

HOW MUCH DOES IT CONSUMPTION MATTER FOR GROWTH? EVIDENCE FROM NATIONAL ACCOUNTS

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La letteratura sulla new economy sinora ha prestato scarsa attenzione all'adozione di prodotti informatici da parte delle famiglie, trascurando una parte considerevole della crescita economica riconducibile alle ICT.

Questo studio fa luce su questo aspetto mediante un'analisi di *growth accounting*, mostrando come l'Europa, ad eccezione di Danimarca e Regno Unito, abbia tratto dal consumo high-tech un beneficio minore rispetto agli Stati Uniti. Nel complesso, poi, il divario tra queste due regioni nella dinamica di sviluppo risulta largamente dipendente dal differente grado di utilizzo delle ICT, sia per scopi di produzione che di consumo.

The literature on the new economy has thus far paid little attention to households' adoption of Information Technologies, leaving un-assessed a sizeable part of the IT-led growth.

This work fills such a lack carrying out a growth accounting analysis on a wide group of EU countries and the US. It shows that, aside from Denmark and UK, Europe has benefited from a smaller growth contribution from IT consumption than the US. Overall, the divergence in the dynamic pattern of growth between these two regions results widely dependent on a different application of ICT, both for production and consumption purposes. [JEL codes: E21, E22, O3, O4]

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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. The EU authorities set of stimulating the spread of Information Technology across firms and households as key operative goal of a broad strategy to increase competitiveness and lead Europe towards a high growth track¹.

Thus 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 these 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 production². 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 are sensibly lower, 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 the 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, instead, have driven the 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 favourable 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 re-organizations were delayed by strong oppositions (Gordon, 2004). Both

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”. European Council (2000), par. 8.

² Pilat and Wolf (2004) gauge the effect of ICT production and usage on productivity growth of OECD countries.

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; 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); rather, the main disease of the European economy seems to reside in the diffused weakness of non-durable manufacturing³. Indirectly, a confirmation of this 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 the firm level is rather rich; see, for instance, the surveys of Dedrick et al. (2003) and Pilat (2004). A lot of attention has also been devoted 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 change⁴. 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 Klenow (2002) investigate on the environmental factors influencing the computer purchase: they find that the proximity of intensive users enhances the probability of buying a PC. Miniaci and Paradisi (2004) analyse 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, this outcome 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 improve the individual ability similarly to the usage on the workplace; thus, high-tech consumption arises as a potential source of skill-enrichment, certainly more than the traditional consumption activities.

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

⁴ See Acemoglu (2002).

There is also another reason at the basis of interest for households' propensity towards Information Technology. Services industry 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 such a propensity, the growth potential of ICT might remain partially unexploited; in this respect, IT consumption may influence aggregate productivity as well as the usage of IT equipment by firms⁵. This explains the strong commitment of the EU institutions in raising the IT literacy and the degree of connectivity of European citizens⁶.

The present 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 describes more in detail than in the past the European delay in the digitalization process of the economy. Clearly, the framework employed does not allow to pick up all the growth effects of ICT such as spillovers (or network externalities), which can be identified only through an econometric analysis. Nevertheless, this paper should be interpreted as a preliminary step in that direction.

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 similarly to investment goods. Section 3 displays the results for the EU and the US; 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 growth contribution of IT consumption close -and *even* larger- to the US. The comparison on the sources of output growth between 1981-95 and 1995-2001 reveals, then, that the different application of ICT, both for production and consumer purposes, entirely accounts for the diverging pace of development recently showed by the two Atlantic regions. Finally, section 4 concludes.

⁵ The home adoption of computers has increased the hours worked outside the workplace which, consequently, are not picked up by official statistics; for this reason, labour contribution to output growth may be underestimated as partly attributed to the residual efficiency. This aspect is discussed in Gordon (2004), p. 40.

⁶ See European Commission (2001), section 5.

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*):

$$(1) \quad Y(C_t, I_t) = A_t f(K_t, L_t).$$

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 choices⁷.

The present 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. This imputation guarantees a consistent treatment between (owner-occupied) residential buildings and (owner-utilized) consumer durables. Indeed, 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), a similar procedure is not followed for consumer durable goods.

The extended version of eq. (1) fills such a gap by including a flow of services for this kind of products, estimated through an user cost⁸ (time sub-scripts are omitted to simplify notation):

$$(2) \quad Y(Y_{nICT}, C_{IT}, I_{ICT}, D_{IT}) = A f(H, K_{ICT}, K_{nICT}, D_{IT}, D_{nIT}).$$

The output side comprises households' purchases of computers (C_{IT}), firms' investment in IT equipment, communication equipment 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}).

⁷ The US resurgence has renewed the interest of researchers for TFP. See Hulten (2000) for a description of the properties of this index and Stiroh (2002) for some related interpretative problems. A survey on the way to formulate the impact of technical change on growth (*embodiment controversy*) is provided by Venturini (2004a); with this regard, Limpsey and Carlaw (2004) have recently raised the possibility that technical change and TFP may be uncorrelated.

⁸ See Christensen et al. (1981), p. 72. The need of treating consumer durables as investment goods was originally put forward by 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) suggest that motor vehicles services should be capitalized through the fee paid to lease a car. Instead, Katz and Peskin (1980) build an user cost alternative either to the *observed market rent* (Fraumeni and Okubo's one) or to the traditional *rental price* (used in this work), based on the operative expenses to manage consumer durables (*opportunity cost measure*).

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 at 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 ($\sum_i \omega_i = \sum_i v_i = 1$). Thus, the (log) first differences of the previous equation yield:

$$(3) \quad \bar{\omega}_{Y,nICT} \Delta \ln Y_{nICT} + \bar{\omega}_{C,IT} \Delta \ln C_{IT} + \bar{\omega}_{I,ICT} \Delta \ln I_{ICT} + \bar{\omega}_{D,IT} \Delta \ln D_{IT} = \\ = \bar{v}_H \Delta \ln H + \bar{v}_{K,ICT} \Delta \ln K_{ICT} + \bar{v}_{K,nICT} \Delta \ln K_{nICT} + \bar{v}_{D,IT} \Delta \ln D_{IT} + \bar{v}_{D,nIT} \Delta \ln D_{nIT} + \Delta \ln A,$$

where the bars denote two-years means of the income shares, deriving from the Tornqvist's formula adopted 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 the GGDC Total Economy Growth Accounting database⁹. 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 the 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 the OECD input-output tables to the final domestic sales of Office machinery and computer industry.

In order to preserve the comparability among 'investment goods' of households (buildings and consumer durables), a measure of the dwellings stock has been constructed from the value of housing reported in the OECD National Accounts. As in Jorgenson and Stiroh (2000), inventories have also been taken into account while, by contrast, land is excluded due to the lack of data (see Table 1).

Consumption series have been collected from national statistics offices and, whenever necessary, integrated with the 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

⁹ This data set is downloadable at URL <http://www.ggdc.net/series/totecon.shtml#top>; it has been employed by van Ark et al. (2002b), Timmer et al. (2003) and, more recently, by OECD to estimate multi-factor productivity.

‘commodity flow’ method has been employed to estimate the values relative to Austria, Germany, Italy and Sweden (see the Appendix)¹⁰.

Table 1: Expenditure variables and depreciation rates of stocks

INVESTMENT GOODS		CONSUMER DURABLES		
	Depre- ciation rate		Depre- ciation 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
Inventories	0.0000	Other major durables for recreation and culture	0.1650	9.2
Residential buildings	0.0120			

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; for IT equipment see Melka et al. (2003), p. 44.

The matching of various sources presented two main difficulties. Firstly, the US National Accounts (NIPA) do not perfectly fit the international classification of consumption (COICOP) and, accordingly, 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. Secondly, expenditure in Telephone and telefax equipment is not taken into consideration as available only for few countries; therefore, the outline presented in the following underestimates the propensity towards hi-tech goods of Finland and Italy, which typically 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 between 1995 and 2001). Italy is the sole country, then, where households’ expenditure for TLC equipment outstrips computer consumption (by a factor of three times)¹¹.

This lack clearly limits the scope of the analysis as it neglects a key factor of the new economy, acknowledged as potential source of network externalities. The technological convergence between Information and Communication Technology has enhanced the importance of TLC equipment as

¹⁰ This approach mimics the one followed by statistical agencies; see, for instance, BEA (1990) for the US and Corea et al. (2000) for Italy. Despite input-output tables follow a classification of production activities (ISIC Rev. 3), there is a full correspondence with the category of computer consumption, because of the irrelevance of secondary productions from other industries.

¹¹ For consumption of TLC equipment, the estimates obtained with the ‘commodity flow’ method do not seem reliable for some countries and, consequently, have not been taken into account.

tool for the Internet access as demonstrated by the increasing share of connections achieved through the TV cable modem or UMTS mobiles¹².

2.3. From nominal expenditure to the productive services of capital

2.3.1. Price Harmonization

Since the mid-1990s the deflation of ICT goods has vertiginously accelerated as a result of the impressive rise in semiconductors' efficiency and the consequent fall in prices. The miniaturization of chips has fuelled the rapid quality improvement of a wide range of high-tech goods, in particular computers whose production costs are accounted for a half by this kind of intermediate inputs¹³.

New PCs perform an increasing amount of tasks as better endowed relative to old models in terms of processing speed and storage capacity; this is the reason why computers are difficultly comparable over time, even between adjacent periods, and 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 since they monitor the price of the same good over time, evidently failing when some characteristics significantly change¹⁴. Hedonic pricing is the most consolidated technique allowing for the rapid growth in quality of ICT goods, as it estimates the unit price as a function of a bundle of product characteristics; accordingly, a PC is evaluated as computing power rather than as a physical box.

In international comparisons a homogeneous treatment has to be guaranteed to quality adjustment of hi-tech products; otherwise, methodological discrepancies in prices measurement may obscure real differences across countries. Figure 1 shows that the gap among national indexes for IT consumption may be very considerable, reaching a factor of 30 times between the US and Finland in 2001.

In order to avoid this problem, IT consumption is deflated employing the price harmonization method proposed by Schreyer (2002). By assuming a global model of relative prices ($P_{ICT}^i / P_n^i = P_{ICT}^{US} / P_n^{US}$), one can use the US deflator for ICT (P_{ICT}^{US}) in place of national price indexes

¹² As formerly pointed out, the development of communication infrastructures is one of the main operative goals pursued by the European Commission, as witnessed by the large effort in monitoring the penetration of ICT across households (INRA, 2004) and firms (e-Business W@tch program). An outline of telecommunication trends in Europe is drawn in ESPON (2004), where the focus is restricted on regional disparities.

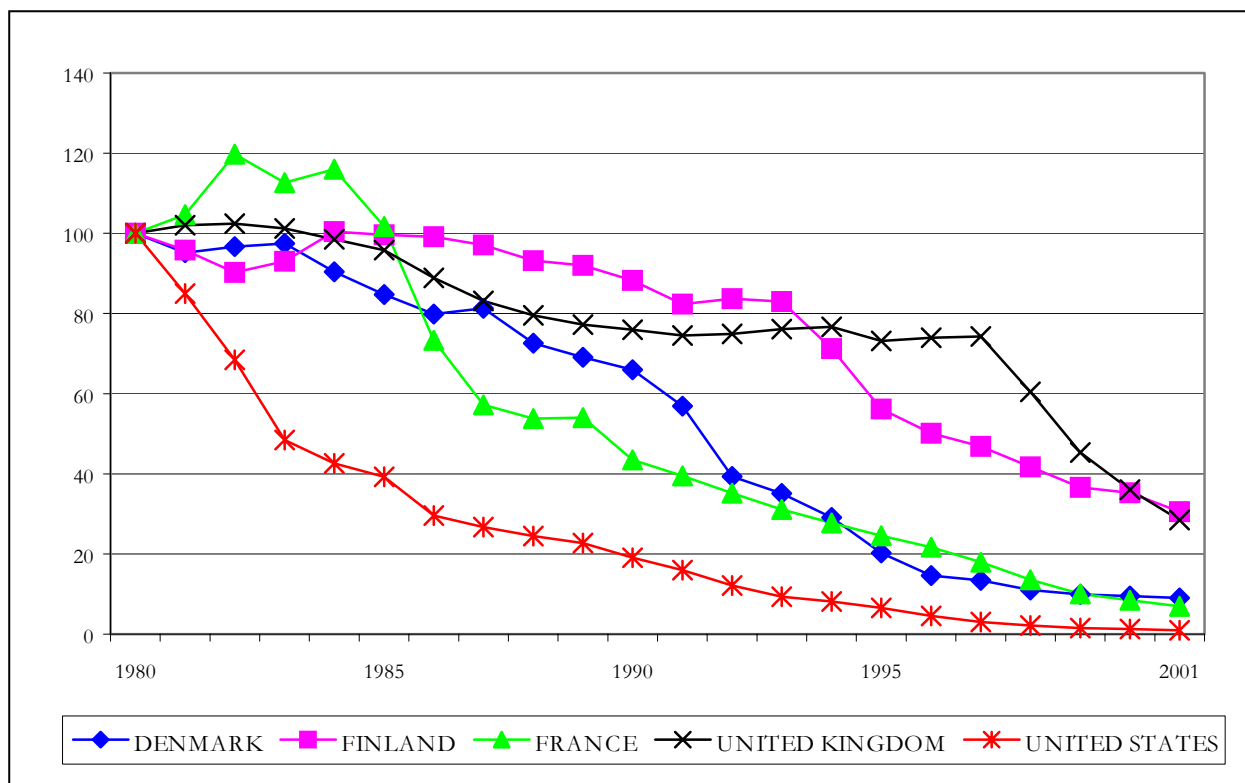
¹³ Jorgenson (2001) influentially describes the impact of semiconductors technology on US productivity growth.

¹⁴ Traditional and hedonic methods are compared in the OECD handbook edited by Triplett (OECD, 2004b).

(P_n^i), after a correction for the differential in consumer durables inflation (P_n^{US} for the US and P_n^i for the EU countries)¹⁵:

$$(4) \quad \Delta \ln P_{ICT}^i = \Delta \ln P_{ICT}^{US} - \Delta \ln P_n^{US} + \Delta \ln P_n^i.$$

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



In order to reach the highest degree of data comparability, two further adjustments have been implemented. Firstly, price harmonization has also been applied to consumption of audio-visual equipment, to avoid the understatement stemming from the residual mechanism of computation of the real value of this aggregate (see Table 1). Secondly, as in Oulton (2001), the official figures for GDP have been corrected in the light of the new estimates of ICT volumes¹⁶. 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), since smaller weights are now attributed to ICT goods (Schreyer, 2001). As the index replacement partly offsets the quality adjustment of hi-tech

¹⁵ The US Bureau of Economic Analysis employs a hedonically adjusted price index to deflate more than a 20 percent of final expenditure; with regard to consumption, it is applied to a wide range of products, from kitchens to PCs and audio-visual equipment. In eq. (4), P_{ICT}^i is estimated as a three-years average of prices change, similarly to 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 while Daveri (2002) uses US prices corrected for the oscillations in exchange rate.

¹⁶ Oulton (2001), p. 17, re-estimates the GDP growth rate by re-aggregating the sub-components; inventories are proportionally imputed to other aggregates.

expenditure, the *pure harmonization effect* can be identified only for such countries as France, Netherlands and Sweden, which originally employ chain aggregation (see OECD, 2003)¹⁷.

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

	GDP	INV	P&S	A&V	GDP*	GDP	INV	P&S	A&V	GDP*
	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>1+4</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>1+4</i>
	Austria					Italy				
1981-95	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
Change post-1995	0.13				0.14	-0.01				0.18
	Denmark					Netherlands^{o†}				
1981-95	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
Change post-1995	0.77				1.06	0.59				0.91
	Finland					Sweden[†]				
1981-95	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
Change post-1995	2.21				2.66	1.20				1.52
	France[†]					United Kingdom				
1981-95	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
Change post-1995	0.57				0.54	0.39				0.89
	Germany					United States[†]				
1981-95	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
Change post-1995	-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 and consumption of audio-visual equipment (A&V).

[†] Originally based on chain-weighted aggregation.

^o Netherlands refer to 1986-95 and 1995-2001.

For France the overall adjustment is minimal (0.10%) as INSEE makes a somewhat use of hedonic pricing; instead, it is of a certain importance for Netherlands and Sweden (0.43 and 0.49% per annum; Table 2). Nevertheless, the size of correction is remarkable especially for the remaining countries, given the depressive effect of index substitution (from 0.25 of Austria to 0.53% of the UK). Note that the price adjustment reduces the EU-US gap in the GDP growth rate of the last years, in particular for those countries intensively spending in ICT for productive (Sweden) and consumption purposes (UK and, to a lesser extent, Denmark).

¹⁷ Table 2 displays the correction factors of GDP 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).

2.3.2. 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 geometric depreciation from series on real expenditure ($I_{i,t}$), assuming no retirement ($F_{i,\tau}=I$) and a time-invariant share of efficiency loss for various vintages ($d_{i,t}=I - \delta_i$):

$$(5) \quad S_{i,t} = \sum_{\tau=0}^T d_{i,\tau} F_{i,\tau} I_{i,t-\tau} = \sum_{\tau=0}^T (1 - \delta_i)^\tau I_{i,t-\tau}.$$

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:

$$(6) \quad S_{i,0} = \sum_{\tau=0}^{\infty} I_{i,-\tau} (1 - \delta_i)^\tau = \frac{I_{i,1}}{g_i + \delta_i};$$

g_i is the growth rate of real expenditure calculated over all the time span (see Guellec and van Pottelsberghe, 2001), while depreciation rates (δ_i) are assumed constant over time and identical across countries (see Table 1)¹⁸. Finally, a measure of productive capital is obtained with the mid-year adjustment of the stocks resulting from eq. (5) ($K_{i,t}=(S_{i,t-1}+S_{i,t})/2$); this device partly mitigates the assumption of regarding capital as fully productive since its installation.

The growth contribution of each asset is given by the growth rate of capital services weighted by the nominal output share, which is estimated with the rental price (or user cost; $c_{i,t}$). $c_{i,t}$ derives from the annualization of the market price of an asset into the price of the corresponding capital input and is identifiable with its marginal product:

$$(7) \quad c_{i,t} = P_{i,t-1}(i_t + \delta_i - \pi_{i,t} + \delta_i \pi_{i,t}).$$

$\pi_{i,t}=(P_{i,t}-P_{i,t-1})/P_{i,t-1}$ is the investment inflation rate, while i_t the nominal rate of return (that is equal for all markets under the assumption of perfect competition)¹⁹.

The user cost is preferred to the market price as allowing for both the efficiency- and price-profile of different asset types (see Jorgenson and Griliches, 1967); in this respect, it provides a qualitative distinction of capital. Such an aspect has become of great importance with the acceleration in the

¹⁸ For IT equipment δ_i is variable over time as derived from the aggregation of assets featured by different depreciation rates and time-varying shares. All vehicles are depreciated at the same rate (0.255), without distinguishing across cars, motorcycles, etc. As in Oulton (2001), the stock of inventories is priced with the implicit deflator for manufacturing value added.

¹⁹ The internal rate (i_t) has been computed with the ‘ex post approach’; it uses capital revenue reported in National Accounts (Gross Operating Surplus and Mixed Income) once detracted the amount of labour income attributable to self-employed (OECD, 2001, p. 88); the formula utilised is displayed by van Ark et al. (2002b), p. 25. Similarly to Colecchia and Schreyer (2002), this work adopts the discrete time version of the rental price formula (without taxation).

innovative activity of hi-tech industries that has speeded up the deflation and economic obsolescence of ICT; consequently, these assets have to earn a high rent (user cost) in order to be profitable. An indication of capital quality can be thus obtained by the ratio between its economic (based on rental prices) and market value; this aspect will be extensively discussed in section 3.4.

3. The growth contribution of IT consumption

3.1. IT expenditure in Europe and United States

A lot of attention has been thus far paid to the EU delay relative to the United States in firms' adoption of ICT; this is considered one of the reasons at the basis of the slower pace of development recently exhibited by Europe and leads to moderate the prospective growth expectations of this region. Nevertheless, a better understanding of the role played by Information Technology on economic growth also requires an examination of consumption, either for the direct impact on GDP (output side) or as potential source of productivity spillovers (input side). This section presents a first evidence on households' propensity towards high-tech goods, showing the similarities (and differences) between expenditure in home computers and investment pattern of firms in Information Technology.

Figure 2 illustrates how the slow convergence of Europe (EU-9)²⁰ towards the US investment rates in office machinery is not matched by a similar trend both in communication and software investment and, especially, households' expenditure for computers. In Europe IT consumption increased sharply only between 1994 and 1998, but remained nearly unchanged from then on; the US, instead, experienced a pronounced rise all through the past decade. As a result, at the end of the millennium these regions revealed a propensity of households towards hi-tech consumption completely reversed relative to the early 1980s, when Europe was clearly ahead.

The variability in ICT uptake is comprehensibly large in the EU, both across countries and within each country according to the kind of ICT considered. For instance, Finland stands out for a high value of TLC investment while ranks on the bottom with regard to firms' purchases of office machinery²¹. A synthetic prospect of such a heterogeneity is provided in Figure 3²²; the lack of data on consumption of communication equipment and non-bundled software leads to restrict the analysis on computers and other office machinery; therefore, the picture drawn offers only a partial representation of the digitalization degree of the Atlantic economies.

²⁰ The EU mean is obtained by summing the country figures converted at the national currency/euro exchange rates as of 1 January 1999 (Timmer et al., 2003); the sample analysed in this study represented a 86% of EU-15 GDP in 2001.

²¹ The international comparison on ICT spending may be undermined by the difficulty in updating the expenditure classification to new products because of the technical convergence between Communication and Information Technology (Ahmad et al., 2003).

²² See Guerrieri et al. (2004) for a cluster analysis on a broader group of countries.

Figure 2: Share of ICT Expenditure in GDP (1980-2001), current prices (%)

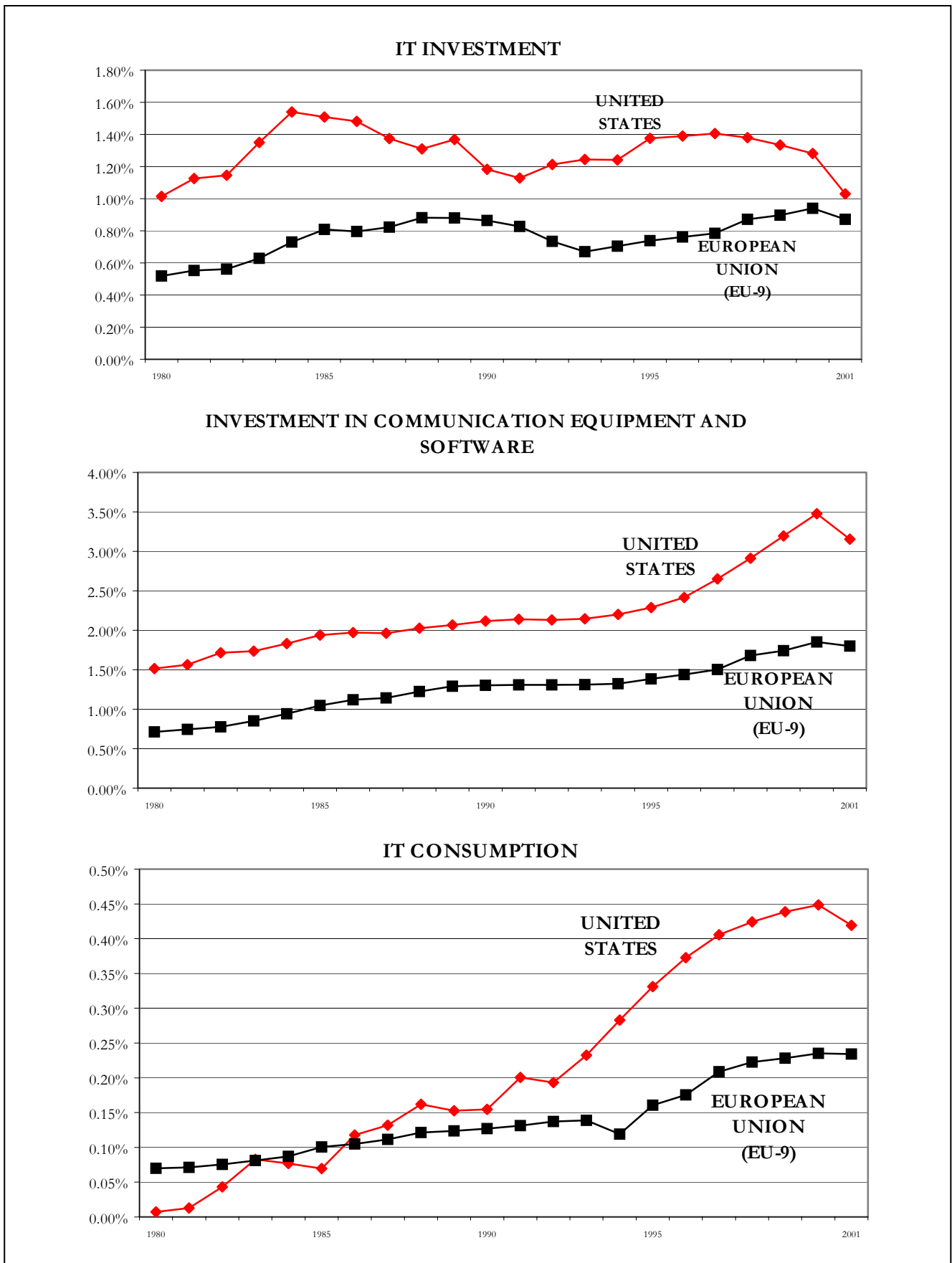
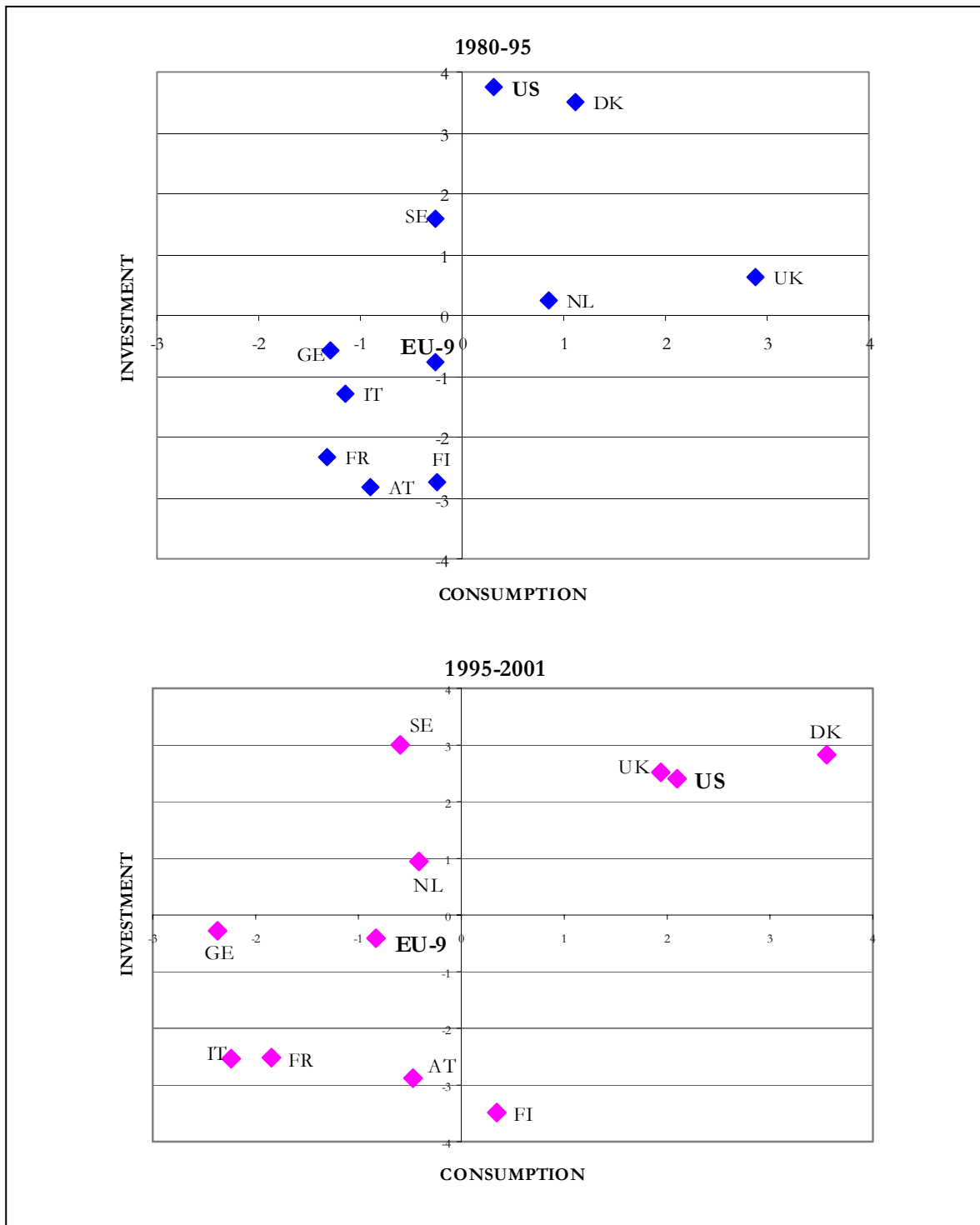


Figure 3: A synthetic prospect of IT expenditure (1980-95 and 1995-2001), deviations from sample mean (%)



Notes: The annual share of investment in office machinery is computed on Gross Fixed Capital Formation (at current prices) while IT consumption on total expenditure for consumer durables; the panels depict the average deviation of each country from the sample mean.

Figure 3 plots the annual average deviation from the sample mean of the IT share in firms' investment (y -axis) and households' expenditure for consumer durables (x -axis). Considering both profiles together, one can note the divergence of Sweden and Netherlands from the cluster of high-spenders (Denmark, US and UK) for a relatively low value of consumption between 1995 and 2001; instead, Finland outdistances low-spenders (France, Germany, Italy and Austria)²³ for a higher expenditure in home computers. The comparison between the two sections of Figure 3 suggests that firms reacted more similarly than households to the price shock of the mid-1990s, as witnessed by the major homogeneity in the average rate of investment.

The picture arising from National Accounts (Table 3) is fully consistent with the penetration rates of ICT goods surveyed across households (Table 4). Sweden is the sole notable exception as it classifies on the top ranking when one considers direct interviews, in sharp contrast with the low figures on consumption spending. This discrepancy is likely to depend on the different nature of sources, even though it may virtually signal a per capita expenditure in home computers considerably lower than elsewhere.

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

	INVESTMENT										EU-9	US
	Austria	Denmark	Finland	France	Germany	Italy	Netherlands	Sweden	United Kingdom			
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										EU-9	US
	Austria	Denmark	Finland	France	Germany	Italy	Netherlands	Sweden	United Kingdom			
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	

Table 4 confirms the leading position of Denmark in terms of consumer applications of Information Technology (computers, Internet and broadband); Danish households devoted a 10% of durables expenditure to computers in 2001 (about one percent of total consumption), a percentage at least four times higher than the value achieved by the major continental countries (Table 3).

²³ Figure A.1 in the Appendix presents in detail the dynamics of IT expenditure in national GDP; this section analyses instead the share of IT in total investment and expenditure in consumer durables to control more accurately for the heterogeneity across countries (development stage, demographic composition, housing market, etc.).

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

	Austria	Denmark	Finland	France	Germany	Italy	Nether-lands	Sweden	United Kingdom	EU-9	EU-15	US*
Mobile phones	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).

* US figures are expressed 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 Key ICT indicators (www.oecd.org/statportal).

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 majority of the EU countries since the early 1980s, especially as share of GDP (see Figure A.1 in the Appendix)²⁴.

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 exhibiting an output growth superior to a 3% per year between 1995 and 2001 (Table 5)²⁵.

Finland rebounded (4.5%) after the deep recession of the early 1990s when 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%). 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 at the economy-wide and the industry level, especially because it was driven by a revival in output per hour worked. At the basis of the 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; p. 2). This is confirmed by

²⁴ Schmitt and Wadsworth (2002) report that the US have overtaken the UK in terms of PC ownership rate of households from the mid-1990s; the British delay already amounted to 1.7 years in 1998. More importantly, a large difference emerges *within* rather than *between* countries because of a high inequality across income groups.

²⁵ Hereinafter the analysis employs the broad concept of output (GDP plus the services of consumer durable).

the new extraordinary cycle of labour productivity started in 2000 (Gordon, 2003)²⁶ and 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 the major economies was favoured by the modest pace of development of the large 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%)²⁷.

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 in the 1980s. Nevertheless, a meaningful acceleration materialized around 1995 when the extraordinary innovative activity of semiconductors firms translated into a marked efficiency gain; 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 whilst the price decline of investment in office machinery was slightly slower (-0.19%)²⁸. As a result, real expenditure of households for PCs increased by around a 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 (Table 5). Sweden and the US exhibit a development pattern dominated by ICT that contributed in average for 0.7 percentage points to the output growth in the late 1990s, that is a fifth of total. On the other hand, the value of high-tech expenditure was only a half in France, Italy and Germany (0.3-0.35%).

Decomposing the output growth in relative terms²⁹, one can note that the German figures are close to big ICT spenders (18%); it signals the marked propensity of this country towards high-tech goods, mainly for productive purposes, and that the low absolute value is probably affected by the depressive phase of 1995-2001.

²⁶ According to the US Bureau of Labour Statistics, the growth rate of output per hour worked of non-farm business sector climbed up to a 4.3% per year in 2001-04 from a 2.5% of 1995-2001 (<http://www.bls.gov/bls/productivity.htm>).

²⁷ Annual tables are available from the author on request.

²⁸ Investment in communication equipment and software showed a flatter fall in prices compared to PCs (-3 and -0.5%); van Ark et al. (2002b) summarize the methodology underlying the construction of US price index for software.

²⁹ The annual average rate is normalized to 100.

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

	ABSOLUTE CONTRIBUTIONS							RELATIVE CONTRIBUTIONS							Total ICT (%)	C _{IT} share
	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}		
Austria																
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
1995-2001	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																
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
1995-2001	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																
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
1995-2001	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																
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
1995-2001	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																
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
1995-2001	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} = Investment in Communication equipment ; I_{SW} = Investment in Software; D_{IT} = IT consumer durables services. The relative values are computed as percentage of output growth (Y = 100); the last two columns report the percentage contribution of ICT expenditure to aggregate output (Total ICT) and the share of IT consumption in total ICT contribution (C_{IT} share).

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

Italy	ABSOLUTE CONTRIBUTIONS							RELATIVE CONTRIBUTIONS							Total ICT (%)	C _{IT} share
	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}		
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
1995-2001	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
1981-95	2.79	2.53	0.03	0.12	0.01	0.07	0.04	100	91	1	4	0	2	1	8	14
1995-2001	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
1995-2001	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
1995-2001	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
1995-2001	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} = Investment in Communication equipment ; I_{SW} = Investment in Software; D_{IT} = IT consumer durables services. The relative values are computed as percentage of output growth (Y = 100); the last two columns report the percentage contribution of ICT expenditure to aggregate output (Total ICT) and the share of IT consumption in total ICT contribution (C_{IT} share).

As the most dynamic component of expenditure, ICT drove the surge in output growth after 1995 of such low hi-tech spending countries as Austria and Italy as well (penultimate column of Table 5). The weight of ICT in smaller Nordic states was less pronounced due to a more favourable business cycle that enhanced the demand for a wide range of goods. Relative to these spending patterns, the United 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 illustrated, households' expenditure in computer acquired a certain importance only in the last period, showing a wide heterogeneity across countries. Consider that the growth 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 investment in communication equipment and software in all countries with the sole exception of France and Italy; this shows how a large part of the economic impact of ICT has thus far remained hidden or not explicitly taken into account.

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

European Union (EU-9)								percentage	
	Y	Y_{ICT}	C_{IT}	I_{IT}	I_{COM}	I_{SW}	D_{IT}	C_{IT}	Total 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								percentage	
	Y	Y_{ICT}	C_{IT}	I_{IT}	I_{COM}	I_{SW}	D_{IT}	C_{IT}	Total 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								percentage	
	Y	Y_{ICT}	C_{IT}	I_{IT}	I_{COM}	I_{SW}	D_{IT}	C_{IT}	Total 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 and consumption) in aggregate output growth.

A particular mention has to be reserved to the United Kingdom. The growth contribution of IT consumption between 1995 and 2001 was bigger than the sum of British firms' expenditure in

communication equipment and software and outstripped *even* the value of office machinery investment registered in Austria, Finland, France and Italy. UK citizens show a well-established familiarity with Information Technology as witnessed by the considerable weight of home computers in ICT expenditure since the early 1980s (last column of Table 5).

Moreover, it is also worthwhile remarking the share of IT consumption in hi-tech spending of Austria (around one quarter of total), a percentage higher than the value showed by Denmark and the US.

The aggregate figures of Europe (EU-9)³⁰ illustrate that around a third of the growth gap with the US of the late 1990s depended on ICT output (Table 6). Aside from investment in office machinery, the United States presented a growth contribution of ICT twice larger than Europe. In addition, the widening in the EU-US difference in output growth after 1995 (-0.22 percentage points) can be widely attributed to the less dynamic hi-tech spending of Europe (57%); the delay in IT expenditure for consumption purposes represents, then, a fifth of this gap (22%).

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 considerable in Sweden and the US (two thirds of percentage 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 against 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 a half of low-tech capital (around 0.30%). It is important to pinpoint, however, that Germany slightly differs from this pattern; indeed, the performance of high-tech equipment cannot be considered negligible if compared to the sluggish trend of traditional capital. Whereas the contribution of low-tech assets amounts to around 0.60%-points in France and Italy, it was only of 0.45% in Germany.

Looking at the change between 1981-1995 and 1995-2001, it is possible to note that the acceleration of output in Finland and France was primarily determined by a more intensive use of labour while the two asset types showed a diverging dynamics. In Sweden the sensible rise in the growth contribution of ICT capital (+0.39% with respect to 1981-95) was not accompanied by a

³⁰ National growth rates are weighted with the shares on the EU income, obtained by converting country values at the national currency/euro exchange rates as of 1 January 1999.

similar trend in traditional assets. Instead, a more rapid accumulation of both kinds of capital was the key factor behind the US resurgence (0.47 out of 0.65%).

Table 7 illustrates clearly the large share of output growth attributable to consumer durables (IT and non-IT) in the UK and the US at the end of the 1990s³¹. 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 group. 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 the states if one looks at low-tech consumer durables. Nevertheless, because of the dismal trend in output growth, the contribution of IT consumer durables appears relevant for these 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 towards the levels of the most advanced economies (Austria, Finland and Sweden)³². On the other hand, this index also mirrors the 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; see, respectively, Nicoletti and Scarpetta (2003) and Inklaar et al. (2003).

The deceleration of Hicks-neutral productivity after 1995 depressed the growth performance of many countries, in particular Netherlands, Germany and Italy. Our estimates of TFP growth, reported in Table 7, do not significantly diverge from Timmer et al. (2003)³³. Nevertheless, the substantial discrepancy arisen for Denmark, Italy and the UK, whose Hicks-neutral efficiency is here estimated to grow faster, suggests that the inclusion of consumer durables services -in particular IT- may add some information to international analyses of productivity.

Moreover, in contrast to Timmer et al. (2003), TFP is found to decelerate in France between 1981-95 and 1995-2001 whilst, similarly, it remained unchanged in the US. The latter outcome is mainly 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.

³¹ A more detailed description of the growth contribution of consumer durables is provided in the following paragraph.

³² See Islam (2003) for a regression analysis on technological convergence carried out on a wide sample of countries. Cameron (2005), instead, focuses on the catch-up (and leapfrog) process of Japan towards the US.

³³ Table A.2 in the Appendix compares the estimates on output, labour productivity and TFP growth of similar studies. This paper sensibly differs from Timmer et al. (2003) in the estimation of output growth of UK, Sweden and Denmark because of 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 cross-country differences in levels as well.

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

Austria	ABSOLUTE CONTRIBUTIONS								ALP	RELATIVE CONTRIBUTIONS								Total ICT (%)	D _{IT} share
	Y	H	K _{ICT}	K _{nICT}	D _{IT}	D _{nIT}	TFP	Y		H	K _{ICT}	K _{nICT}	D _{IT}	D _{nIT}	TFP				
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		
1995-2001	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	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	2.05	0.08	0.31	0.36	0.06	0.07	1.17	1.94	100	4	15	18	3	3	57	18	15		
1995-2001	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	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	1.64	-0.87	0.19	0.50	0.03	0.18	1.60	2.80	100	-53	12	31	2	11	98	13	12		
1995-2001	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	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	2.12	-0.30	0.16	0.70	0.01	0.18	1.36	2.51	100	-14	8	33	0	9	64	8	6		
1995-2001	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	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	2.30	-0.45	0.23	0.49	0.01	0.23	1.78	2.96	100	-19	10	21	1	10	77	11	6		
1995-2001	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: 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; ALP= average labour productivity.

The relative values are computed as percentage of output growth (Y = 100); the last two columns report the percentage contribution of total services from ICT assets -capital and consumer durables- to aggregate output (Total ICT) and the share of IT consumer durables in total ICT contribution (D_{IT} share).

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

Italy	ABSOLUTE CONTRIBUTIONS								ALP	RELATIVE CONTRIBUTIONS							Total ICT (%)	D _{IT} share
	Y	H	K _{ICT}	K _{nICT}	D _{IT}	D _{nIT}	TFP	Y		H	K _{ICT}	K _{nICT}	D _{IT}	D _{nIT}	TFP			
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	
1995-2001	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	
1981-95	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	
1995-2001	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	
1995-2001	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	
1995-2001	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	
1995-2001	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; ALP= average labour productivity.

The relative values are computed as percentage of output growth (Y = 100); the last two columns report the percentage contribution of total services from ICT assets -capital and consumer durables- to aggregate output (Total ICT) and the share of IT consumer durables in total ICT contribution (D_{IT} share).

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

European Union (EU-9)									percentage	
	ALP	Y	H	K_{ICT}	K_{nICT}	D_{IT}	D_{nIT}	TFP	D_{IT}	Total 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									percentage	
	ALP	Y	H	K_{ICT}	K_{nICT}	D_{IT}	D_{nIT}	TFP	D_{IT}	Total 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									percentage	
	ALP	Y	H	K_{ICT}	K_{nICT}	D_{IT}	D_{nIT}	TFP	D_{IT}	Total 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 shares of IT consumer durable services and total services from ICT assets (capital and consumer durables) in aggregate output growth.

The synthetic picture drawn in Table 8 shows that the growth delay of Europe stemmed from a smaller contribution of all factor inputs; the EU maintained an advantage only in TFP in the late 1990s (+0.33%) but its growth rate was sensibly slower than in the past.

Europe was able to reduce the gap in the occupational basis in the latter part of the last decade (0.67%); a more intensive use of labour was fuelled by the active labour market policies adopted by many countries in those years (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 countries³⁴. 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). Indeed, more recently, 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 by an annual 0.7% between 2001 and 2004³⁵.

³⁴ The broad 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).

³⁵ See GGDC Total Economy Database, January 2005 (<http://www.ggdc.net/dseries>).

Finally, but not less importantly, the comparison on the sources of 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 consumption purposes (0.08%). Therefore, these technologies arise as a fundamental driver of the divide between the European Union and the United States, at least with regard to output growth.

3.4 The role of Information Technology across consumer durables

A quantitative perspective

The usage of IT goods has become customary in people's daily-life as widely documented by several micro studies and surveys on households (see OECD, 2004b, ch. 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 biggest overall 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) are influenced by the slow economic growth of those years and, finally, the total contribution from consumer durables decreased compared to the previous period.

The growth contribution of home computers in the United Kingdom was substantial also before the turning-point of 1995 (0.10% per year and 0.22% later) while Denmark and the US experienced an impressive increase only more recently. It is nonetheless important to notice that, aside from the major countries and Sweden, the output growth attributable to the services of hi-tech goods in Europe is diffusely larger than non-IT products. Home computers accounted for around a third of total contribution provided by consumer durables in Austria, Finland, UK and US, reaching a fifty percent in Denmark³⁶.

In absolute terms, France, Germany and Italy present a scarce propensity to adopt Information Technology at home as demonstrated by the fact that the value of vehicles, audio-visual equipment, and even furniture in Italy, is superior to the contribution of computers.

³⁶ Nevertheless, note how in France the fractional growth of traditional goods enlarges the share of IT in total contribution of consumer durables.

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

Austria									Total CDs	P&S on CDs (%)
Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD			
1981-95	2.61	0.06	0.01	0.02	0.08	0.07	0.02	0.00	0.27	8
1995-2001	2.79	0.07	0.03	0.00	0.07	0.07	0.11	0.00	0.35	32
1995-2001 less 1981-95	0.18	0.00	0.02	-0.02	-0.01	0.00	0.09	0.00	0.08	
Denmark									Total CDs	P&S on CDs (%)
Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD			
1981-95	2.05	-0.01	0.00	0.00	0.04	0.04	0.06	0.00	0.12	45
1995-2001	3.05	0.02	0.01	0.01	0.09	0.05	0.18	0.00	0.37	49
1995-2001 less 1981-95	1.01	0.04	0.01	0.00	0.05	0.01	0.13	0.00	0.25	
Finland									Tot CDs	P&S on CDs (%)
Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD			
1981-95	1.64	0.03	0.02	0.01	0.07	0.04	0.03	0.01	0.21	13
1995-2001	4.49	0.02	0.02	0.01	0.10	0.05	0.10	0.00	0.30	35
1995-2001 less 1981-95	2.85	-0.01	0.00	0.01	0.03	0.00	0.08	0.00	0.09	
France									Tot CDs	P&S on CDs (%)
Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD			
1981-95	2.12	0.02	0.02	0.00	0.07	0.07	0.01	0.00	0.19	5
1995-2001	2.66	0.00	0.02	0.00	0.05	0.06	0.05	0.00	0.17	31
1995-2001 less 1981-95	0.54	-0.02	0.00	0.00	-0.03	-0.01	0.04	0.00	-0.02	
Germany									Tot CDs	P&S on CDs (%)
Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD			
1981-95	2.30	0.04	0.02	0.01	0.10	0.06	0.01	0.00	0.24	6
1995-2001	1.95	0.03	0.01	0.01	0.07	0.02	0.05	0.00	0.19	26
1995-2001 less 1981-95	-0.35	-0.01	0.00	0.00	-0.03	-0.04	0.04	0.00	-0.05	
Italy									Tot CDs	P&S on CDs (%)
Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD			
1981-95	2.23	0.10	0.03	0.02	0.09	0.03	0.01	0.01	0.30	5
1995-2001	2.38	0.06	0.01	0.01	0.08	0.02	0.05	0.00	0.25	22
1995-2001 less 1981-95	0.16	-0.04	-0.02	-0.01	-0.02	-0.01	0.04	-0.01	-0.06	
Netherlands									Tot CDs	P&S on CDs (%)
Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD			
1981-95	2.79	0.06	0.02	0.02	0.00	0.10	0.04	0.00	0.24	16
1995-2001	3.79	0.06	0.02	0.01	0.08	0.08	0.10	0.01	0.36	28
1995-2001 less 1981-95	1.00	0.00	0.00	-0.01	0.08	-0.01	0.06	0.00	0.13	
Sweden									Tot CDs	P&S on CDs (%)
Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD			
1981-95	1.83	0.01	0.00	0.02	0.00	0.05	0.02	-0.02	0.08	25
1995-2001	3.44	0.01	0.00	0.01	0.13	0.04	0.07	0.00	0.25	27
1995-2001 less 1981-95	1.61	0.00	0.00	-0.01	0.13	-0.01	0.05	0.02	0.18	
United Kingdom									Tot CDs	P&S on CDs (%)
Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD			
1981-95	2.82	0.03	0.03	0.02	0.14	0.09	0.10	0.01	0.42	24
1995-2001	3.63	0.05	0.03	0.04	0.17	0.13	0.22	0.02	0.65	33
1995-2001 less 1981-95	0.81	0.02	-0.01	0.02	0.02	0.04	0.12	0.01	0.23	

Continued...

European Union (EU-9)									Tot	P&S on
	Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD	CDs	CDs (%)
1981-95	2.31	0.04	0.02	0.01	0.09	0.06	0.03	0.00	0.26	12
1995-2001	2.74	0.04	0.02	0.01	0.09	0.06	0.10	0.01	0.31	30
1995-2001 less 1981-95	0.43	0.00	0.00	0.00	0.00	-0.01	0.06	0.00	0.05	
United States									Tot	P&S on
	Y	FUR	KIT	OTH	VEI	A&V	P&S	ORD	CDs	CDs (%)
1981-95	3.04	0.03	0.01	0.03	0.11	0.07	0.05	0.02	0.33	16
1995-2001	3.68	0.04	0.01	0.04	0.17	0.07	0.20	0.04	0.57	35
1995-2001 less 1981-95	0.65	0.01	0.00	0.01	0.06	0.00	0.15	0.02	0.25	

Notes: Y=Output; FUR=Furniture, KIT=kitchens and household appliances, OTH=Other home furnishings, VEI=vehicles, A&V=Audio-visual and photographic equipment, P&S=Personal computer and bundled software, ORD=Other major recreational durables. Tot CDs is the total contribution of consumer durables to output growth; the last column reports the percentage share of computers in the total contribution of consumer durables.

Nevertheless, this finding is partly affected by the government incentives disbursed during the 1990s to promote cars' sales; instead, the initiatives for the digitalization of the European society were planned later, mainly after the Lisbon Conference³⁷.

As a result of the low high-tech performance of the largest economies, a considerable fraction of the EU-US difference in the overall contribution from consumer durables can be traced to 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 dissemination of hi-tech assets across firms has significantly enhanced the knowledge content (quality) of aggregate capital stock, as IT goods are characterized by a very pronounced technical progress. Because of the rapid price decline and economic obsolescence, these assets need to earn a high rent in order to offset the huge value loss; accordingly, they present a marginal productivity (rental price³⁸) superior to traditional equipment.

An indication of capital quality can be obtained by the ratio between the economic value of the aggregate stock –that is evaluated at the user cost- and its market value ($q_t = \sum_i v_{i,t} D_{i,t} / \sum_i \omega_{i,t} D_{i,t}$); an increase in the index

$$(8) \quad \Delta \ln q_t = \sum_{i=1}^n (\bar{v}_{i,t} - \bar{\omega}_{i,t}) \Delta \ln D_{i,t}$$

³⁷ See Miniaci and Paradisi (2004) for a summary of the policy measures recently adopted in Italy.

³⁸ See section 2.3.

reflects the substitution toward more short-lived assets with high marginal product³⁹.

Figure 4 presents a complete picture on the quality change determined by the replacement of old assets with IT goods, adopted either for production or consumption purposes. The top panel illustrates the marked qualitative rise of firms' capital experienced by all countries in the late 1990s. However, despite the sharp improvement exhibited by Sweden, UK, Denmark and Netherlands (1.5% and more per year), there is a widening in the gap of the innovative profile of capital between the EU and the US (1.1 against 1.7%).

Interestingly, note that the index growth rate doubled in Austria and Italy in the latter part of the last decade with respect to 1981-95 (both +0.5%). A careful scrutiny of data reveals that such a rise has foundation in the valuable growth of IT capital for the former country; on the other hand, 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 determined either by a limited growth of IT assets or the large share of communication equipment that, as known, is characterized by modest rates of depreciation and deflation compared to computers. In Germany, instead, the sizeable quality growth fuelled by firms' adoption of office machinery contrasts sharply with an almost-zeroed contribution of non-IT assets.

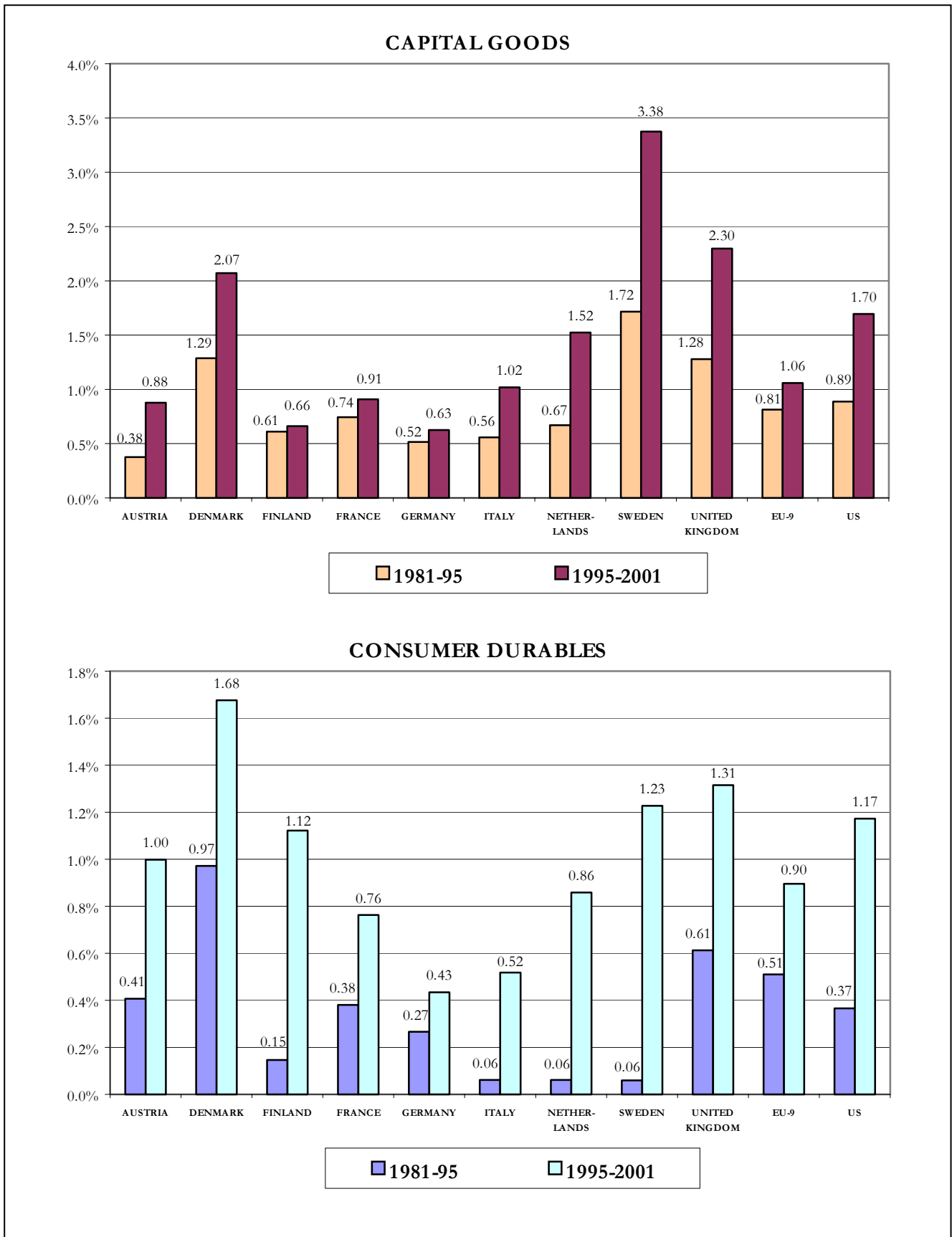
A significant improvement can be also found in the profile of consumer durables in both Atlantic regions, even though at rates inferior to capital goods (0.4 – 1.7% against 0.6 – 3.4%)⁴⁰. Danish households show the most innovative profile; the quality index climbed up to a 1.7% per year between 1995 and 2001 from a 1% of the previous period, because of the massive uptake of computers. Instead, the rise experienced by Austria, France and Netherlands was driven by vehicles and audio-visual equipment. These goods showed 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 and DVD recorders, TV, etc.

Aside from Germany where the low (or negative) contribution of non-IT goods offset the effect of computers diffusion, the qualitative growth 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 favourable dynamics in vehicles.

³⁹ $v_{i,t}$ and $\omega_{i,t}$ are the nominal shares of each asset on the economic and market value of capital (or consumer durables); the bars represent two-years means.

⁴⁰ This outcome is partly influenced by the inclusion of dwellings into the category of consumer durables in the present section; indeed, residential buildings are characterized by a minimal quality growth 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 (%)



Overall, Europe presents a lower innovative profile of consumer durables relative to the US (0.9 against 1.7%), because of the slower adoption of high-tech goods during the 1990s; this contrasts with the foregoing period when quality grew faster in the EU (0.5 against 0.4%).

In conclusion, the comparison between the two panels of Figure 4 reveals that in Austria the quality of consumer durables rose more rapidly than capital goods over time; this finding suggests that households might be characterized by an innovative propensity more pronounced than firms in such a country.

4. Concluding remarks

The body of research that investigates the link between technological capital and economic growth has extensively described the large impact of ICT production and usage on the US resurgence. In contrast, Europe has exhibited a scarce ability to catch the growth opportunity supplied by the advances in semiconductors and computer 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 two Atlantic sides is attributable to a different degree of home adoption of computers. By employing a well-consolidated framework of growth accounting, it has been illustrated that the output contribution of IT consumption 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 new technologies has been neglected or not accurately analysed; this bias becomes relevant whenever home computers influence aggregate productivity, through spillovers or skill-enriching effects.

The EU delay in households' uptake of IT is severely affected by the scarce innovative propensity of the major countries (France, Germany and Italy) which, in the late 1990s, presented a context less favourable relative to the other EU member states for the adoption of high-tech goods. Denmark and the United Kingdom show values similar to the US in terms of output contribution from IT consumption; in particular, British households stand out for a well-established familiarity with Information Technology. Overall, these countries are characterized by a similar, excellent pattern in high-tech expenditure of firms and households and, thus, can be identified as big spenders in Information Technology.

In contrast, in Sweden the expenditure for home computers results particularly undersized with respect to investment in office machinery. This finding is not confirmed by the ICT penetration rates surveyed across households, where Sweden stands out as one of the most innovative countries in Europe, suggesting that further (and more focused) research is needed on this issue.

Moreover, the EU-US gap in the dynamic growth pattern has been showed to be strictly dependent on the different degree of ICT usage, both for production and consumption. Indeed, aside from IT capital, the contribution of the other high-tech factor inputs (including home computers) in the US is twice higher than in Europe. Finally, the qualitative analysis has illustrated how ICT have improved substantially the knowledge content of capital goods as well as of consumer durables in both Atlantic sides; very interestingly, in Austria households seem to exhibit an innovative profile more pronounced than firms.

The scope of the work is evidently limited by the lack of evidence on consumer applications of communication equipment. Moreover, the outlook on the social and economic transformations related to IT consumption is partial as well. More definitive results call for an econometric investigation, especially if one is interested to check the presence of spillovers. Thus far, the lack of comparable data has compromised the development of the econometric literature on the link between IT capital and TFP growth at the economy-wide level of analysis. In addition, the controversy on the ability of IT assets to improve technical efficiency is far to be solved as witnessed by the results of industry studies, which differ considerably even when employing similar data.

APPENDIX

Data sources

1. *GDP, Housing, Changes in Inventories* (at current and constant prices) and *Employment* (in persons): OECD National Accounts 2003, on-line release from 1970 onwards; 1953-69 OECD National Accounts, various issues;
2. *Gross Fixed Capital Formation, Gross Fixed Capital Stock* (except Housing) and *Hours worked* (1980-2001): GGDC Total Economy Growth Accounting Database;
3. *Implicit deflator for Total Manufacturing Value Added* (1970-2001): OECD STAN Database 2003;
4. *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);
5. *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 for 1993-2001, unpublished quarterly data for 1980-92, September 2003; United Kingdom (1964-2001): ONS, on-line release, October 2003; USA (1947-2001): BEA, on-line release, December 2003.

The analysis takes into consideration the following consumer 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 (see Table 1 in the text). Finally, Textile and Tools and equipment for house and garden have been joined into a single category similar to NIPA Other home furnishings.

China and Glassware, Jewellery, Therapeutic appliances and equipment, Books and Maps are left out from the analysis as, in contrast to NIPA, they are not strictly regarded as consumer durables in COICOP and, in addition, are not available for several countries. The matching between NIPA and COICOP is largely satisfactory even though some discrepancies remain. For instance, COICOP includes Photographic equipment and Musical instruments respectively into 9.1 and 9.2 categories while NIPA doing vice versa. Thus, it is hypothesized that these outlays perfectly balance in the US.

6. *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. Similarly to Timmer et al. (2003), the figures of Unified Germany for 1980-90 are estimated through the *linking method*, following the same strategy adopted at 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.

Netherlands: households' purchases are classified according to COICOP from 1987 onwards; data for 1985-86 follow a similar (but not identical) classification. Therefore, these have been linked to COICOP series by employing the annual growth rates relative to 1985 and 1986.

Sweden: COICOP series are available only from 1993. Nevertheless, SCB provided us with very detailed quarterly data for the period 1980-98. At first, these values have been converted into an annual base and aggregated as closely as possible to 2-digit COICOP categories. Then, they were joined to the official series (from 1993) through the linking method.

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

	Source	Period	Commodities Flow Method ^c	Period
Austria	Stat. AT ^a	1995-2001	Stat. AT I-O Table 1990	1980-95
Denmark	Stat. DK	1966-2001		
Finland	Stat. FI ^a	1975-2001		
France	INSEE	1960-2001	OECD I-O Tables 1978, 1986, 1988, 1990, 1995	1980-2001
Germany	not available			
Italy	ISTAT ^b	1995-2000	OECD I-O Tables 1985, 1992	1980-95, 2001
Netherlands	CBS ^a	1985-2001	share of consumption of 1993 from Nat. Acc. on final domestic purchases of Office machinery	1980-93
Sweden	Stat. SE	1993-2001		
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)

$$C_t = (O_t - E_t + M_t) s_b, \quad s_b = \frac{C_t^{IO}}{O_t^{IO} - E_t^{IO} + M_t^{IO}};$$

s_b is the consumption 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.

Figure 1.A: IT Expenditure in National GDP (1980-2001), current prices (%)

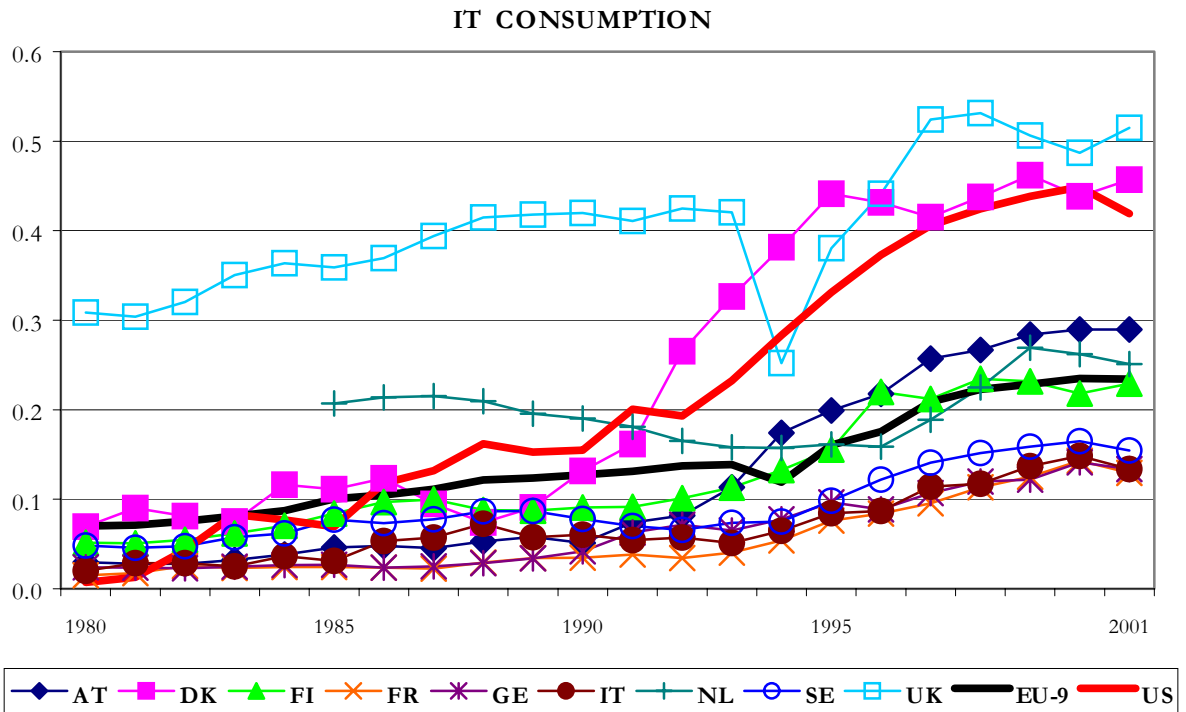
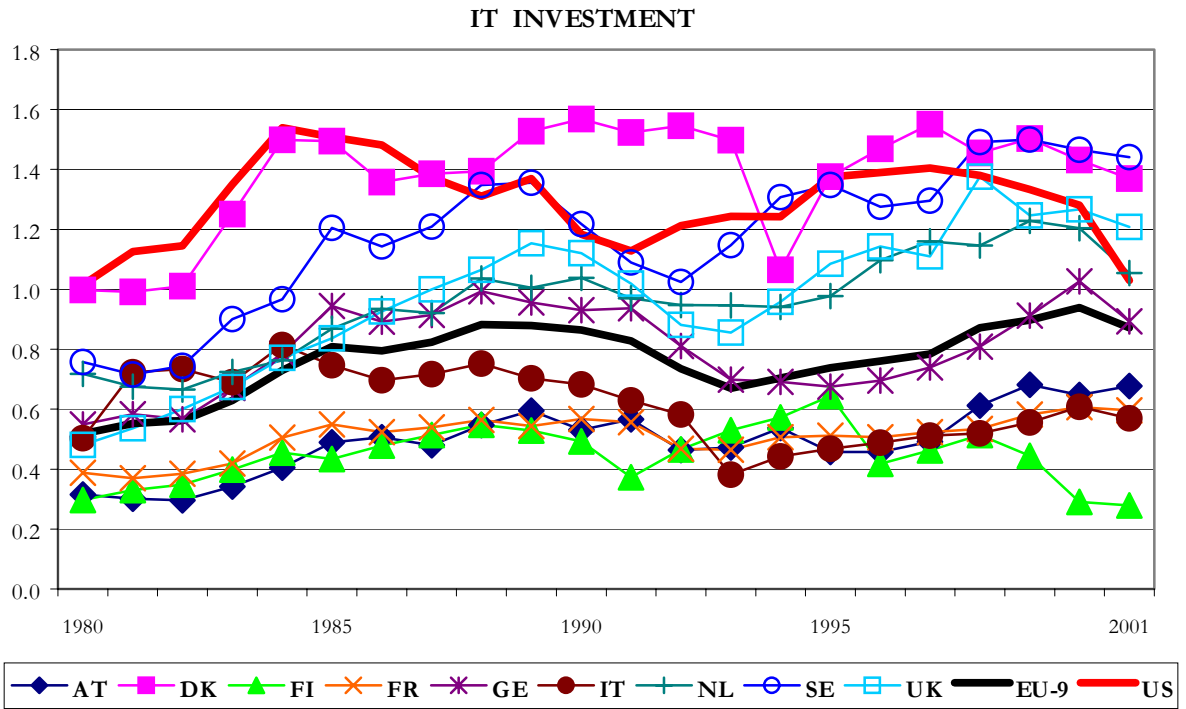


Table A.2: **A Comparison on output, labour productivity and TFP (1995-2001),**
annual average growth rates (%)

	Timmer et al. (2003)			This work			Jorgen- son (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 (EU-9)	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: Y= output; ALP= average labour productivity; TFP= total factory productivity.

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