | | ***1,06*** | ***0,59*** | | | | ***0,91*** |
| | FINLAND | | | | | SWEDEN$^{+}$ | | | | |
| **1981-1995** | 1,81 | -0,06 | -0,05 | -0,02 | 1,80 | 1,66 | 0,15 | 0,15 | 0,17 | 1,83 |
| **1995-2001** | 4,03 | 0,37 | 0,41 | 0,43 | 4,46 | 2,86 | 0,49 | 0,49 | 0,49 | 3,34 |
| **Δ** ***post-95*** | ***2,21*** | | | | ***2,66*** | ***1,20*** | | | | ***1,52*** |
| | FRANCE$^{+}$ | | | | | UNITED KINGDOM | | | | |
| **1981-1995** | 1,98 | 0,13 | 0,13 | 0,13 | 2,11 | 2,34 | -0,02 | 0,04 | 0,04 | 2,37 |
| **1995-2001** | 2,55 | 0,09 | 0,10 | 0,10 | 2,65 | 2,73 | 0,47 | 0,54 | 0,53 | 3,26 |
| **Δ** ***post-95*** | ***0,57*** | | | | ***0,54*** | ***0,39*** | | | | ***0,89*** |
| | GERMANY | | | | | UNITED STATES$^{+}$ | | | | |
| **1981-1995** | 2,19 | -0,04 | -0,04 | -0,02 | 2,17 | 2,87 | - | - | - | 2,87 |
| **1995-2001** | 1,58 | 0,28 | 0,28 | 0,32 | 1,91 | 3,36 | - | - | - | 3,36 |
| **Δ** ***post-95*** | ***-0,61*** | | | | ***-0,27*** | ***0,49*** | | | | ***0,49*** |

**Notes**: **1**- GDP growth rate from OECD National Accounts; **2**- correction factor due to the harmonization of ICT investment (INV); **3**- correction factor due to the harmonization of ICT investment (INV) and IT consumption (P&S); **4**- correction factor due to the harmonization of ICT spending (INV, P&S) and audio & video consumption (A&V);
$^{+}$ Originally built using chain-weighted aggregation.
$^{\circ}$ Netherlands refer to 1986-95 and 1995-2001.

As the index replacement partly offsets the quality correction of ICT expenditure, the pure harmonization effect can be identified only for such countries as France, Netherlands and Sweden which originally rely upon chain aggregation (see OECD (2003))[21]. For France the overall adjustment is minimal (0,10%) as a somewhat use of hedonic pricing is made at INSEE while it is of a certain importance for Netherlands and Sweden (0,43 and 0,49% per annum). Nevertheless, the size of correction is remarkable especially for the remaining countries in light of the depressive effect of the index substitution (from 0,25 per annum of Austria to 0,53% of the UK).
In conclusion, it is important to note that price adjustment tends to considerably reduce the EU-US gap in GDP growth rate of the last years.

### Permanent inventory method and Rental prices

The stock of capital assets and consumer durables ($S_{i,t}$) has been computed with the permanent inventory method and depreciation geometric from series

[21]Table 2 displays the correction factors stemming from the harmonization of ICT investment (INV), ICT investment and consumption (P&S) and, finally, ICT expenditure and consumption of audio-visual equipment (A&V).
O'Mahony and van Ark (2003) follow a production side strategy of adjustment, correcting for the quality the value added of hi-tech industries (cat. 30-33, ISIC Rev. 3). Their estimates of GDP slightly diverge from ours probably due to a discrepancy in the original data (OECD STAN vs. OECD National Accounts).

on real expenditure ($I_{i,t}$):

$$S_{i,t} = \sum_{\tau=0}^{T} d_{i,\tau} F_{i,\tau} I_{i,t-\tau} = \sum_{\tau=0}^{T} (1-\delta_i)^{\tau} I_{i,t-\tau}. \quad (4)$$

It assumes no retirement ($F_{i,\tau} = 1$) and a time-invariant share of efficiency loss $\left(d_{i,\tau} = 1 - \delta_i\right)$[22].
In addition, the initial stock of dwellings, inventories and consumer durables has been estimated through the formula proposed by Hall and Mairesse (1995) as such data are available from different years:

$$S_{i,0} = \sum_{\tau=0}^{\infty} I_{i,-\tau} (1-\delta_i)^{\tau} = \frac{I_{i,1}}{g_i + \delta_i}; \quad (5)$$

$g_i$ is the growth rate of real expenditure calculated over all the time span (see Guellec and van Pottelsberghe de la Potterie (2001)).
Depreciation rates ($\delta_i$) are assumed constant over time and identical across countries (see Table 1); they are taken from van Ark *et al.* (2002b) for investment assets, from Oulton (2001) for dwellings, while the reference is Jorgenson and Stiroh (2000) for inventories and consumer durables. Consider that $\delta_i$ is variable for IT equipment as derived from the aggregation of sub-components with different rates and time-varying weights[23].
Finally, a measure of *productive* capital has been obtained with the mid-year adjustment of the stocks resulting from eq. (4):

$$K_{i,t} = \frac{S_{i,t-1} + S_{i,t}}{2};$$

this device partly mitigates the assumption of regarding capital as fully productive from the time of its installation.

The growth contribution of each asset is given by the growth rate of capital services multiplied with their share on nominal income.
Asset-specific shares were estimated with the rental price (or user cost; $c_{i,t}$). $c_{i,t}$ is preferred to the market price as allowing for both the efficiency- and

[22]This assumption guarantees the coincidence between the profiles of efficiency (*deterioration*) and price (*depreciation*) of capital vintages. See OECD (2001) for a survey on the main methods employed by national statistical offices to compute capital stock.

[23]The depreciation rates of IT capital are taken from Melka *et al.* (2003). Similarly to Oulton (2001), the stock of inventories is priced with the implicit deflator for manufacturing value added (extracted from OECD STAN).
Because of the lack of detailed data, the depreciation rate for automobiles (0,255) was applied to any vehicle without distinguishing among cars, motorcycles and other vehicles.

price-profile of different kinds of capital (Jorgenson and Griliches (1967)). The user cost derives from the annualization of the price of an asset into the price of the corresponding capital input and, accordingly, is identifiable with its marginal product:

$$c_{i,t} = P_{i,t-1}\big(i_t + \delta_i - \pi_{i,t} + \delta_i\pi_{i,t}\big).$$

$\pi_{i,t} = \frac{P_{i,t}-P_{i,t-1}}{P_{i,t-1}}$ is the inflation rate while $i_t$ the nominal rate of return that is equal for all markets under the assumption of perfect competition[24].
$c_{i,t}$ provides a qualitative distinction of capital. As the acceleration in the innovative activity of hi-tech industries has speed up the price decline and the loss in productive capacity of ICT, such asset type has to earn a high rent (user cost) in order to be profitable.
A measure of capital quality is given by ratio between its economic (based on rental prices) and market value. This aspect will be more extensively discussed in section 3.4.

# 3 The growth contribution of IT consumption

## 3.1 IT expenditure in Europe and the United States

Taking into account the home usage of computer allows to analyze the role played by Information Technology on growth from a twofold perspective, by the side of investment and the one of consumption.
This paragraph presents a comparison on the adoption pattern of high-tech goods showed by firms and households in Europe and the US. The lack of data on consumption of communication equipment and non-bundled software leads to restrict the analysis on computers. Therefore, the picture drawn in this paragraph offers only a partial representation of the digitalization degree

[24]The internal rate ($i_t$) is computed following the 'ex post approach'. It employs capital revenue reported in National Accounts (Gross Operating Surplus and Mixed Income -GOS-), once detracted the amount of labour income attributable to self-employed (OECD (2001), p. 88):

$$i_t = \frac{GOS_t - \Sigma_i(\delta_i - \pi_{i,t} + \delta_i\pi_{i,t})K_{i,t}}{\Sigma_i K_{i,t}}.$$

This expression stems from the substitution of the user cost formula into the identity between the rental payments for all assets and total property compensation ($GOS_t = \Sigma_i c_{i,t}K_{i,t}$). As in Colecchia and Schreyer (2002), this work adopts the discrete time version of the rental price formula.

of the Atlantic economies as the diffusion rate of the various kinds of ICT may significatively diverge as witnessed by the Finnish case. This country stands out for a high value of TLC investment while ranks on the bottom for firms' purchases of office machinery[25].

If one looks at the share of IT investment in GDP (Figure 2), it is possible identify two clusters of spenders from the mid-1990s[26]: *high-investors* (US, UK, Denmark, Netherlands and Sweden) with a share ranging from 1 to 1,5% and *low-investors*, averaging around 0,5% (Austria, Italy, Finland and France). Germany instead stands in between.
By aggregating the values of the EU countries (EU-9)[27], it emerges the slow convergence of Europe towards the US levels occurred in the second part of the last decade. Note, then, that the fall of 2001 appears more pronounced in the US.

The home uptake of computers is clearly more heterogenous than investment, showing a sizable share in GDP only from the mid-1990s. Denmark, United States and United Kingdom arise as *high-consuming* countries as well, while the major continental states (France, Germany and Italy) and Sweden ranked on the bottom (*low-consumers*). An inter-medium group is then made up by Austria, Finland and Netherlands.
It is apparent from Figure 2 that the delay of the followers sensibly widened during the 1990s when Denmark, UK and US exhibited a marked acceleration. IT consumption in Europe (EU-9) sharply increased only between 1994 and 1998 but remained nearly unchanged from then on. As a result, the digitalization degree of households on the two Atlantic sides at the end of the millennium is completely reversed with respect to the early 1980s when Europe was ahead.

A synthetic outline on the diffusion pattern of computers and other office machinery is reported in Figure 3. It plots the annual average deviations from sample mean of the share of IT in firms' investment ($y$-axis) and households' expenditure in consumer durables ($x$-axis) for 1980-95 and 1995-2001.
Considering both IT profiles together, one can note the divergence of Sweden and Netherlands from the cluster of *high-spenders*, located in the top-right

[25]Ahmad *et al.* (2003) points out that the difficulty to constantly updating the expenditure classification to new products may undermine the international comparison on ICT spending. This problem has become of a certain importance with the technical convergence between Communication and Information Technology that might give rise to some significant discrepancy across countries in the composition of ICT expenditure.

[26]See Guerrieri *et al.* (2004) for a cluster analysis carried out on a broader group of countries.

[27]The community mean is obtained by summing the values converted at the national currency/euro exchange rates as of 1 January 1999. See Timmer *et al.* (2003). The sample of countries analyzed in this study represented a 86% of total GDP of the EU-15 in 2001.

Figure 2. **Share of IT Expenditure in GDP** (1980-2001), current prices (%)

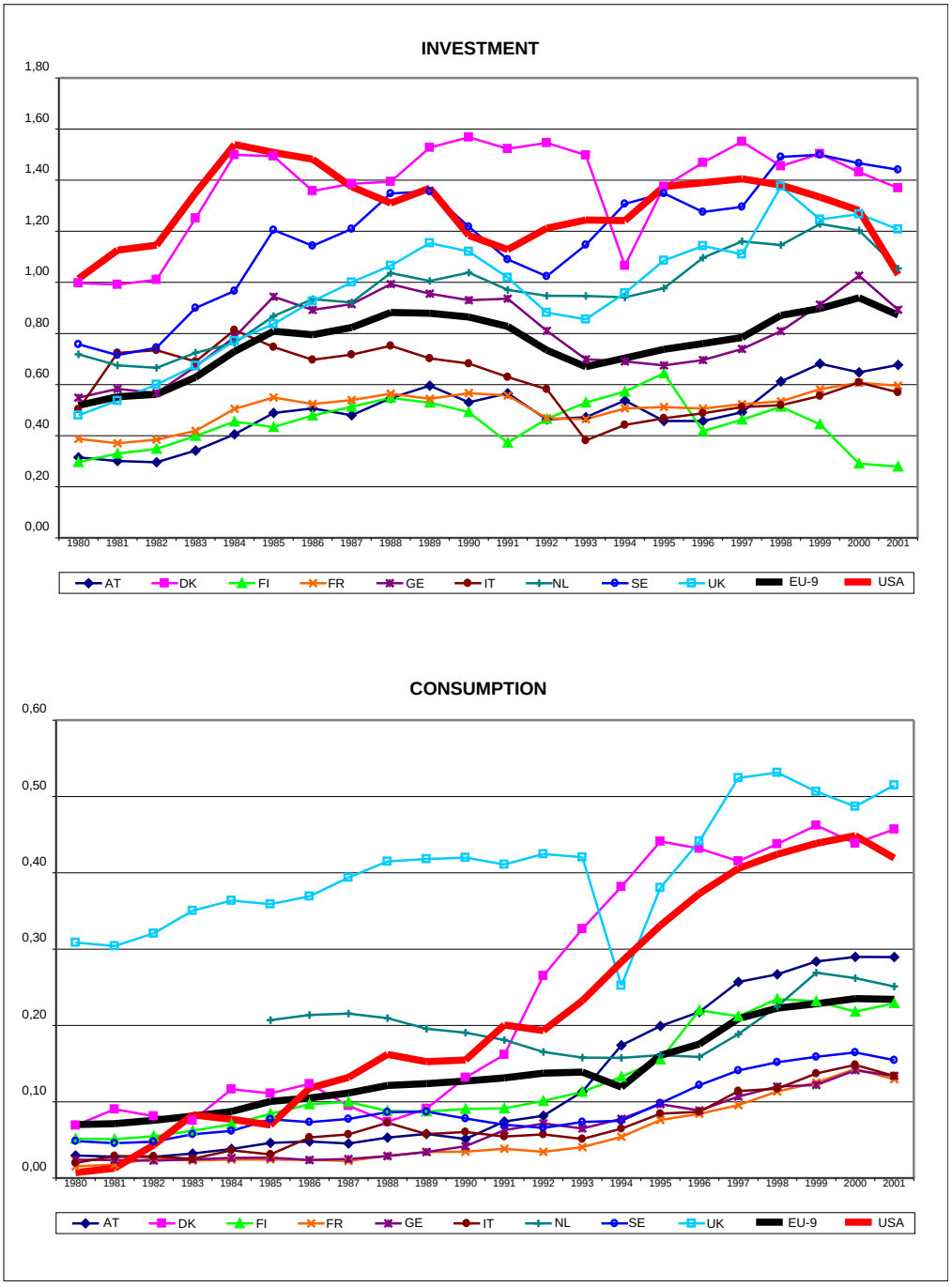


Figure 3. **A synthesis on the diffusion of IT across firms and households**, (1980-95 and 1995-2001), deviations from sample mean (%)

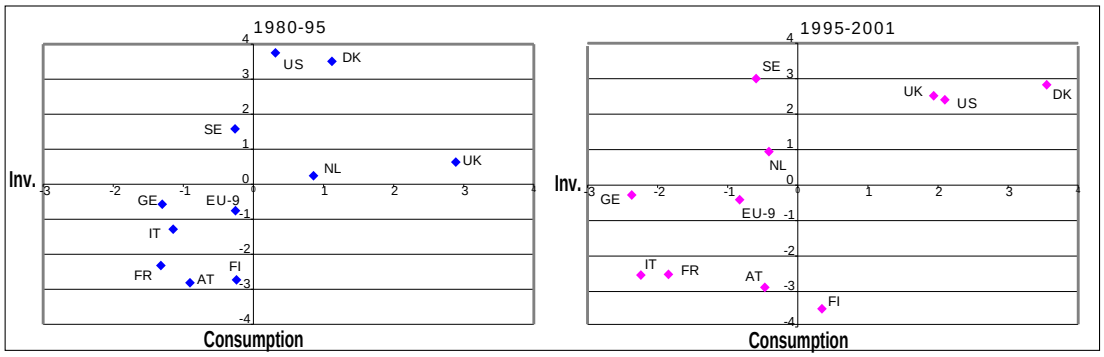



Table 3. **IT share in total investment and consumer durables expenditure** (1980-2001), current prices (%)

| | AT | DK | FI | FR | GE | IT | NL | SE | UK | EU-9 | US |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **INVESTMENT** | | | | | | | | | | | |
| 1980 | 1,6 | 6,8 | 1,5 | 2,3 | 3,1 | 2,8 | 4,5 | 4,6 | 3,2 | **3,0** | **6,4** |
| 1985 | 2,9 | 9,2 | 2,2 | 3,7 | 5,9 | 4,8 | 5,6 | 7,1 | 5,7 | **5,2** | **10,0** |
| 1990 | 2,8 | 9,7 | 2,3 | 3,2 | 5,4 | 4,2 | 6,1 | 6,8 | 6,7 | **5,0** | **8,7** |
| 1995 | 2,8 | 9,1 | 4,9 | 3,5 | 4,6 | 3,5 | 6,7 | 9,3 | 8,2 | **5,2** | **10,0** |
| 2001 | 3,7 | 8,2 | 1,8 | 3,8 | 6,5 | 3,7 | 6,6 | 9,1 | 8,8 | **5,9** | **6,9** |
| **CONSUMPTION** | | | | | | | | | | | |
| | **AT** | **DK** | **FI** | **FR** | **GE** | **IT** | **NL** | **SE** | **UK** | **EU-9** | **US** |
| 1980 | 0,4 | 1,3 | 0,8 | 0,2 | 0,3 | 0,3 | - | 1,0 | 4,2 | **1,1** | **0,1** |
| 1985 | 0,7 | 1,6 | 1,3 | 0,4 | 0,4 | 0,5 | 3,0 | 1,8 | 4,8 | **1,5** | **1,0** |
| 1990 | 0,7 | 2,9 | 1,5 | 0,5 | 0,5 | 0,8 | 2,7 | 1,7 | 5,1 | **1,7** | **2,4** |
| 1995 | 2,7 | 6,9 | 3,4 | 1,4 | 1,4 | 1,3 | 2,6 | 2,6 | 4,9 | **2,5** | **5,1** |
| 2001 | 3,9 | 9,5 | 4,7 | 2,4 | 1,9 | 2,0 | 4,1 | 3,5 | 5,9 | **3,4** | **6,0** |

panel, because of a relatively low value of consumption between 1995 and 2001. Instead, Finland outdistances *low-spenders* (bottom-left panel) for a higher adoption rate of home computers.
The comparison between the sections of Figure 3 (1995-2001 *vs.* 1980-95) suggests that firms reacted more similarly than households to the price shock of the mid-1990s as evident from the major homogeneity across countries in the average rate of investment.

Overall, the picture thus far described, relying upon National Accounts data (Table 3), is fully consistent with the penetration rates of ICT goods surveyed across households (Table 4)[28]. Sweden is the sole notable exception as it classifies on the top ranking when one considers direct interviews. This

[28]See footnote 13 for a brief description of INRA (2004).

Table 4. **Home Penetration of ICT** (2002), percentage of households

| | **AT** | **DK** | **FI** | **FR** | **GE** | **IT** | **NL** | **SE** | **UK** | **EU -9** | **EU -15** | **US*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MOBILE | 72 | 77 | 86 | 66 | 66 | 83 | 85 | 84 | 81 | 74 | 77 | 45 |
| **PC** | **46** | **68** | **52** | **33** | **50** | **44** | **68** | **73** | **56** | **49** | **48** | **57** |
| INTERNET ACCESS | 33 | 54 | 36 | 20 | 33 | 34 | 48 | 64 | 45 | 35 | 34 | 51 |
| BROADBAND | 8 | 17 | 6 | 3 | 3 | 1 | 12 | 13 | 4 | 4 | 5 | 3 |

**Source**: Survey on EU households, INRA (2004).
* Figures per 100 inhabitants, 2001. The share of mobile subscribers is taken from ITU (International Telecommunications Union), the percentages of access to computer, internet and broadband from OECD ICT Outlook, 2001.

discrepancy is likely to depend on the nature of sources, even though it may virtually signal a per capita expenditure in home computers considerably lower than elsewhere.
Table 4 confirms the leading position of Denmark in terms of consuming applications of Information Technology (computers, Internet and the broadband)[29]; Danish households devoted a 10% of durables expenditure to computers in 2001 (about one percent of total consumption), a percentage five times bigger the values achieved by the major continental countries (Table 3).
Looking at penetration rates, the performance of United Kingdom seems slightly undersized with respect to expenditure data; indeed, the UK has steadily spent for home computers more than the other countries since the early 1980s[30].

## 3.2 Growth decomposition from the Output side

The recession of 2001 closed a phase of expansion common to many countries of the Atlantic area, with a large majority of them exhibiting an output growth superior to a 3% per year between 1995 and 2001 (Table 5)[31].
Finland rebounded (4,5%) after the deep recession of the early 1990s when

[29]ICT goods are listed in an increasing order of technological complexity and, to a broader extent, priority attributed by the EU policymakers. See in this respect ESPON (2004).

[30]By comparing the degree of ICT adoption between UK and US households, Schmitt and Wadsworth (2002) report that the United States has overtaken the United Kingdom in terms of PC ownership rate from the mid-1990s. The delay of the UK already amounted to 1,7 years in 1998. More importantly, these authors provide evidence of a wider difference *within* rather than *between* countries because of a high inequality across income groups.

[31]Hereinafter the analysis focuses on the broad concept of output (GDP plus the services of consumer durable).

it started the transition from a semi-planned to an open market economy. Daveri and Silva (2004) document that the brilliant performance of the latter part of the last decade was also affected by the strong specialization in hi-tech production (communication equipment) where Finland is one of the EU leading countries together with Ireland and Sweden.
The Netherlands accelerated of one percentage point after 1995 (from 2,8 to 3,8% per annum). The input side analysis will illustrate that it was mainly due to a more intensive use of labour relative to the other inputs, with heavily negative implications for labour productivity.
The American growth resurgence has been extensively described both with at an economy-wide and an industry level of detail, especially because it was driven by a revival in output per hour worked. At the basis of such upsurge there is a diffused application and efficient production of ICT goods which provoked a structural change in the foundations of the economy (Jorgenson (2004)). This assessment is confirmed by the new extraordinary cycle of labour productivity started in 2000 (Gordon (2003))[32] and in the anomalous shortness (and mildness) of the 2001 recession (Baily (2002)). Jorgenson (2004) estimates that, despite the downturn, the average growth rate of output was of an annual 4,02% between 1995 and 2002.
In Europe the catch-up of Nordic countries towards the levels of bigger economies was favored by the modest pace of development of the continental states. Germany grew by less than 2% per year between 1995 and 2001, decelerating of a third of percentage point with respect to the foregoing period. France instead performed slightly better, recovering from the very low rates of 1981-95. Italy and Austria improved their performance marginally after 1995 (both +0,2%), showing rates comparable to the fast-growing countries only in 2000 (both with 4,2%)[33].

The expansion of the second half of the 1990s was driven for a large fraction by the rise in ICT expenditure. Some of these products like personal computers spread out in both Atlantic sides since the 1980s; nevertheless, a meaningful acceleration materialized around 1995 when the extraordinary innovative activity of semiconductors firms translated into marked efficiency gains. This caused a very rapid deflation that has been then transmitted to downstream industries.
The price of consumption computer averagely declined by a 32% per year in the latter part of the last decade (see the US index in Figure 1) whilst the

[32]The US Bureau of Labour Statistics computes that the growth rate of output per hour worked of non-farm business sector climbed up to a 4,3% per year in 2002-04 from a 2,5% of 1995-2001 (http://www.bls.gov/bls/productivity.htm).

[33]Annual tables are available from the author on request.

Table 5. **Absolute and Relative Sources of Growth: the Output Side** (1981-2001), annual average growth rates (%-points)

| **AUSTRIA** | | | | | | | | | | | | | | | | | **Total** | **$C_{IT}$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | **ICT (%)** | **share** |
| **1981-95** | 2,61 | 2,42 | 0,03 | 0,07 | 0,04 | 0,03 | 0,02 | | 100 | 93 | 1 | 3 | 2 | 1 | 1 | 7 | 16 |
| **1995-01** | 2,79 | 2,27 | 0,10 | 0,16 | 0,05 | 0,10 | 0,11 | | 100 | 81 | 3 | 6 | 2 | 4 | 4 | 15 | 24 |
| **1995-2001 less 1981-95** | 0,18 | -0,15 | 0,07 | 0,09 | 0,01 | 0,07 | 0,09 | | 100 | -82 | 39 | 50 | 4 | 40 | 50 | 132 | 29 |
| **DENMARK** | | | | | | | | | | | | | | | | | **Total** | **$C_{IT}$** |
| | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | **ICT (%)** | **share** |
| **1981-95** | 2,05 | 1,60 | 0,06 | 0,19 | 0,01 | 0,12 | 0,06 | | 100 | 78 | 3 | 9 | 1 | 6 | 3 | 19 | 16 |
| **1995-01** | 3,05 | 2,24 | 0,15 | 0,32 | 0,01 | 0,15 | 0,18 | | 100 | 74 | 5 | 10 | 0 | 5 | 6 | 20 | 23 |
| **1995-2001 less 1981-95** | 1,01 | 0,64 | 0,09 | 0,13 | -0,01 | 0,03 | 0,13 | | 100 | 64 | 9 | 13 | -1 | 3 | 13 | 24 | 36 |
| **FINLAND** | | | | | | | | | | | | | | | | | **Total** | **$C_{IT}$** |
| | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | **ICT (%)** | **share** |
| **1981-95** | 1,64 | 1,35 | 0,03 | 0,08 | 0,07 | 0,09 | 0,03 | | 100 | 82 | 2 | 5 | 4 | 6 | 2 | 16 | 10 |
| **1995-01** | 4,49 | 3,73 | 0,09 | 0,05 | 0,36 | 0,15 | 0,10 | | 100 | 83 | 2 | 1 | 8 | 3 | 2 | 14 | 13 |
| **1995-2001 less 1981-95** | 2,85 | 2,39 | 0,06 | -0,03 | 0,29 | 0,06 | 0,08 | | 100 | 84 | 2 | -1 | 10 | 2 | 3 | 13 | 16 |
| **FRANCE** | | | | | | | | | | | | | | | | | **Total** | **$C_{IT}$** |
| | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | **ICT (%)** | **share** |
| **1981-95** | 2,12 | 1,95 | 0,01 | 0,08 | 0,03 | 0,04 | 0,01 | | 100 | 92 | 1 | 4 | 2 | 2 | 0 | 8 | 7 |
| **1995-01** | 2,66 | 2,28 | 0,04 | 0,14 | 0,05 | 0,10 | 0,05 | | 100 | 86 | 2 | 5 | 2 | 4 | 2 | 12 | 14 |
| **1995-2001 less 1981-95** | 0,54 | 0,33 | 0,03 | 0,05 | 0,01 | 0,07 | 0,04 | | 100 | 61 | 6 | 10 | 3 | 12 | 8 | 31 | 20 |
| **GERMANY** | | | | | | | | | | | | | | | | | **Total** | **$C_{IT}$** |
| | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | | **Y** | **$Y_{nICT}$** | **$C_{IT}$** | **$I_{IT}$** | **$I_{COM}$** | **$I_{SW}$** | **$D_{IT}$** | **ICT (%)** | **share** |
| **1981-95** | 2,30 | 2,07 | 0,01 | 0,11 | 0,03 | 0,07 | 0,01 | | 100 | 90 | 1 | 5 | 1 | 3 | 1 | 10 | 6 |
| **1995-01** | 1,95 | 1,56 | 0,04 | 0,20 | 0,04 | 0,07 | 0,05 | | 100 | 80 | 2 | 10 | 2 | 4 | 3 | 18 | 12 |
| **1995-2001 less 1981-95** | -0,35 | -0,51 | 0,03 | 0,09 | 0,00 | 0,00 | 0,04 | | -100 | -145 | 8 | 26 | 1 | 1 | 10 | 35 | 22 |

**Notes**: Each contribution is given by the growth rate multiplied by the value share.
$Y$ = Total output; $Y_{nICT}$ = non-ICT output (investment, consumption and consumer durable service); $C_{IT}$ = IT Consumption; $I_{IT}$ = IT Investment; $I_{COM}$ = Communication Investment; $I_{SW}$ = Software Investment; $D_{IT}$ = IT Durable Services. The relative values are computed as percentage of Total Output growth ($Y = 100$); Total ICT = $C_{IT} + I_{IT} + I_{COM} + I_{SW}$; $C_{IT}$ share = $C_{IT}$/Total ICT.

Table 5.b **Absolute and Relative Sources of Growth: the Output Side** (1981-2001), annual average growth rates (%-points)

| ITALY | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | Total ICT (%) | $C_{IT}$ share |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1981-95** | 2,23 | 2,00 | 0,01 | 0,08 | 0,07 | 0,05 | 0,01 | | 100 | 90 | 1 | 4 | 3 | 2 | 1 | 10 | 7 |
| **1995-01** | 2,38 | 2,00 | 0,04 | 0,13 | 0,10 | 0,06 | 0,05 | | 100 | 84 | 2 | 6 | 4 | 2 | 2 | 14 | 13 |
| **1995-2001 less 1981-95** | 0,16 | 0,00 | 0,03 | 0,05 | 0,03 | 0,01 | 0,04 | | 100 | -3 | 19 | 35 | 20 | 4 | 25 | 78 | 25 |
| **NETHERLANDS** | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | Total ICT (%) | $C_{IT}$ share |
| **1986-95** | 2,79 | 2,53 | 0,03 | 0,12 | 0,01 | 0,07 | 0,04 | | 100 | 91 | 1 | 4 | 0 | 2 | 1 | 8 | 14 |
| **1995-01** | 3,79 | 3,13 | 0,09 | 0,27 | 0,01 | 0,18 | 0,10 | | 100 | 83 | 2 | 7 | 0 | 5 | 3 | 15 | 16 |
| **1995-2001 less 1981-95** | 1,00 | 0,60 | 0,06 | 0,15 | 0,01 | 0,11 | 0,06 | | 100 | 60 | 6 | 15 | 1 | 11 | 6 | 33 | 17 |
| **SWEDEN** | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | Total ICT (%) | $C_{IT}$ share |
| **1981-95** | 1,83 | 1,47 | 0,02 | 0,18 | 0,03 | 0,12 | 0,02 | | 100 | 80 | 1 | 10 | 2 | 6 | 1 | 19 | 5 |
| **1995-01** | 3,44 | 2,65 | 0,06 | 0,34 | 0,04 | 0,28 | 0,07 | | 100 | 77 | 2 | 10 | 1 | 8 | 2 | 21 | 8 |
| **1995-2001 less 1981-95** | 1,61 | 1,18 | 0,04 | 0,16 | 0,01 | 0,16 | 0,05 | | 100 | 74 | 2 | 10 | 1 | 10 | 3 | 23 | 10 |
| **UNITED KINGDOM** | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | Total ICT (%) | $C_{IT}$ share |
| **1981-95** | 2,82 | 2,34 | 0,09 | 0,15 | 0,03 | 0,11 | 0,10 | | 100 | 83 | 3 | 5 | 1 | 4 | 4 | 13 | 24 |
| **1995-01** | 3,63 | 2,83 | 0,18 | 0,29 | 0,04 | 0,07 | 0,22 | | 100 | 78 | 5 | 8 | 1 | 2 | 6 | 16 | 31 |
| **1995-2001 less 1981-95** | 0,81 | 0,48 | 0,09 | 0,14 | 0,02 | -0,04 | 0,12 | | 100 | 60 | 11 | 17 | 2 | -5 | 15 | 26 | 44 |
| **UNITED STATES** | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | | Y | $Y_{nICT}$ | $C_{IT}$ | $I_{IT}$ | $I_{COM}$ | $I_{SW}$ | $D_{IT}$ | Total ICT (%) | $C_{IT}$ share |
| **1981-95** | 3,04 | 2,58 | 0,06 | 0,19 | 0,04 | 0,11 | 0,05 | | 100 | 85 | 2 | 6 | 1 | 4 | 2 | 13 | 14 |
| **1995-01** | 3,68 | 2,77 | 0,15 | 0,25 | 0,10 | 0,21 | 0,20 | | 100 | 75 | 4 | 7 | 3 | 6 | 5 | 19 | 22 |
| **1995-2001 less 1981-95** | 0,65 | 0,19 | 0,10 | 0,06 | 0,06 | 0,09 | 0,15 | | 100 | 29 | 15 | 10 | 9 | 14 | 23 | 48 | 32 |

**Notes**: Each contribution is given by the growth rate multiplied by the value share.
$Y$ = Total output; $Y_{nICT}$ = non-ICT output (investment, consumption and consumer durable service); $C_{IT}$ = IT Consumption; $I_{IT}$ = IT Investment; $I_{COM}$ = Communication Investment; $I_{SW}$ = Software Investment; $D_{IT}$ = IT Durable Services. The relative values are computed as percentage of Total Output growth ($Y = 100$); Total ICT = $C_{IT} + I_{IT} + I_{COM} + I_{SW}$; $C_{IT}$ share = $C_{IT}$/Total ICT.

price decline of investment in office machinery was slightly slower (-0,19%)[34]. As a result, real expenditure of households in PC increased by around 40% annually; it ranged from 36% of Denmark to 44% of France and Netherlands, largely outstripping the rise in IT investment (20-30%). In contrast to the EU countries, real consumption of IT in the US expanded more rapidly before 1995 when it rose by a 50% per year.

Despite a similar trend in prices, the contribution of high-tech spending (investment and consumption) to economic growth varied remarkably across countries in the late 1990s (Table 5). Sweden and the US exhibited a development pattern dominated by ICT that contributed for 0,7 percentage points to output growth (a fifth of total). On the other hand, the value of ICT expenditure was around a half in France, Italy and Germany (0,3-0,35%).

Decomposing the output growth in relative terms[35], one can note that the German figures are close to big ICT spenders (18%). This finding signals the marked propensity of such country towards high-tech goods, mainly for productive purposes, and that the low absolute value is probably affected by the depressive phase faced between 1995 and 2001.
As the most dynamic component of expenditure, ICT drove after 1995 the surge in output growth of such low-spending countries as Austria and Italy as well (the penultimate column of Table 5). The weight of ICT in smaller Nordic states was less pronounced due to a more favorable business cycle that enhanced the demand for a wide range of goods. Relative to these spending patterns, the Unites States stand in between as high-tech goods accounted for nearly a half of output acceleration.

When the focus is restricted on consumption two noteworthy aspects arise. As previously described, households' spending in computer acquired a certain importance only in the last period, showing a wide heterogeneity across countries. Consider that the contribution of computer consumption in the United Kingdom was 4,4 times higher than in Germany (0,18 against 0,04%), while for investment the proportion factor between the biggest (Sweden) and smallest spender (France) amounted to 2,3. More importantly, home computers provided a growth contribution superior to communication and software investment in all countries with the sole exception of France and Italy; this shows how a large part of the economic impact of Information and Communication Technology has thus far remained hidden or, erroneously, not explicitly taken into account.

[34]Investment in communication equipment and software showed a flatter fall in prices compared to PCs (-3 and -0,5%); see Table A.2 in the Appendix. van Ark *et al.* (2002b) summarizes the methodology underlying the construction of the price index for software in the United States.

[35]The annual average rate is normalized to 100.

Table 6. **Output side: EU-9 vs US** (1981-2001), annual average growth rates (%-points)

| **EUROPEAN UNION (EU-9)** | | | | | | | | $\mathbf{C}_{IT}$ | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| | $\mathbf{Y}$ | $\mathbf{Y}_{nICT}$ | $\mathbf{C}_{IT}$ | $\mathbf{I}_{IT}$ | $\mathbf{I}_{Com}$ | $\mathbf{I}_{Sw}$ | $\mathbf{D}_{IT}$ | **(%)** | **ICT (%)** |
| **1981-95** | 2,31 | 2,04 | 0,03 | 0,11 | 0,04 | 0,07 | 0,03 | 1 | 11 |
| **1995-2001** | 2,74 | 2,22 | 0,08 | 0,20 | 0,05 | 0,09 | 0,10 | 3 | 16 |
| **1995-2001 less 1981-95** | 0,43 | 0,18 | 0,05 | 0,09 | 0,02 | 0,02 | 0,06 | 2 | 5 |
| **UNITED STATES** | | | | | | | | $\mathbf{C}_{IT}$ | **Total** |
| | $\mathbf{Y}$ | $\mathbf{Y}_{nICT}$ | $\mathbf{C}_{IT}$ | $\mathbf{I}_{IT}$ | $\mathbf{I}_{Com}$ | $\mathbf{I}_{Sw}$ | $\mathbf{D}_{IT}$ | **(%)** | **ICT (%)** |
| **1981-95** | 3,04 | 2,58 | 0,06 | 0,19 | 0,04 | 0,11 | 0,05 | 2 | 13 |
| **1995-2001** | 3,68 | 2,77 | 0,15 | 0,25 | 0,10 | 0,21 | 0,20 | 4 | 19 |
| **1995-2001 less 1981-95** | 0,65 | 0,19 | 0,10 | 0,06 | 0,06 | 0,09 | 0,15 | 2 | 6 |
| **EU-9 less US** | | | | | | | | $\mathbf{C}_{IT}$ | **Total** |
| | $\mathbf{Y}$ | $\mathbf{Y}_{nICT}$ | $\mathbf{C}_{IT}$ | $\mathbf{I}_{IT}$ | $\mathbf{I}_{Com}$ | $\mathbf{I}_{Sw}$ | $\mathbf{D}_{IT}$ | **(%)** | **ICT (%)** |
| **1981-95** | -0,72 | -0,55 | -0,03 | -0,08 | 0,00 | -0,05 | -0,02 | 4 | 22 |
| **1995-2001** | -0,94 | -0,56 | -0,07 | -0,05 | -0,04 | -0,11 | -0,10 | 8 | 30 |
| **1995-2001 less 1981-95** | -0,22 | -0,01 | -0,05 | 0,03 | -0,04 | -0,07 | -0,08 | 22 | 57 |

**Notes**: $C_{IT}$ and Total ICT are the percentage shares of IT consumption and ICT expenditure (investment plus consumption) on total output growth.

A particular mention has to be reserved to the United Kingdom. The amount spent in last years by households for PCs is bigger than the sum of British firms' expenditure in communication and software and is *even* superior to the growth contribution of investment in office machinery registered Austria, Finland, France and Italy. Home computers represent a large share of British expenditure in ICT since the early 1980s (last column of Table 5), pointing out the well-established familiarity of UK citizens with Information Technology.
It is worthwhile remarking with regard to the other countries the valuable share of IT consumption in hi-tech expenditure of Austria (around one quarter of total) that is higher than the percentage showed by Denmark and the US.

The aggregate figures of Europe (EU-9)[36] illustrate that around a third of the growth gap relative to the US of the late 1990s depended on ICT output (0,94%; Table 6). Aside from investment in office machinery, the United States presented a growth contribution of ICT twice larger than Europe. Moreover, the widening after 1995 in the EU-US difference in output growth (-0,22 percentage points) can be widely attributed to the less dynamic hi-tech spending of Europe (57%); the delay in IT expenditure for consuming purposes represents a fifth of the gap in output acceleration (22%).

[36]National growth rates are weighted with the shares on the European income obtained by converting values at the national currency/euro exchange rates as of 1 January 1999.

## 3.3 Growth decomposition from the Input side

The output growth decomposition from the input side allows to identify more accurately the contribution provided by ICT capital to economic growth. The role played by hi-tech assets was admittedly considerable in Sweden and the US (two thirds of %-point) where it outstripped traditional capital between 1995 and 2001. The ratio between ICT and non-ICT capital services is even higher in Finland (0,51 vs 0,17%) but, mainly, because of a weak increase in non-IT equipment, transport equipment and structures.
The innovative performance of firms was particularly undersized in the major continental countries and Austria where ICT contributed to output growth for less than half of low-tech capital in the latter part of the 1990s (around 0,30%). It is important to pinpoint, however, that Germany slightly diverges from this pattern for a more sluggish trend in traditional assets that shows up the performance of high-tech equipment.
Looking at the change between 1981-1995 and 1995-2001, one can note that the acceleration of output in Finland and France was primarily driven by a more intensive use of labour while the two asset types showed a diverging dynamics. In Sweden the rise in the growth contribution of ICT capital (+0,39% compared to 1981-95) was not accompanied by a similar trend in traditional assets. Instead, a more rapid accumulation of each type of capital was the key factor behind the resurgence of the US (0,47 out 0,65%).

Table 7 clearly illustrates how large was the share of output growth attributable to consumer durables (IT and non-IT) in the UK and the US at the end of the 1990s[37]. Strikingly, the growth contribution of home computers achieved a level similar to traditional products in Denmark, principally due to the dismal performance of the latter. The figures of France, Germany and Italy are particularly low with regard to IT goods (around 0,04% per year) whilst they are lined up to the majority of countries if one looks at traditional consumer durables. Nevertheless, because of the slight improvement in output growth occurred after 1995, the contribution of IT consumer durables becomes relevant for this group of countries as well.

A significant level of variation emerges, not surprisingly, in dynamics of Hicks-neutral index of productivity as notoriously dependent on a broad range of factors. TFP growth usually reflects the technological convergence of smaller countries (Finland and Sweden) towards the efficiency levels of the most advanced economies[38]; on the other hand, such index also mirrors the

[37] A more detailed description of the growth contribution of consumer durables is provided in the following paragraph.

[38] This is the key outcome found by Islam (2003) in a regression analysis on technological convergence of a wide sample of countries. Cameron (2005) instead focuses on the catch-up

Table 7. **Absolute and Relative Sources of Growth: the Input Side** (1981-2001), annual average growth rates (%-points)

| **AUSTRIA** | | | | | | | | | | | | | | | | Total | $D_{IT}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ALP** | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ICT (%)** | **share** |
| **1981-95** | 2,61 | 0,43 | 0,14 | 0,40 | 0,02 | 0,25 | 1,37 | 2,07 | 100 | 16 | 5 | 15 | 1 | 10 | 52 | 6 | 14 |
| **1995-01** | 2,79 | -0,23 | 0,28 | 0,54 | 0,11 | 0,24 | 1,85 | 3,10 | 100 | -8 | 10 | 19 | 4 | 9 | 66 | 14 | 29 |
| **1995-2001 less 1981-95** | 0,18 | -0,66 | 0,14 | 0,13 | 0,09 | -0,01 | 0,48 | 1,03 | 100 | -361 | 77 | 74 | 50 | -5 | 266 | 127 | 39 |
| **DENMARK** | | | | | | | | | | | | | | | | Total | $D_{IT}$ |
| | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ALP** | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ICT (%)** | **share** |
| **1981-95** | 2,05 | 0,08 | 0,31 | 0,36 | 0,06 | 0,07 | 1,17 | 1,94 | 100 | 4 | 15 | 18 | 3 | 3 | 57 | 18 | 15 |
| **1995-01** | 3,05 | 0,42 | 0,52 | 0,60 | 0,18 | 0,19 | 1,13 | 2,43 | 100 | 14 | 17 | 20 | 6 | 6 | 37 | 23 | 26 |
| **1995-2001 less 1981-95** | 1,01 | 0,34 | 0,22 | 0,24 | 0,13 | 0,12 | -0,04 | 0,48 | 100 | 34 | 22 | 24 | 13 | 12 | -4 | 34 | 37 |
| **FINLAND** | | | | | | | | | | | | | | | | Total | $D_{IT}$ |
| | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ALP** | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ICT (%)** | **share** |
| **1981-95** | 1,64 | -0,87 | 0,19 | 0,50 | 0,03 | 0,18 | 1,60 | 2,80 | 100 | -53 | 12 | 31 | 2 | 11 | 98 | 13 | 12 |
| **1995-01** | 4,49 | 0,98 | 0,51 | 0,17 | 0,10 | 0,19 | 2,53 | 2,97 | 100 | 22 | 11 | 4 | 2 | 4 | 56 | 14 | 17 |
| **1995-2001 less 1981-95** | 2,85 | 1,84 | 0,32 | -0,33 | 0,08 | 0,01 | 0,92 | 0,18 | 100 | 65 | 11 | -12 | 3 | 0 | 32 | 14 | 20 |
| **FRANCE** | | | | | | | | | | | | | | | | Total | $D_{IT}$ |
| | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ALP** | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ICT (%)** | **share** |
| **1981-95** | 2,12 | -0,30 | 0,16 | 0,70 | 0,01 | 0,18 | 1,36 | 2,51 | 100 | -14 | 8 | 33 | 0 | 9 | 64 | 8 | 6 |
| **1995-01** | 2,66 | 0,57 | 0,27 | 0,59 | 0,05 | 0,12 | 1,06 | 1,81 | 100 | 22 | 10 | 22 | 2 | 4 | 40 | 12 | 16 |
| **1995-2001 less 1981-95** | 0,54 | 0,87 | 0,11 | -0,12 | 0,04 | -0,06 | -0,31 | -0,70 | 100 | 161 | 20 | -21 | 8 | -12 | -56 | 28 | 28 |
| **GERMANY** | | | | | | | | | | | | | | | | Total | $D_{IT}$ |
| | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ALP** | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **ICT (%)** | **share** |
| **1981-95** | 2,30 | -0,45 | 0,23 | 0,49 | 0,01 | 0,23 | 1,78 | 2,96 | 100 | -19 | 10 | 21 | 1 | 10 | 77 | 11 | 6 |
| **1995-01** | 1,95 | -0,13 | 0,30 | 0,45 | 0,05 | 0,14 | 1,15 | 2,15 | 100 | -7 | 15 | 23 | 3 | 7 | 59 | 18 | 14 |
| **1995-2001 less 1981-95** | -0,35 | 0,31 | 0,07 | -0,04 | 0,04 | -0,09 | -0,63 | -0,81 | -100 | 89 | 19 | -13 | 10 | -26 | -180 | 29 | 35 |

**Notes**: The contribution of each input is given by the rate of growth multiplied by the value share. $Y$ = Output; $H$ = Hours worked; $K_{ICT}$ = ICT capital services; $K_{nICT}$ = non-ICT capital services; $D_{IT}$ = IT consumer durables services; $D_{nIT}$ = non-IT consumer durables services. The relative values are computed as percentage of Total Output growth ($Y = 100$): Total ICT = $K_{ICT} + D_{IT}$; $D_{IT}$ share = $D_{IT}$/Total ICT.

Table 7.b **Absolute and Relative Sources of Growth: the Input Side** (1981-2001), annual average growth rates (%-points)

| ITALY | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | ALP | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | Total ICT (%) | $D_{IT}$ share |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1981-95** | 2,23 | -0,10 | 0,22 | 0,57 | 0,01 | 0,29 | 1,24 | 2,37 | 100 | -5 | 10 | 26 | 1 | 13 | 55 | 11 | 6 |
| **1995-01** | 2,38 | 0,52 | 0,29 | 0,60 | 0,05 | 0,19 | 0,72 | 1,57 | 100 | 22 | 12 | 25 | 2 | 8 | 30 | 15 | 15 |
| **1995-2001 less 1981-95** | 0,16 | 0,62 | 0,07 | 0,03 | 0,04 | -0,10 | -0,51 | -0,79 | 100 | 400 | 46 | 21 | 25 | -62 | -330 | 71 | 35 |
| **NETHERLANDS** | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | ALP | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | Total ICT (%) | $D_{IT}$ share |
| **1986-95** | 2,79 | 0,70 | 0,24 | 0,57 | 0,04 | 0,20 | 1,04 | 1,71 | 100 | 25 | 9 | 20 | 1 | 7 | 37 | 10 | 14 |
| **1995-01** | 3,79 | 2,11 | 0,46 | 0,62 | 0,10 | 0,26 | 0,24 | 0,59 | 100 | 56 | 12 | 16 | 3 | 7 | 6 | 15 | 18 |
| **1995-2001 less 1981-95** | 1,00 | 1,40 | 0,22 | 0,05 | 0,06 | 0,06 | -0,80 | -1,12 | 100 | 141 | 22 | 5 | 6 | 6 | -80 | 28 | 23 |
| **SWEDEN** | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | ALP | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | Total ICT (%) | $D_{IT}$ share |
| **1981-95** | 1,83 | 0,17 | 0,29 | 0,43 | 0,02 | 0,06 | 0,86 | 1,57 | 100 | 9 | 16 | 24 | 1 | 3 | 47 | 17 | 6 |
| **1995-01** | 3,44 | 0,63 | 0,68 | 0,43 | 0,07 | 0,18 | 1,44 | 2,53 | 100 | 18 | 20 | 13 | 2 | 5 | 42 | 22 | 9 |
| **1995-2001 less 1981-95** | 1,61 | 0,46 | 0,39 | 0,00 | 0,05 | 0,13 | 0,58 | 0,96 | 100 | 29 | 24 | 0 | 3 | 8 | 36 | 27 | 11 |
| **UNITED KINGDOM** | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | ALP | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | Total ICT (%) | $D_{IT}$ share |
| **1981-95** | 2,82 | 0,22 | 0,25 | 0,48 | 0,10 | 0,32 | 1,44 | 2,47 | 100 | 8 | 9 | 17 | 4 | 12 | 51 | 13 | 28 |
| **1995-01** | 3,63 | 0,78 | 0,50 | 0,55 | 0,22 | 0,44 | 1,15 | 2,48 | 100 | 22 | 14 | 15 | 6 | 12 | 32 | 20 | 30 |
| **1995-2001 less 1981-95** | 0,81 | 0,56 | 0,24 | 0,07 | 0,12 | 0,11 | -0,30 | 0,01 | 100 | 70 | 30 | 9 | 15 | 14 | -37 | 45 | 33 |
| **UNITED STATES** | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | ALP | Y | H | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | TFP | Total ICT (%) | $D_{IT}$ share |
| **1981-95** | 3,04 | 1,09 | 0,38 | 0,48 | 0,05 | 0,27 | 0,76 | 1,38 | 100 | 36 | 13 | 16 | 2 | 9 | 25 | 14 | 12 |
| **1995-01** | 3,68 | 1,05 | 0,66 | 0,66 | 0,20 | 0,37 | 0,74 | 2,03 | 100 | 28 | 18 | 18 | 5 | 10 | 20 | 23 | 23 |
| **1995-2001 less 1981-95** | 0,65 | -0,05 | 0,28 | 0,19 | 0,15 | 0,10 | -0,02 | 0,65 | 100 | -7 | 44 | 29 | 23 | 16 | -3 | 66 | 34 |

**Notes**: Each contribution is given by the rate of growth multiplied by the value share.
$Y$ = Output; $H$ = Hours worked; $K_{ICT}$ = ICT capital services; $K_{nICT}$ = non-ICT capital services; $D_{IT}$ = IT consumer durables services; $D_{nIT}$ = non-IT consumer durables services. The relative values are computed as percentage of Total Output growth ($Y = 100$): Total ICT = $K_{ICT} + D_{IT}$; $D_{IT}$ share = $D_{IT}$/Total ICT.

Table 8. **Input side: EU-9 vs US** (1981-2001), annual average growth rates (%-points)

| **EUROPEAN UNION (EU-9)** | | | | | | | | | $D_{IT}$ | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **ALP** | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **(%)** | **ICT (%)** |
| **1981-95** | 2,47 | 2,31 | -0,16 | 0,22 | 0,54 | 0,03 | 0,23 | 1,45 | 1 | 11 |
| **1995-2001** | 2,27 | 2,74 | 0,47 | 0,36 | 0,53 | 0,10 | 0,22 | 1,06 | 3 | 17 |
| **1995-2001 less 1981-95** | -0,20 | 0,43 | 0,63 | 0,14 | -0,01 | 0,06 | -0,01 | -0,39 | 15 | 49 |
| **UNITED STATES** | | | | | | | | | $D_{IT}$ | **Total** |
| | **ALP** | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **(%)** | **ICT (%)** |
| **1981-95** | 1,94 | 3,04 | 1,09 | 0,38 | 0,48 | 0,05 | 0,27 | 0,76 | 2 | 14 |
| **1995-2001** | 2,64 | 3,68 | 1,05 | 0,66 | 0,66 | 0,20 | 0,37 | 0,74 | 5 | 23 |
| **1995-2001 less 1981-95** | 0,69 | 0,65 | -0,05 | 0,28 | 0,19 | 0,15 | 0,10 | -0,02 | 23 | 66 |
| **EU-9 less US** | | | | | | | | | $D_{IT}$ | **Total** |
| | **ALP** | **Y** | **H** | $K_{ICT}$ | $K_{nICT}$ | $D_{IT}$ | $D_{nIT}$ | **TFP** | **(%)** | **ICT (%)** |
| **1981-95** | 0,53 | -0,72 | -1,25 | -0,16 | 0,06 | -0,02 | -0,04 | 0,69 | 3 | 25 |
| **1995-2001** | -0,36 | -0,94 | -0,58 | -0,30 | -0,13 | -0,10 | -0,16 | 0,33 | 11 | 43 |
| **1995-2001 less 1981-95** | -0,89 | -0,22 | 0,67 | -0,14 | -0,19 | -0,08 | -0,11 | -0,37 | 38 | 101 |

**Notes**: $D_{IT}$ and Total ICT are the percentage share of IT consumer durable services and total services from ICT assets (capital and consumer durables) on total output growth.

degree of market competition and industry specialization. It is well-known that countries with less administrative regulation and large ICT industries show higher growth rates in TFP as documented by study of Nicoletti and Scarpetta (2003) on the effect of trade liberalization on industry efficiency and the EU-US comparison carried out by Inklaar *et al.* (2003) on TFP growth of ICT-producing, -using and non-ICT sectors.

Overall, the deceleration of productivity after 1995 depressed the growth performance of many countries, in particular Netherlands, Germany and Italy. The growth rates of TFP reported in Table 7 do not significatively diverge from the estimates of Timmer *et al.* (2003)[39]. There is a considerable discrepancy only for Denmark, Italy and the UK that we find to grow faster, especially in the second half of the 1990s. This outcome suggests that the inclusion of consumer durables services -in particular IT- may add some information to cross-countries analyses of productivity.

Moreover, TFP is found to decelerate in France between 1981-95 and 1995-2001 whilst it remained unchanged in the US. The latter outcome is mainly

vs leapfrog process of Japan towards the US levels.

[39]Table A.3 in the Appendix compares the estimates of output, labour productivity and TFP growth reported in similar studies. This paper sensibly differs from Timmer *et al.* (2003) in the value estimated of output growth of UK, Sweden and Denmark due to a huge imputation of consumer durables and dwellings' services. The discrepancy with Jorgenson (2004) is likely to depend on methodological differences; he employs a relative approach of growth accounting based on PPPs that allows to measure the cross-country difference in levels of variables as well.

influenced by the severe fall of 2001 (-0,81%); indeed, if this year is left out, US productivity jumps up to an annual growth rate of 1,04% for the period 1995-2000, showing an acceleration of 0,26 percentage points with respect to 1981-95.

The synthetic picture drawn in Table 8 exhibits that the growth delay of Europe stemmed from a smaller contribution of all factor inputs; the EU maintained an advantage only in TFP (+0,33%) but its growth rate was sensibly slower than in the past.
Europe was able to exclusively reduce the gap in the occupational basis; a more intensive use of labour was fuelled by the active labour market policies adopted by many countries during the 1990s (wage moderation and higher flexibility). However, as discussed in Timmer *et al.* (2003), this had strongly negative implications for output per hour worked, especially in Netherlands and the large continental countries[40]. The trade-off between occupation and labour productivity is expected to continue in Europe in the medium term because of the goal set by the Lisbon strategy to achieve a 70% occupation ratio by 2010 (Mason *et al.* (2003) and Daveri (2004))). In the more recent years GDP per hour worked slowed down further in the majority of EU member states, in particular in Italy where the level of labour productivity diminished of a 0,7% per year between 2001 and 2004[41].

Finally, but not less importantly, the comparison on the sources of the economic growth between 1981-95 and 1995-2001 (last row of Table 8) reveals that the diverging pace of development recently showed by the two Atlantic regions (-0,22%) is completely attributable to a different degree of ICT application, either for productive (-0,14%) or consuming purposes (-0,08%). Therefore, such technologies arise as a fundamental driver of the divide between the European Union and the United States, at least with regard to output growth.

[40]The measure of output used in this work is sometimes regarded unfit to study labour productivity as international differences may remain obscured by the fact that the housing markets perform differently across countries and national accounts vary in the way of computing the services of dwellings (van Ark *et al.* (2002b), p. 8). It is considered particularly unsatisfactory when the aggregate performance is decomposed into sector-specific contributions as imputed rentals for housing are artificially attributed to real estate industry under the assumption that households behave as unincorporated firms.

[41]See GGDC Total Economy Database, January 2005 (http://www.ggdc.net/dseries/).

## 3.4 The role of Information Technology across consumer durables

### A *quantitative* perspective

The usage of IT goods has become usual in people's daily-life as largely documented by several micro studies and surveys on households (see OECD (2004b), chapter 4, or ESPON (2004)). In order to depict the marked change occurred in households' habits during the 1990s, this paragraph presents in detail the role played by home computers and non-IT durable goods (furniture, vehicles, etc.) on economic growth. The point of view employed is the input side as it allows to carry out a qualitative analysis as well.

Table 9 displays the contribution to output growth of each consumer durable, reporting the total sum and the share attributable to computers in the last two columns. As previously illustrated, the US and the UK exhibit the largest growth contribution from consumer durables (0,57 and 0,65%-points) as a result of the solid expansion of the late 1990s. By contrast, the low values of the major continental countries (from 0,17 of France to 0,25% of Italy) reflect the less favourable phase faced in those years; thus, such downward trend ends to enhance the rise of home computer services. The growth contribution of home computers in the United Kingdom was substantial also before the turning-point of 1995 (0,10% per year before and 0,22% later) while Denmark and the US reveal an impressive increase only more recently. It is nonetheless important to notice that, aside from the bigger countries and Sweden, the output growth attributable to IT durables in Europe is diffusely larger than non-IT goods. Home computers accounted for around a third of total contribution provided by durables services in Austria, Finland, UK and US, reaching a fifty percent in Denmark[42].

In absolute terms, France, Germany and Italy present a scarce propensity to adopt Information Technology at home as demonstrated by the fact that vehicles, audio-visual equipment and, even, furniture in case of Italy outstripped the contribution of home computers. Nevertheless, such finding may be partly affected by the government incentives disbursed during the 1990s (in France and Italy) to promote cars' sales. Instead, the commitment of policy institutions to sustain the digitalization of the European society started later, mainly from the Lisbon Conference[43]. Overall, as evident from the bottom panel of Table 9, despite the surge of Information Technology

[42]The frictional growth of traditional goods is at the basis of the large share of IT in total contribution of consumer durables in France.

[43]Miniaci and Paradisi (2004) for a brief summary of the policy measures recently adopted in Italy.

Table 9. **Growth contribution of consumer durables** (1981-2001), annual average growth rates (% -points)

| AUSTRIA | growth rates | | | | | | | | contributions | | | | | | | Total | P&S on |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FUR | KIT | OTH | VEI | A&V | P&S | ORD | Y | FUR | KIT | OTH | VEI | A&V | P&S | ORD | CDs | CDs (%) |
| **1981-95** | 3,5 | 1,6 | 4,7 | 3,9 | 9,3 | 36,2 | 1,4 | 2,61 | 0,06 | 0,01 | 0,02 | 0,08 | 0,07 | 0,02 | 0,00 | **0,27** | **8** |
| **1995-2001** | 3,1 | 4,1 | 0,9 | 3,0 | 7,6 | 43,6 | -1,4 | 2,79 | 0,07 | 0,03 | 0,00 | 0,07 | 0,07 | 0,11 | 0,00 | **0,35** | **32** |
| **change post-1995** | -0,4 | 2,6 | -3,8 | -0,9 | -1,7 | 7,4 | -2,7 | 0,18 | 0,00 | 0,02 | -0,02 | -0,01 | 0,00 | 0,09 | 0,00 | **0,08** | |
| **DENMARK** | | | | | | | | | | | | | | | | **Total** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | -1,2 | 0,7 | 0,7 | 2,1 | 4,3 | 34,5 | -0,1 | 2,05 | -0,01 | 0,00 | 0,00 | 0,04 | 0,04 | 0,06 | 0,00 | **0,12** | **45** |
| **1995-2001** | 2,0 | 3,1 | 1,5 | 3,6 | 5,9 | 37,7 | 1,5 | 3,05 | 0,02 | 0,01 | 0,01 | 0,09 | 0,05 | 0,18 | 0,00 | **0,37** | **49** |
| **change post-1995** | 3,2 | 2,4 | 0,7 | 1,6 | 1,6 | 3,2 | 1,6 | 1,01 | 0,04 | 0,01 | 0,00 | 0,05 | 0,01 | 0,13 | 0,00 | **0,25** | |
| **FINLAND** | | | | | | | | | | | | | | | | **Tot** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | 2,6 | 3,8 | 1,3 | 1,9 | 5,0 | 30,9 | 1,0 | 1,64 | 0,03 | 0,02 | 0,01 | 0,07 | 0,04 | 0,03 | 0,01 | **0,21** | **13** |
| **1995-2001** | 1,3 | 2,9 | 2,6 | 4,0 | 6,3 | 44,0 | 1,0 | 4,49 | 0,02 | 0,02 | 0,01 | 0,10 | 0,05 | 0,10 | 0,00 | **0,30** | **35** |
| **change post-1995** | -1,3 | -0,9 | 1,3 | 2,1 | 1,3 | 13,2 | 0,0 | 2,85 | -0,01 | 0,00 | 0,01 | 0,03 | 0,00 | 0,08 | 0,00 | **0,09** | |
| **FRANCE** | | | | | | | | | | | | | | | | **Tot** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | 1,3 | 2,8 | 0,0 | 3,0 | 7,4 | 34,5 | 0,8 | 2,12 | 0,02 | 0,02 | 0,00 | 0,07 | 0,07 | 0,01 | 0,00 | **0,19** | **5** |
| **1995-2001** | 0,0 | 2,5 | -0,2 | 2,0 | 5,9 | 48,2 | 0,1 | 2,66 | 0,00 | 0,02 | 0,00 | 0,05 | 0,06 | 0,05 | 0,00 | **0,17** | **31** |
| **change post-1995** | -1,4 | -0,3 | -0,1 | -1,0 | -1,5 | 13,7 | -0,7 | 0,54 | -0,02 | 0,00 | 0,00 | -0,03 | -0,01 | 0,04 | 0,00 | **-0,02** | |
| **GERMANY** | | | | | | | | | | | | | | | | **Tot** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | 2,1 | 2,2 | 1,0 | 3,5 | 4,7 | 32,4 | 2,0 | 2,30 | 0,04 | 0,02 | 0,01 | 0,10 | 0,06 | 0,01 | 0,00 | **0,24** | **6** |
| **1995-2001** | 1,7 | 1,8 | 1,2 | 2,1 | 2,1 | 40,9 | 1,8 | 1,95 | 0,03 | 0,01 | 0,01 | 0,07 | 0,02 | 0,05 | 0,00 | **0,19** | **26** |
| **change post-1995** | -0,4 | -0,4 | 0,1 | -1,3 | -2,6 | 8,5 | -0,2 | -0,35 | -0,01 | 0,00 | 0,00 | -0,03 | -0,04 | 0,04 | 0,00 | **-0,05** | |
| **ITALY** | | | | | | | | | | | | | | | | **Tot** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | 5,1 | 3,0 | 4,4 | 4,3 | 5,1 | 32,0 | 4,0 | 2,23 | 0,10 | 0,03 | 0,02 | 0,09 | 0,03 | 0,01 | 0,01 | **0,30** | **5** |
| **1995-2001** | 2,5 | 1,6 | 2,1 | 3,2 | 4,3 | 43,7 | 1,3 | 2,38 | 0,06 | 0,01 | 0,01 | 0,08 | 0,02 | 0,05 | 0,00 | **0,25** | **22** |
| **change post-1995** | -2,6 | -1,4 | -2,3 | -1,1 | -0,8 | 11,7 | -2,7 | 0,16 | -0,04 | -0,02 | -0,01 | -0,02 | -0,01 | 0,04 | -0,01 | **-0,06** | |
| **NETHERLANDS** | | | | | | | | | | | | | | | | **Tot** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | 3,4 | 5,1 | 2,7 | 0,2 | 7,8 | 19,1 | 1,7 | 2,79 | 0,06 | 0,02 | 0,02 | 0,00 | 0,10 | 0,04 | 0,00 | **0,24** | **16** |
| **1995-2001** | 3,4 | 4,8 | 1,8 | 3,4 | 6,9 | 42,3 | 3,1 | 3,79 | 0,06 | 0,02 | 0,01 | 0,08 | 0,08 | 0,10 | 0,01 | **0,36** | **28** |
| **change post-1995** | -0,1 | -0,2 | -0,9 | 3,2 | -0,9 | 23,2 | 1,4 | 1,00 | 0,00 | 0,00 | -0,01 | 0,08 | -0,01 | 0,06 | 0,00 | **0,13** | |
| **SWEDEN** | | | | | | | | | | | | | | | | **Tot** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | 1,8 | 1,6 | 2,5 | -0,4 | 5,5 | 26,8 | -5,5 | 1,83 | 0,01 | 0,00 | 0,02 | 0,00 | 0,05 | 0,02 | -0,02 | **0,08** | **25** |
| **1995-2001** | 1,6 | 0,8 | 1,6 | 5,9 | 4,8 | 44,2 | -1,9 | 3,44 | 0,01 | 0,00 | 0,01 | 0,13 | 0,04 | 0,07 | 0,00 | **0,25** | **27** |
| **change post-1995** | -0,1 | -0,8 | -0,9 | 6,3 | -0,7 | 17,5 | 3,5 | 1,61 | 0,00 | 0,00 | -0,01 | 0,13 | -0,01 | 0,05 | 0,02 | **0,18** | |
| **UNITED KINGDOM** | | | | | | | | | | | | | | | | **Tot** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | 2,0 | 4,1 | 2,8 | 4,6 | 10,1 | 25,9 | 4,6 | 2,82 | 0,03 | 0,03 | 0,02 | 0,14 | 0,09 | 0,10 | 0,01 | **0,42** | **24** |
| **1995-2001** | 3,3 | 3,6 | 5,6 | 4,5 | 10,5 | 40,3 | 6,6 | 3,63 | 0,05 | 0,03 | 0,04 | 0,17 | 0,13 | 0,22 | 0,02 | **0,65** | **33** |
| **change post-1995** | 1,3 | -0,5 | 2,8 | -0,1 | 0,4 | 14,3 | 2,1 | 0,81 | 0,02 | -0,01 | 0,02 | 0,02 | 0,04 | 0,12 | 0,01 | **0,23** | |

**Notes**: FUR=Furniture, KIT=households appliances, OTH=Other home furnishings, VEI=vehicles, A&V=Audio-visual and photographic equipment, P&S=Personal computer and bundled softwares, ORD=Other major recreational durables; Y=Output; Tot CDs=total contribution of consumer durables to output growth ( $\sum_{i=1} D_i$, i=FUR, KIT, OTH, VEI, A&V, P&S, ORD), P&S share=100*(P&S/Tot CDs).

Table 9.b **Growth contribution of consumer durables** (1981-2001), annual average growth rates (%-points)

| | growth rates | | | | | | | | contributions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EUROPEAN UNION (EU-9)** | | | | | | | | | | | | | | | | **Tot** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | 2,4 | 2,9 | 1,7 | 3,5 | 6,4 | 27,9 | 2,0 | 2,31 | 0,04 | 0,02 | 0,01 | 0,09 | 0,06 | 0,03 | 0,00 | **0,26** | **12** |
| **1995-2001** | 2,1 | 2,5 | 2,4 | 3,1 | 6,0 | 41,6 | 2,8 | 2,74 | 0,04 | 0,02 | 0,01 | 0,09 | 0,06 | 0,10 | 0,01 | **0,31** | **30** |
| **change post-1995** | -0,4 | -0,4 | 0,6 | -0,4 | -0,4 | 13,7 | 0,8 | 0,43 | 0,00 | 0,00 | 0,00 | 0,00 | -0,01 | 0,06 | 0,00 | **0,05** | |
| **UNITED STATES** | | | | | | | | | | | | | | | | **Tot** | **P&S on** |
| | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **Y** | **FUR** | **KIT** | **OTH** | **VEI** | **A&V** | **P&S** | **ORD** | **CDs** | **CDs (%)** |
| **1981-95** | 3,3 | 2,9 | 3,7 | 3,6 | 8,3 | 50,7 | 3,7 | 3,04 | 0,03 | 0,01 | 0,03 | 0,11 | 0,07 | 0,05 | 0,02 | **0,33** | **16** |
| **1995-2001** | 4,6 | 3,0 | 5,3 | 4,7 | 8,2 | 43,8 | 6,3 | 3,68 | 0,04 | 0,01 | 0,04 | 0,17 | 0,07 | 0,20 | 0,04 | **0,57** | **35** |
| **change post-1995** | 1,3 | 0,1 | 1,6 | 1,1 | -0,1 | -6,9 | 2,5 | 0,65 | 0,01 | 0,00 | 0,01 | 0,06 | 0,00 | 0,15 | 0,02 | **0,25** | |

**Notes**: FUR=Furniture, KIT=households appliances, OTH=Other home furnishings, VEI=vehicles, A&V=Audio-visual and photographic equipment, P&S=Personal computer and bundled softwares, ORD=Other major recreational durables; Y=Output; Tot CDs=total contribution of consumer durables to output growth ( $\sum_{i=1} D_i$, i=FUR, KIT, OTH, VEI, A&V, P&S, ORD), P&S share=100*(P&S/Tot CDs).

across EU households after 1995 (+0,06%), a very large fraction of the difference between Europe and the US in the growth contribution of consumer durables comes from home computers and, to a lesser extent, vehicles.

### A *qualitative* perspective

The examination of the quality growth of consumer durables is based on the index ($q_t$) employed by Jorgenson and Stiroh (2000), p. 195, to gauge the innovative profile of capital.

The widespread uptake of hi-tech assets by firms has significatively enhanced the knowledge content (quality) of aggregate capital stock as IT goods are characterized by a vertiginous technical progress. This is at the basis of the rapid decline in prices and economic obsolescence of these assets which, accordingly, need to earn a high rent to offset the huge value loss. For such reason, IT capital presents a marginal productivity superior to traditional equipment.

As this aspect is grasped by rental price (see section 2.3), a quality measure can be obtained by the ratio between the economic value of the aggregate capital stock, that is evaluated at the user cost, and its market value $\left(q_t = \frac{\sum_i \nu_{i,t} D_{i,t}}{\sum_i \omega_{i,t} D_{i,t}}\right)$[44]. Therefore, an increase in the quality index

$$\Delta \ln q_t = \sum_i (\bar{\nu}_{i,t} - \bar{\omega}_{i,t}) \Delta \ln D_{i,t}. \tag{6}$$

[44] $\nu_{i,t}$ and $\omega_{i,t}$ are the nominal shares of each asset on the economic and market value of capital (or consumer durables).

reflects the substitution towards more short-lived assets featured by high marginal product (rental price).

Figure 4 presents a complete picture on the quality change determined by the replacement of old assets with new, hi-tech goods adopted either for production or consumption aims.

The top panel illustrates the marked rise in quality of firms' capital experienced by all countries in the late 1990s. Despite the sharp improvement exhibited by Sweden, UK, Denmark and Netherlands (1,5% and more per year), there is a widening in the innovative profile of capital between the EU and the US after 1995 when quality grew respectively by an annual rate of 1,1 and 1,7%.

Interestingly, note that the innovation rate of firms doubled in Austria and Italy in the late 1990s with respect to 1981-95 (both +0,5%). A careful scrutiny of data reveals that such rise has foundation in a valuable growth of IT capital for the former country; instead, Italy benefited from a marked increase in transport equipment that is notoriously characterized by a relatively high innovation rate across non-ICT goods.

By contrast, the low value of Finland is caused either by a slow growth of IT assets or a large share of communication equipment that, as known, is featured by modest rates of depreciation and deflation compared to computers. In Germany, instead, the sizeable quality growth determined by the widespread adoption of office machinery contrasts to an almost-zeroed contribution of non-IT assets.

A significant improvement in the aggregate quality of consumer durables occurred during the 1990s in both Atlantic regions, even though at rates inferior to capital goods (0,4 - 1,7% against 0,6 - 3,4%)[45].

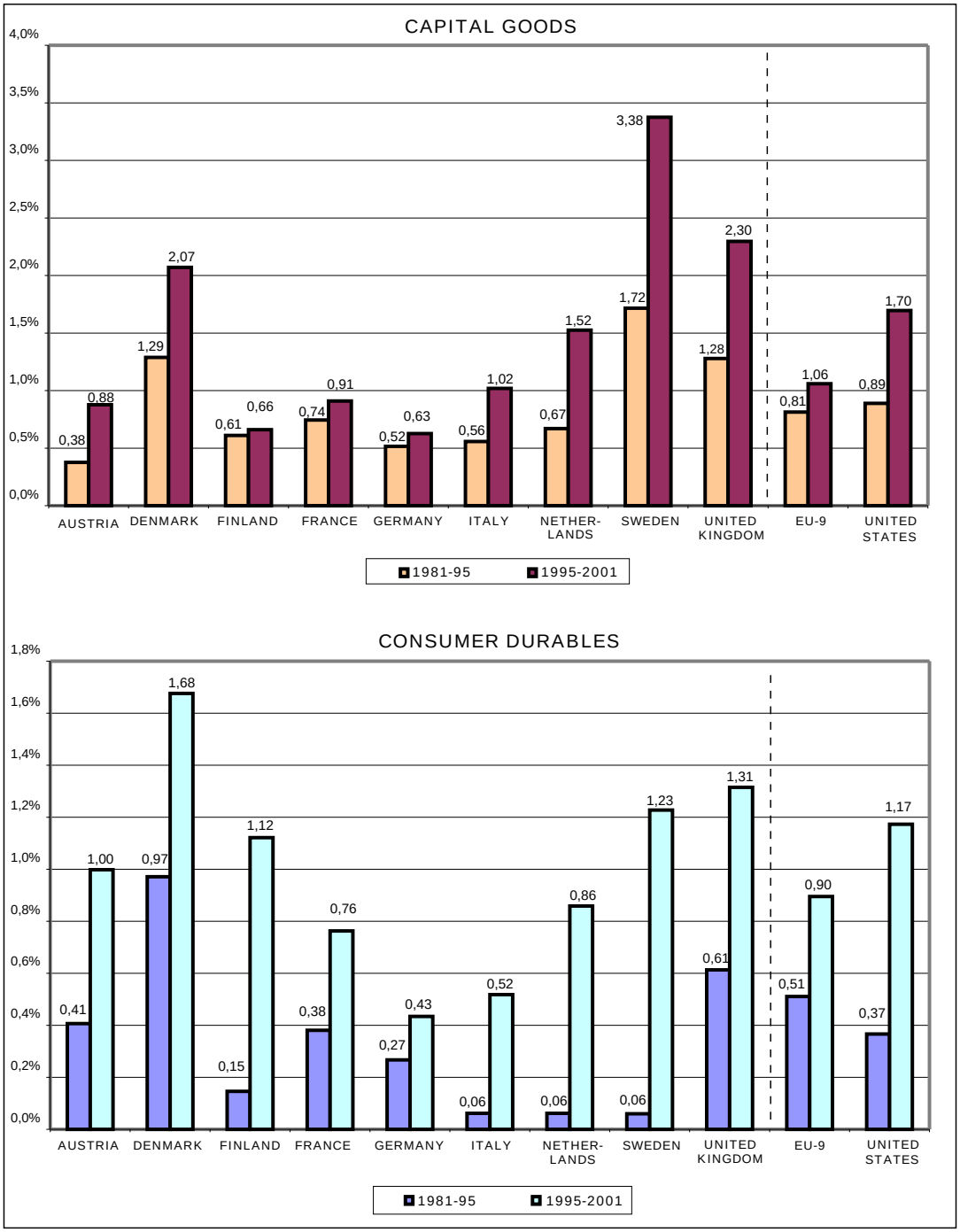
Danish households show the most innovative profile in both periods; the growth rate of the quality index climbed up to 1,7% per year between 1995-2001 from 1% of the previous period, exclusively for the massive uptake of computers.

Instead, the rise in the quality of consumer durables in Austria, France and Netherlands was driven by vehicles and audio-visual equipment. These goods exhibited a sensible technical improvement in the last years as well; even though to a minor extent, they have been affected by the fundamental advances in semiconductors technology, especially some goods such as cameras, video recorders, TV, etc.

Aside from Germany where the low or negative contribution of non-IT goods

[45]This outcome is partly influenced by the inclusion of dwellings across consumer durables in this section. Residential structures are typically characterized by a minimal growth of quality with respect to the other goods.

Figure 4. **Quality growth of capital assets and consumer durables** (1981-95 and 1995-2001), annual average growth rates (%)



offset the effect of computers diffusion, the rise in quality of consumer durables was largely significant. The acceleration was impressive in Finland and Sweden (around one percent per year) where the increasing share of computers summed up to a favorable dynamics in vehicles.
Overall, the slow uptake of high-tech goods exhibited by European households in the late 1990s translated into a lower innovative profile of consumer durables compared to the United States (0,9 against 1,7%); this contrasts with the figures of the foregoing period when the rise in the quality of domestic stock of consumer durables was slightly higher in Europe (0,5 against 0,4%).

In conclusion, the comparison between the two panels of Figure 4 allows to observe that in Austria and Finland the quality of consumer durables grew faster than for capital goods in the late 1990s (+0,1 and +0,5%). The fact that for Austria this also happened between 1981 and 1995 suggests that in such country households might be characterized by a innovative propensity more pronounced than firms.

# 4 Concluding remarks

The body of research that investigates on the link between technological capital and economic growth has extensively described the great impact exerted by the application and production of ICT on the US resurgence. In contrast, Europe has exhibited a scarce ability in catching the growth opportunity supplied by the advances in semiconductors and computers technology.
This work has added a new piece of information to this branch of research, showing that a non-negligible fraction of the growth gap between the Atlantic regions is attributable to a different degree of computer adoption at home.
By employing a well-consolidated framework of growth accounting it has been illustrated that the contribution of IT consumption to the output growth was generally larger than firms' investment in communication and software in the late 1990s. This means that, thus far, a sizeable part of the economic impact of ICT has been neglected or not accurately analyzed; such lack assumes a certain importance whenever home computers are found to influence aggregate productivity.
Overall, the EU delay in the IT uptake by households - the growth contribution is around a half of the US one - is strictly affected by the scarce innovative propensity of the major countries (France, Germany and Italy). In contrast, Denmark and the United Kingdom show adoption rates similar to the US; in particular, British households stand out for a long-term, diffused familiarity with IT goods.

Evidently, this work offers only a partial outlook on the social and economic transformations related to IT consumption such as spillovers; more conclusive results call for some econometric tests. Thus far, because of the lack of comparable data, the econometric literature on the link between IT capital and TFP growth is still rather scarce at the economy-wide level of analysis[46], especially if compared to industry studies which, however, do not present univocal outcomes.
The controversy on the presence of IT spillovers does not only regard the slowdown age -before 1995- when the stock of high-tech equipment was relatively small[47] but also features the most recent studies. For instance, in contrast to the uncorrelation found by Stiroh (2002), a proof of the positive link between ICT and TFP is reported by O'Mahony and Vecchi (2004). Controlling for the industry heterogeneity and the dynamic properties of high-tech investment, they find a coefficient for ICT capital significatively higher than the income share. Such outcome admits the possibility of an excess of returns for this asset kind.

[46]To our knowledge, the sole analyses carried out across countries employ private data for ICT expenditure (WITSA); see for instance Dewan and Kraemer (2000) and Park and Shin (2004).

[47]For instance, whereas Siegel and Griliches (1992), Morrison (1997) Siegel (1997) find a positive correlation, on the other hand, Berndt and Morrison (1995) provide evidence of a negative link between IT capital and the index of disembodied technical change.

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# Appendix

## Data Sources

- *GDP*, *Housing*, *Changes in Inventories* (at current and constant prices) and *Employment* (in persons): OECD National Accounts 2003, on-line release from 1970 onwards; 1953-1969 OECD National Accounts, various issues;

- *Gross Fixed Capital Formation*, *Gross Fixed Capital Stock* (except *Housing*) and *Hours worked* (1980-2001): GGDC Total Economy Growth Accounting Database;

- *Implicit deflator* for *Total Manufacturing Value Added* (1970-2001): OECD STAN Database;

- *Production* (current prices) of "Office machinery and computing equipment" (cat. 30 ISIC Rev. 3): OECD STAN Database 2003, on-line release; for Italy unpublished data for 1980-90 were kindly provided by Colin Webb (OECD);

- *Consumption* (less Information processing equipment): OECD National Accounts 2003, on-line release for Austria (1980-2001) and Italy (1970-2001).
  Denmark (1966-2001): *StatDen*, on-line release, September 2003; Finland (1975-2001): *StatFin*, July 2003; France (1960-2001): *INSEE*, March 2004; Germany (1970-90 for West Germany, 1991-2001 for Unified Germany): *Statistisches Bundesamt*, February 2004; Netherlands (1985-2001): *CBS*, February 2004; Sweden (1980-2001): *SCB*, on-line release from 1993-2001, September 2003; United Kingdom (1964-2001): *ONS*, on-line release, October 2003, USA (1947-2001): *BEA*, on-line release, December 2003;

- *Information processing equipment* (P&S): see Table A.1.

### Particular cases

*Germany*: official data after unification are available from 1991, while series relative to West German since 1970. Figures on Unified Germany for 1980-90 are estimated through the *linking method*, similarly to OECD (see OECD (2003), p. 256). Data back to 1970 are built from the 1991 level of Unified Germany by applying the growth rates of West Germany.

Table A.1 **Data sources for IT Consumption**

| | **National Accounts** | **Period** | **Commodities Flow Method**[c] | **Period** |
|---|---|---|---|---|
| **Austria** | Stat. AT[a] | 1995-2001 | Stat. AT I-O Table 1990 | 1980-1995 |
| **Denmark** | Stat. DK | 1966-2001 | | |
| **Finland** | Stat. FI[a] | 1975-2001 | | |
| **France** | INSEE | 1960-2001 | | |
| **Germany** | Not Available | | OECD I-O Tables 1978, 1986, 1988, 1990, 1995 | 1980-2001 |
| **Italy** | ISTAT[b] | 1995-2000 | OECD I-O Tables 1985, 1992 | 1980-1995, 2001 |
| **Netherlands** | CBS[a] | 1985-2001 | | |
| **Sweden** | Stat. SE | 1993-2001 | 1993 share on Production of cat. 30 | 1980-1993 |
| **United Kingdom** | Stat. UK | 1964-2001 | | |
| **United States** | BEA | 1977-2001 | | |

**Notes**:
a) Provided by National Statistical Offices on request of author;
b) From Italian Make-and-Use tables 1995-2000, February 2004;
c)

$$C_t = (O_t - E_t + M_t)s_b, \qquad s_b = \frac{C^{IO}}{O^{IO} - E^{IO} + M^{IO}};$$

$s_b$ is the expenditure coefficient obtained from the benchmark OECD I-O tables. It is applied to domestic final sales of 'Office machinery' (cat. 30 ISIC Rev. 3) extracted from OECD STAN database. $O_t$ is gross production, $E_t$ exports, $M_t$ imports. For Italy we adopted an unpublished series kindly provided by Colin Webb (OECD). $s_b$ is interpolated between benchmark years and maintained constant for years before (and after) the first (and last) observation available.

*Netherlands*: households' purchases are classified according to COICOP from 1987 onwards. Series following a similar classification are available for 1985-86 as well. Therefore, in order to smooth series, such values are linked to COICOP series by employing the growth rates of 1985 and 1986.

*Sweden*: COICOP series are available only from 1993. However, SCB provided us with very detailed quarterly data for the period 1980-98. In this respect, such data have been converted into an annual base and aggregated as closely as possible to 2-digit COICOP categories. Then, once provided with such aggregates, the *linking method* has been used to build the detailed level of consumption expenditure for 1980-98 from the official values of 1993.

Table A.2 **Real growth rates of ICT expenditure** (1981-95 and 1995-2001), annual average growth rates (%)

| **AUSTRIA** | | | | | **ITALY** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ | | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ |
| **1981-1995** | 38 | 16 | 5 | 15 | **1981-1995** | 31 | 13 | 8 | 12 |
| **1995-2001** | 41 | 30 | 5 | 20 | **1995-2001** | 41 | 27 | 10 | 9 |
| **DENMARK** | | | | | **NETHERLANDS** | | | | |
| | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ | | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ |
| **1981-1995** | 34 | 15 | 5 | 17 | **1981-1995** | 19 | 14 | 2 | 10 |
| **1995-2001** | 36 | 23 | 4 | 9 | **1995-2001** | 44 | 26 | 5 | 17 |
| **FINLAND** | | | | | **SWEDEN** | | | | |
| | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ | | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ |
| **1981-1995** | 32 | 18 | 14 | 12 | **1981-1995** | 28 | 17 | 5 | 17 |
| **1995-2001** | 43 | 12 | 23 | 12 | **1995-2001** | 43 | 25 | 7 | 16 |
| **FRANCE** | | | | | **UNITED KINGDOM** | | | | |
| | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ | | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ |
| **1981-1995** | 34 | 18 | 7 | 11 | **1981-1995** | 26 | 19 | 9 | 20 |
| **1995-2001** | 44 | 26 | 9 | 16 | **1995-2001** | 41 | 26 | 9 | 6 |
| **GERMANY** | | | | | **UNITED STATES** | | | | |
| | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ | | $C_{IT}$ | $I_{IT}$ | $I_{Com}$ | $I_{Sw}$ |
| **1981-1995** | 34 | 15 | 5 | 15 | **1981-1995** | 48 | 15 | 4 | 14 |
| **1995-2001** | 39 | 27 | 6 | 9 | **1995-2001** | 41 | 20 | 10 | 13 |

**Notes**: $C_{IT}$=IT consumption; $I_{IT}$= Investment in IT equipment; $I_{Com}$= Investment in communication equipment; $I_{Sw}$= Investment in software.

Table A.3 **A Comparison on output, labour productivity and TFP** (1995-2001), annual average growth rates (%)

| | **Timmer et al. (2003)** | | | **This work** | | | **Jorgenson (2004)** | | | **Jorgenson et al. (2003)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Y** | **ALP** | **TFP** | **Y** | **ALP** | **TFP** | **Y** | **ALP** | **TFP** | **Y** | **ALP** | **TFP** |
| **AUSTRIA** | 2,4 | 2,7 | 1,3 | 2,8 | 3,1 | 1,9 | - | - | - | - | - | - |
| **DENMARK** | 2,5 | 1,8 | 0,3 | 3,1 | 2,4 | 1,1 | - | - | - | - | - | - |
| **FINLAND** | 4,5 | 3,0 | 2,7 | 4,5 | 3,0 | 2,5 | - | - | - | - | - | - |
| **FRANCE** | 2,6 | 1,7 | 0,9 | 2,7 | 1,8 | 1,1 | 2,3 | 1,4 | 0,6 | - | - | - |
| **GERMANY** | 1,5 | 1,7 | 0,9 | 2,0 | 2,1 | 1,2 | 1,2 | 1,3 | -0,5 | - | - | - |
| **ITALY** | 1,9 | 1,1 | 0,1 | 2,4 | 1,6 | 0,7 | 1,9 | 0,9 | -0,1 | - | - | - |
| **NETHERLANDS** | 3,3 | 0,1 | -0,1 | 3,8 | 0,6 | 0,2 | - | - | - | - | - | - |
| **SWEDEN** | 2,8 | 1,9 | 1,3 | 3,4 | 2,5 | 1,4 | - | - | - | - | - | - |
| **UNITED KINGDOM** | 2,8 | 1,7 | 0,5 | 3,6 | 2,5 | 1,1 | 2,7 | 1,7 | 0,9 | - | - | - |
| **EUROPEAN UNION*** | **2,4** | **1,4** | **0,5** | **2,7** | **2,7** | **1,1** | **-** | **-** | **-** | **-** | **-** | **-** |
| **UNITED STATES** | **3,5** | **1,9** | **0,8** | **3,7** | **2,0** | **0,7** | **4,2** | **2,7** | **1,0** | **3,6** | **2,2** | **0,4** |

**Notes**:* EU-14 in Timmer *et al.* (2003), EU-9 in this work.