Is growth an information technology story in Europe too?

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Is growth an information technology story in Europe too?

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Abstract

While the return to growth in the US is largely credited to the rapid spreading of information technology, a key policy concern everywhere, and notably in Europe, is whether and when the US economic boom will extend abroad, and what role new technologies are about to play. In this paper, I collect and supplement data on the extent and the contribution to growth of 'new economy' activities in Europe, and in a sample of OECD countries at large, in the 1990s. Available evidence indicates that capital accumulation in information technologies did make a contribution to growth in the EU too, though not equally everywhere. The growth contribution of new technologies was substantial in the UK and the Netherlands, and rapidly increasing over time in Finland, Ireland and Denmark. These were also the fast growing EU countries in the 1990s. Information technology contributed less in France, Germany, Belgium and Sweden, and marginally in Italy and Spain. Most of these countries were also 'slow growers'. I conclude that the growth gaps between the EU and the US, as well as within Europe, can (also) be associated to the diverse pace of adoption of new technologies across countries.

Outline

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1 Introduction

After two decades of productivity slowdown, the United States are now in the midst of a period of economic rebirth. While a large fraction of this economic miracle is credited to the rapid spreading of information technologies in the economy, a key policy concern everywhere, and notably in Europe, is whether and when the US economic boom will extend abroad, and what role new technologies are about to play.

In this paper, I collect and supplement the available cross-country evidence on the extent and the contribution to growth of ‘new economy’ activities in the European Union in the 1990s. Although the paucity of the available data outside the US is startling, the question raised in the paper title can be given an answer anyway. Information technology activities did make a contribution to growth in the EU too, but not equally everywhere. Over the 1990s, the contribution of new technologies to growth was substantial in the UK and the Netherlands - although of a smaller order of magnitude than in the US, Canada Australia - and rapidly increasing over time in Finland, Ireland and Denmark. It was instead less quantitatively relevant in France, Germany, Belgium and Sweden, and outright marginal in Italy and Spain.

How to measure the contribution of information technology to growth has been an issue of public concern in the US for a long time. In his oft-cited 1987 article in the *New York Times Book Review*, Robert Solow concisely summarized the widespread concern that computers had been deeply changing the lives of the Americans without leaving too much of their presence in the official statistics. (“Computers are everywhere, but in the national accounting data”). Since then, the US Bureau of Economic Analysis (BEA) has undertaken an impressive work of data revision – a concise rendition of which is offered by Moulton (2000). Among other important changes, hedonic (*i.e.* quality-adjusted) price indexes for computers and semiconductors were constructed. Broadly speaking, this has redistributed the nominal growth of computer-related incomes from prices to quantities.[1]

Overall, the BEA statistical amendments have possibly contributed to the sizable upward revision of the estimated contribution of new technologies to growth shown in recent studies. At first, Oliner and Sichel (1994) and Jorgenson and Stiroh (1995) reported rather low estimates of the contribution of computers to growth – some 0.2 percentage points per year, to

[1] Now the quality-adjusted price index for IT hardware exhibits a marked reduction over time, at yearly rates of 20% or so in the last twenty years. The price index of semiconductors – a key input in computer production - was adjusted for quality as well, which helped achieve a sensible balance between cost and revenue effects of quality improvements over time. Finally, the traditional fixed-weight indexes were supplemented, and soon replaced, by chained price indexes. Indeed, chained data provide better measures of economic growth when innovation makes the shares of activities subject to the fastest pace of technical progress rapidly diminishing over time.

be compared with yearly GDP growth rates in the order of 3 percentage points. As more recent evidence became available, these estimates were revised upwards. Oliner and Sichel (2000) provided a comprehensive assessment of the contribution of new technologies to growth. They credited the use of computers, software and communication technologies a hefty yearly contribution of 1.10 percentage points in 1996-99, markedly bigger than 0.57 in 1991-95 and 0.49 in 1974-90 (see Table 1 in their paper).

Their findings did not go unchallenged, however. Jorgenson and Stiroh (2000), while agreeing on the relevance of the contribution of new technologies to today's US economic growth, raised a note of caution about its long-term sustainability, as long as gains in productivity growth do not tangibly materialize outside the high-tech producing sectors. Gordon (1999, 2000) reached a broadly similar conclusion. The growth acceleration in the second part of the 1990s – in Gordon's view - is the combined effect of the BEA revision and of an unusually strong cyclical upswing, originating from, but also largely confined to, the computer-producing sector.

No discussion of this sort and momentum has taken place elsewhere in the world. News and magazines have popularized the view that a large technology gap exists between the US and the rest of the world. A similar view is also held by businessmen and politicians. While episodes and anecdotal evidence on the much advertised 'new economy' abound, little work has been done, though, to reconcile sketchy pieces of evidence from different countries with the impressive amount of work carried out in the US. Stephen Roach and Eric Chaney at Morgan Stanley (Morgan Stanley, 2000) have argued that, while Europe will likely catch up over the next five years in terms of use of new technologies, the ICT production gap is harder to bridge, and is hence bound to persist through 2005, and beyond. In parallel, the Council on Competitiveness, a Washington-based forum of experts, such as Michael Porter and an array of top executives from large US corporations, has recently analyzed international patenting, R&D and human capital indicators, reaching the conclusion that Denmark, Finland and Sweden may be the next technological leaders (Porter and Stern, 1999).

My primary undertaking in this paper is to contribute to lay some numerical basis for this discussion. By taking advantage of data collection at both private (WITSA/IDC) and official (the OECD, the US BEA) sources, I provide a broad picture of the aggregate extent and contribution to economic growth of 'new economy' activities in the EU, and in a sample of OECD countries at large, in the 1990s.

Available evidence indicates that Italy, Spain and, to a lesser extent, France and Germany invest and accumulate fewer resources in new technologies than the US. In 1997, ICT spending and investment in Italy and Spain reached 4.5 and 2.0% of their GDP, which falls short by 3 and 1.5 percentage points of the values recorded for the same items in the US and in other non-European countries. This gap has even widened between 1992 and 1997. But this is not all. Countries in continental Europe also significantly lag behind other countries in the EU (the UK, the Netherlands, Sweden, Finland) and outside the EU (Canada, Australia, New Zealand).

Furthermore, and partly as a result of that, the contribution from the use of new technologies to GDP growth in the 1990s has been smaller in most countries in the European Union than in other Industrial Countries. In the US, Canada and Australia, about two thirds of a percentage point of GDP growth in the 1990s are explained by capital accumulation in new technologies. In the EU, slightly smaller figures obtain for the UK and the Netherlands only. Italy, Spain, France, Belgium and Ireland showed much lower contributions of ICT to growth (0.2-0.3), with Germany and Sweden in between. This gap in the adoption and assimilation of new technologies can be paralleled to the GDP growth gaps suffered by Europe vis-a-vis the US over the last decade. Similar results obtain when decomposing growth performances over time, with the notable exceptions of Finland, Ireland and Denmark. In these countries, new technologies explained very little at the beginning of the decade, but their contributions rapidly expanded over time. At the same time, aggregate growth accelerated too.

In conclusion, while the modest growth performance of countries in Continental Europe in the 1990s have obviously many causes, it can also be associated to the delayed adoption of new technologies.

This paper is complementary to the work of Paul Schreyer (2000), where broadly similar questions were asked and the same primary data (WITSA/IDC, a private data source) employed in a study on the G-7, with some implementation differences. My and his results for the G-7 countries are not too far apart. [2] I do not have comparative evidence for other OECD countries than the G-7, instead.

The structure of the paper is as follows. In Section 2, the size of the 'new economy' in Europe and other OECD countries is evaluated. In Section 3, investments, price deflators, capital stocks and capital income shares - *i.e.* the toolkit for the growth accounting exercise - in Section 4 are obtained. Section 4 describes the growth accounting exercise and its main results, by first decomposing GDP growth into its labor, capital and TFP components, then looking at capital in new technologies and 'other capital', and finally at the separate growth

[2] Bassanini, Scarpetta and Visco (2000) and Scarpetta, Bassanini, Pilat and Schreyer (2000) employ Schreyer's data in broader studies on, respectively, the cross-country determinants of TFP growth differences and aggregate and sectoral economic growth trends in the OECD area.

contribution of hardware, software and communications equipment. In Section 5, my findings are compared with the results from previous studies on the US and the G-7. Section 6 provides an alternative, more conservative set of estimates, based on smaller figures for nominal investment spending. Section 7 concludes.

2 The depth of the 'new economy' in Europe

In 1997 - the latest year for which a full set of comparable data is available - OECD countries as a whole spent about 1600 billion US$ in information and communication technologies - a figure higher by one third than in 1992, as a result of yearly growth rates of 6% per year. ICT spending in the US alone amounted to 640 billion dollars: about one third of the entire world market, 20% higher than the amount spent by the EU15 as a whole, and nearly twice as much as spending in Japan.

These figures concern total spending in new technologies and do not thus provide *per se* an indicator of the depth of 'new economy' activities in each country. That large and rich countries take the lion's share in the world market of ICT goods is hardly surprising: they do the same with world trade at large. However, as made clear below, not all of the large countries have developed equally sizable 'new economy' sectors.

The GDP share of ICT spending is a proxy for the order of magnitude of ICT spending relative to each country's endowment. Being in value terms, the GDP share of ICT spending is a better indicator (to an economist) than others often reported in magazines, such as the number of Internet connections and the number of PCs held at home or used for educational purposes. These other measures are useful indicators of the social impact of new technologies on everyday life. Yet only variables in nominal values provide the scope for separating prices and quantities - a necessary condition to analyze the economics of any phenomenon. [3]

Even a cursory look at data availability immediately suggests, however, that the alleged technology gap between the US and the rest of the world manifests itself, first of all, in a data availability gap. In the US, in the last few years, the BEA and the Bureau of Labor Statistics have gradually adjusted their methods of data collection and processing to better incorporate

[3] At the same time, the amount of spending is *not* a measure of the technological capability of a particular country in producing new technologies. ICT production is much more geographically concentrated than ICT spending. Yet the extraordinary economic performance of technology-importing countries, such as Italy and Japan in the post-II World War, also suggests that perhaps a handful of technological leaders may suffice for a technological revolution to get started. Here I stick to usage data as measures of diffusion and omit analysing ICT production data. OECD (1999) provides a broad and documented survey of high-tech production and trade.

quality improvements. In other countries, instead, most national statistical offices are still taken with surprise as ‘new economy’ activities show up. This produces a ‘data availability gap’ between the US and the rest of the world over and above the technological gap.

To gain a sense of the technological revolution occurring around the world, data from private sources must then supplement, or outright substitute for, official ones. The primary data source I am relying on here is WITSA/IDC (1998). In their Report, WITSA [4] and IDC [5] put together ICT spending data for the fifty largest markets in the years between 1992 and 1997 (six years, overall). Aggregate spending data, in current local and dollar values, are obtained by adding up various items, such as information technology hardware, software and related external and internal services, plus telecommunications.

Table 1 is a summary of what GDP shares of ICT spending have to tell us about the degree of penetration of new technologies in 18 OECD countries (11 EU countries, the US and a composite ‘control’ group of countries inclusive of Norway, Switzerland, Canada, Japan, Australia and New Zealand). [6] The GDP shares of ICT spending reported in **Table 1** are the ratios between nominal spending in local currency from WITSA/IDC, and the nominal GDP in local currency reported in the OECD National Accounts. [7] Morgan Stanley (2000) estimates for 1998 are also reported.

In 1997, ICT spending averaged 6.7% of the GDP of the OECD countries in the sample, up from 6% in 1992. New Zealand, Sweden and Australia showed the highest ratios – all devoting more than 8% of their GDP to new technologies. The United States were actually very close to this group of strong high-tech users, spending 7.7% of their GDP, with Japan ranking slightly lower with its 7,4%.

In the same year, the eleven EU countries in the sample as a whole destined about 6.3% of their GDP to new technologies, hence a smaller fraction than the US and most other Industrial Countries. France, Germany, Belgium and Finland spent in ICT approximately the same as the EU average, with Sweden, the UK, the Netherlands and Denmark clearly above the EU

[4] WITSA is for World Information Technology and Services Alliance - a consortium of 32 information technology industries associations around the world.

[5] IDC is for International Data Corporation – a research and consulting company on hi-tech industries.

[6] The eleven EU countries included are: Germany, France, the UK, Italy, Spain, the Netherlands, Belgium, Ireland, Denmark, Sweden, Finland. Sample size is dictated by unavailability of the values for the aggregate capital stocks necessary to carry out the growth accounting exercise in the sections to follow. No large ICT market within the Industrialized world is left out, though.

[7] As long as one is not interested in world market shares, sticking to *local currency* flows, as opposed to flows denominated in current dollars, is preferable. WITSA/IDC (1998, p.35; fig.18) shows that the occasionally wild year-to-year fluctuations of nominal exchange rates have sometimes dominated the fluctuations of dollar-denominated flows. In particular, given the depreciation of EU currencies vs. the dollar, converting ICT flows into dollars in 1992-97 implies a reduction of the growth rate of ICT spending in EU countries with respect to the US.

average and Italy and Spain (and Greece and Portugal, not included in this study) lower than the EU average by roughly 2 percentage points.

Hence, while the US, Japan *and* Europe act prominently in the ICT world market, the degree of domestic involvement of the EU, and more markedly of its Southern members, in the 'new economy' is much smaller than that of the US and Japan.

Have these gaps got bigger or smaller over time? In 1992, the US spent in new technologies slightly more than 7% of their GDP – 0.6 percentage points less than in 1997, while the EU11 and Japan destined about 5.7% of their respective GDP. Hence, the EU-US gap has stayed roughly constant since then. Japan, instead, substantially narrowed its distance from the US. Strikingly, the severe economic stagnation experienced by the Japanese economy in the 1990s has not seemingly led to a slowdown in the pace of adoption of new technologies in this country.

Another piece of evidence from **Table 1** is that, within the EU, countries starting with a low (high) ICT share in 1992 still had a low (high) share in 1997 and 1998. The only notable exception is Finland, a country clearly below the average in 1992 and slightly above the average in 1997, due to an increase in its ICT share of 1.5 points. This outcome was partly driven by the success of Nokia, which now represents the bulk of the capitalization of the Finnish stock market. It also has to do with the unusually rapid diffusion of telecommunications and Internet usage among the Finnish population (as confirmed by the impressive share of population connected to the Internet, and by anecdotal evidence in a recent 'On-line banking' survey in the *Economist* magazine).

To sum up, Europe as a whole indeed lags behind the United States and Japan in the usage of information and communication technologies. Data up to 1998 do not show much evidence of a closing gap between Europe and the US. Moreover, sharp differences exist in the pace of new technology adoption within Europe between the Northern front-runners and the Southern laggards, with France and Germany in between.

3 Information technology data for growth accounting

In the previous section, some evidence on the penetration of information technologies in a sample of OECD countries and in Europe in particular was reported. Yet investment, not spending, matters when accounting for the contribution of new technology to growth.

Calculating such investment data implies going through a few steps. First, nominal investment for three categories of ICT capital goods (hardware, software and telecommunication equipment) must be calculated. Then price indices are derived for these same categories, so as to construct series on investment spending in real terms. Finally, capital stocks are computed through the perpetual inventory method, by adding up real investments at various dates in accordance with depreciation and service lives of each capital good. In this Section I describe the various steps and clarify the shortcuts and assumptions to be made to obtain the data for the growth accounting exercise in Section 4.

A caveat before starting. It is just fair to say that data detailed enough for growth accounting purposes simply do *not* exist for other OECD countries than the US. Here I blend data from different sources (WITSA/IDC, OECD, BEA) to come up with the most plausible proxies for investment spending of the business sector. This makes the outcome of the numerical exercise in this and the next section not strictly comparable with the field-work-based results in the previous studies on the US.

3.1 Nominal investment shares

The starting point for computing ICT investment is the WITSA/IDC data on hardware, software and telecommunications spending. WITSA/IDC provides data for hardware, software and telecommunications. Yet none of these items can be included or excluded *as such* in an 'investment spending' item. Each capital good involves separate issues.

Hardware The WITSA/IDC item for 'IT hardware' includes computer system central units, storage devices, printers, bundled operating systems, and data communication equipment bought by corporations, households, schools or government agencies from an external agent or corporation. All of these items would be properly (from a national accounts perspective) assigned to investment, but for household spending. In turn, to calculate investment spending of the business sector, hardware spending by public schools and government agencies should be subtracted out as well. Hence, classifying the WITSA/IDC 'IT hardware' item as investment would introduce an upward bias in the measured value of investment spending. At the same time, though, the WITSA/IDC definition leaves out hardware spending from unincorporated enterprises, which represents a downward bias. Schreyer (2000, p.9) concludes that 'the two effects roughly cancel out', arguing that 'a comparison for the United States suggests that this approximation is not unreasonable'. I checked this assertion, using the latest available data from the BEA. According to WITSA/IDC, 'IT hardware' amounted to 138 billion US$ in 1997, while 'computers and other peripherals equipment' added up to some 88 billions in the BEA national accounts. The same applies to the years back to 1992.

Clearly, discrepancies of such magnitudes cannot be easily swept under the rug. Hence, in my calculations, I used BEA data for computers and other peripherals for the US. Absent better alternatives, I took the shortcut of correcting downwards WITSA/IDC hardware data for the other countries in the sample, picking 0.654 - the 1992-97 average of the ratio between BEA data and WITSA/IDC data for the US – as a correcting factor. Hence, the hardware part of investment spending in this paper is equal to the original WITSA/IDC datum times 0.654.

Software The treatment of software as a capital good, and not as an intermediate good like in the past, is another result of the major revision of national accounts by the BEA. The WITSA/IDC 'IT software' item includes pre-packaged software as well as software applications, but does not include software spending internal to the firm. The internal fraction of information systems' operating budgets as well as internally customized software expenses are instead lumped together in a residual item, called 'internal services', together with depreciation of physical assets and other expenses that cannot be associated to a vendor. Once again, I double-checked what was available for the US from both WITSA/IDC and BEA sources. WITSA/IDC reports 'IT software' outlays for 54 billion $ and 'Internal IT services' outlays for 98 billion $ in the US in 1997, while the software item for BEA was 123 billions. Moreover, the 'Internal services' item stagnated over time, while the narrow software item of WITSA/IDC and the BEA software item kept rising steadily at roughly similar growth rates. In conclusion, as for hardware, I employed BEA data for the US and adjusted data for the other countries in the sample. The adjusted software data for the other countries are generated multiplying the original WITSA/IDC narrow software item – whose trend is similar to the BEA item – by 2.289, the 1992-97 average ratio between the BEA and the WITSA/IDC narrow item for the US.

Telecommunications equipment WITSA/IDC 'telecommunications spending' includes public and private network equipment, which belong to investment spending, and telecommunications services, which do not. Unfortunately, no information is provided in the WITSA/IDC Report as to how to break the total into these two items. I took investment spending for PTOs (Public Telecommunications Operators) reported in the OECD *2000 Telecommunications Database*. These data go back to 1980, something useful for later purposes. In order to come up with a proxy for business sector investment spending, PTO spending was multiplied by 1.786, the 1980-97 average ratio of BEA and OECD data for the US. Thus, as before, I employed BEA data for the US and adjusted data for the other countries in the sample.

ICT investment of the business sector for three categories of ICT capital goods (computers and other peripheral equipment, software and communications equipment) was eventually computed as described above. **Table 2** presents the GDP shares of business sector investment in information and communication technologies for the 18 OECD countries in the sample in 1992 and 1997 (column [1] and [2]). In the same Table, the GDP shares of total (public and private) fixed investment are also shown in column [3] and [4].

Table 2 documents the rise of ICT investment over time and its increased importance within total fixed investment in the OECD countries, and in most EU countries in particular.

The United States can be usefully taken as a benchmark. In the US, both the GDP share and the fraction of total ICT outlays devoted to investment went up steadily over time. As a result, in 1997, 3.4% of the US GDP was being invested in information and communication technologies. This figure amounts to 45% of total ICT spending – a very high investment ratio by any standards, and about one fifth of total investment spending (17.7% of GDP in the same year).

The US data compare with much lower figures for most European countries. In 1997, Italy and Spain invested in information technology around 2% of their GDP – about one tenth of their total investment. Most other countries in Continental Europe invested less than 2.5% of their GDP, while the Netherlands, Finland and Sweden were close to 3% - a slightly smaller figure than the US. In the UK, ICT investment was close to 4% of GDP - the highest investment share in the sample.

Table 2 provides another element to consider. It was emphasized above that the US-EU gap in total ICT spending stayed constant over time. The investment shares gap has instead widened. In 1992, the EU11 invested 2.3% of their GDP, a bare 0.3 points less than the US. By 1997, the difference had nearly tripled, up to 0.8 percentage point of GDP.

It is also worth mentioning, however, that such differences in the amount of ICT investment across countries are not closely associated to remarkable cross-country differences in the propensities to invest in ICT. As shown in the bracketed number in column [1] and [2], the EU11 and the OECD18 (arithmetic) average shares of ICT investment over total ICT spending were rather similar across countries. Most countries, with the exceptions of Denmark, Sweden, France and Japan, devoted 40 to 45% of total ICT spending to investment. Ireland, the UK and the Netherlands markedly increased their propensities to invest over time, from some 35% of total ICT spending in 1992 to 45%, or more, in 1997.

To sum up, **Table 1** and **2** document existence and persistence of an investment gap in new technologies between the US and Europe, and within Europe. Wherever this gap shows up, it does not crucially stem from lower propensities to invest, but rather from a smaller amount of resources devoted to information technologies in general.

3.2 Prices and real investment

Nominal investment flows are routinely converted into real investment flows deflating each nominal series by the appropriate investment price deflator. This is not an easy task to accomplish in a cross-country framework, given that national statistical offices employ different methods to construct such price indexes. The problem here is that the US-BEA employs hedonic price techniques [8], while most countries in the Industrial world do not.[9]

The hedonic price index for computers in use today in the US is the result of a lengthy process initiated by the BEA in 1985, taking advantage of previous work done at the IBM on mainframe prices in 1969-1984. This process has led to improve the methods of accounting for quality changes in output and inputs, as well as to reduce the bias arising from the use of fixed reference points for comparing changes in quantities.

The price index for computers and other peripherals published by the BEA now incorporates all such improvements. **Table 3** reports the yearly rates of change of such index, of various components of the index (computers and peripherals, software, communications equipment), and of the aggregate equipment and software index for 1988-1999. **Table 3** documents two important facts. First, the price of *all* equipment and software goods declined over the period, more clearly so in 1993-1999. Second, while the price of information equipment declined faster than the price of other equipment goods, the difference in the deflation rates between ICT and non-ICT equipment stayed roughly constant, ranging between 3.5 and 4% per year over the period.

As mentioned above, no such hedonic price index is available by now in Europe. So here is the problem: sticking to traditional price indices would probably lead to understate the relevance of the ‘new economy’, but European statistical offices have not produced yet new quality-adjusted price indices.

Schreyer (2000, pp.10-11) has suggested a way out, which I follow too. The newly constructed US price index and the high tradability of ICT capital goods among countries are

[8] The hedonic function relates changes in the price of a product to product characteristics, unlike the traditional matched-model technique, which computes price changes by comparing identical products over time. For computers, this amounts to considering its speed, memory and disk capacity, and processor speed as determinants of the computer price.

[9] Scarpetta, Bassanini, Pilat and Schreyer (2000, p.92) report, however, that progress is being made in a variety of countries in Europe and outside Europe in this area.

exploited to derive a price index for each of the ICT capital goods in all non-US countries. The price index of ICT capital good *k* in country *c* can in fact be calculated under the assumption that the rate of change of the price of each ICT good with respect to the other capital goods is the same in each country *c* as in the US. Hence, knowledge of the hedonic price index for ICT capital good *k* in the US and of the producer price indices of the other capital goods in the US and in country *c* suffices to infer the (unobserved) price index of capital good *k* in country *c*. This rule amounts to assuming a full pass-through of US ICT price variations into EU or Japanese price variations, once allowance is made for differences in investment good inflation.

Obviously, the real world is possibly far off from the assumptions implied by the pricing rule described above. If perfect substitutability in use, no impediments to foreign trade, uniform domestic regulations, tax regimes and market structures are not observed, the similarity in the price dynamics of information technology capital goods across countries is exaggerated by this procedure, as well as the upward trend in real ICT investment in Europe. This is important to bear in mind when looking at the summary statistics on OECD countries' price trends and real investments reported in **Table 4** and **5**, computed assuming that the mentioned rule holds.

Table 4 reports ICT price inflation data and provides a picture of striking similarity in price dynamics across countries. As emphasized above, this is built in the procedure employed to construct the price indices as long as the rates of change of *all* capital goods are roughly similar across countries. If this is the case, price inflation of ICT goods in country *c* is in practice solely determined by the rate of change in the price of the same good in the US. Hence, unsurprisingly, countries with a consolidated tradition of price stability do not exhibit marked deviations from ICT inflation in the US. Italy, Spain and Ireland, instead, show less pronounced deflation rates for hardware [10] and mildly positive inflation rates for software and communication equipment, whereas the price of both capital goods declined on average by 1 or 2 points per year in the US. In some non-European countries (including the neighboring Canada), furthermore, the reconstructed deflation rates in hardware prices were actually more pronounced than in the US, as a result of a negative inflation differential with the US producer prices for capital goods.

In **Table 5,** investment price and quantity rates of change in 1992-97 are contrasted. Hardware and software growth rates proved positive in all countries. The same holds for communications equipment, with the exceptions of Germany, Italy, Belgium and New

Zealand. The growth rates of hardware investment are the highest, reaching and outweighing a yearly 25% in many cases. Investment spending in software increased a lot too, although at somewhat smaller rates (about less than one half in the US) than hardware. Communication equipment increased more moderately, except for the UK and Ireland, where growth rates of 23.5 and 18.5 were recorded. A somewhat negative relation between prices and quantities can be traced for hardware and software (with some outliers), while no relation at all emerges for communication equipment. [11]

3.3 Capital stocks and income shares

Growth accounting exercises require knowledge of both nominal and real capital stocks. Nominal capital is an ingredient to compute the values of capital shares in value added, but it is the growth in real capital stocks that matters when evaluating the productive services and the contribution of each capital good to growth.

Unfortunately, capital stocks are not directly observable. However, the perpetual inventory method allows one to calculate them as the cumulated sum of past investment flows, weighted so as to reflect the relative efficiency in production of each vintage of capital.

The availability of quality-adjusted price indices for investment provides a natural weighting scheme.[12] As long as quality improvements are accounted for on the price side, each new vintage of capital is effectively the same as the vintages of the past. Investment flows can then be simply added up to the previous ones, once allowance is made of the loss in productive efficiency of each capital good over time.

The perpetual inventory method also requires assumptions on the service lives of capital goods and their pace of depreciation. The assumptions made on service lives and depreciation determine how far one has to go backwards in time in adding up investment flows to obtain the extent of today's capital stocks. Implicitly, the perpetual inventory method assumes that there is a point in time back in the past when the capital stock was effectively equal to zero. From then onwards, investments cumulate literally from scratch.

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[10] As shown in **Table 4**, the reduction of hardware prices in Italy, Spain and Ireland was in the order of an yearly 10% in 1990-95, and 20% in 1996-97, whereas hardware prices fell by 13% and 23.6%, respectively, in the US.

[11] This is not particularly striking if one considers that the use of hedonic pricing by the BEA to deflate software and communications spending is so far limited. Jorgenson and Stiroh (2000) evaluate that only about one third of software spending (prepackaged software only) and few items within communications equipment are deflated using constant-quality techniques. This may lead to severe underestimates of both software and communications equipment quantities in the figures reported by the BEA.

[12] See *Appendix B* in Jorgenson and Stiroh (2000) for a rigorous discussion of the issues on the measurement of capital services within the perpetual inventory method.

Here I have three types of ICT capital goods (communication equipment, hardware and software), plus the aggregate capital stock to be employed in the growth accounting exercise. In line with existing studies on the US,[13] depreciation rates are assumed constant, though different across goods. In particular, software, hardware and communications equipment are assumed to respectively depreciate at yearly rates of 44%, 32% and 15% - much faster than the aggregate capital stock, whose depreciation rate is 7.5% per year.[14] Depreciation rate assumptions are actually immaterial in the stage of calculation of the capital stock, since to evaluate the contribution of capital to the growth rate of *Gross* Domestic Product, I am using the *gross* (productive) capital stock. Depreciation rates are employed, though, when computing the user costs of capital necessary to calculate the value added share of each type of capital good (see below).

Following the same sources as above, service lives for communication equipment, hardware and software are assumed to be equal to eleven, seven and four years, and deterministic retirement at the end of the service life is assumed. No assumption is employed for the aggregate capital stock, instead, for I am using capital stocks of the business sector computed by the OECD (for their Economic Outlook), and BEA data for the US. In the absence of better alternatives, US depreciation and scrapping rates are assumed to equally apply to all other countries in the sample.

Finally, productive stocks obtain by appending an age-related rule for the loss of efficiency of each capital good. Here I simply assume that the loss of productive efficiency is zero in the early years of life of an ICT capital good – respectively, three, four and five years for software, hardware, and communication equipment - and then it starts gaining momentum at an increasing rate as the capital good 'ages'. The rule chosen for each capital good is consistent, however, with the assumed rule for depreciation. The efficiency loss rate in the final period of use of the capital good is such that, at the time of scrapping, the fraction of the capital good still not depreciated equals the fraction of the initial efficiency left after the age-related loss has occurred.

Now, suppose that investment at time t enters the capital stock immediately at the end of time t.[15] Then, investment flows must go back to 1980 for telecommunications investment, to 1984 for hardware and to 1987 for software, to enable one to compute capital stocks from 1990

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[13] Here I mostly refer to the work by Fraumeni (1997), where a detailed table of service lives based on used-asset data is provided. Estimates for software depreciation and service lives are in Seskin (1999, pp.37-39).

[14] The 7.5% depreciation rate is the weighted average of the depreciation rates of 25 equipment goods and 18 structures listed in Fraumeni (1997). Residential buildings are left out.

[15] This is not the usual practice in national accounting, where a gestation lag of one year is customarily assumed. I simply found this practice meaningless when dealing with such capital goods as software and computers, and thus I decided to omit the gestation lag. Jorgenson and Stiroh (2000) did the same.

onwards. Accordingly, the series of hardware and software investment had to be projected backwards for a few years. In doing so, I took what happened in the US as an educated guess for the other countries. Hence, I computed the compounded growth rate of the nominal GDP share of software in the US in 1987-1991 (+7.5% per year) and took that as the growth rate of the investment spending shares in software in the other countries in the sample. I did the same for hardware, with one notable difference. While the software growth rate was relatively constant in 1987-1991, the same does not apply to the growth rate of the hardware share. Hence I computed two different average growth rates for the US: +7.2% in 1990-1992 and –4.5% in 1984-1989. These growth rates were then used to backward project existing hardware series for the other countries in the sample.

This may look rough. However, the marked decline in ICT prices and the steady rise in nominal spending experienced throughout 1992-97 tend to reduce the importance of investment flows before 1992 in the determination of the total capital stocks. This is particularly true for hardware.

The growth rates of real capital stocks in the three ICT goods in the 1990s are reported in **Table 6**, together with the growth rates of the aggregate capital stocks in the business sector taken from the OECD. The growth rates of hardware and software outweighed by far the growth rates of communications equipment and aggregate capital stocks everywhere. This is well known from the US-based literature. The growth rates of software capital in Canada, the UK and the Netherlands were markedly bigger than in the US (12.6% per year). Instead, hardware capital grew in the US faster (25.7% per year) than in any other country, but Australia. The data for the US in **Table 6** are consistent with the summary statistics on growth rates of the various capital goods reported in Oliner and Sichel (2000, Table 1, which refers to 1991-95 though).

Finally, before evaluating the contribution of capital to growth, the shares of capital incomes in value added must be calculated. The capital share of capital good *k* in value added is equal to:

(1) $$(r + \delta_k - \dot{p}_k)\frac{P_k K}{PY}$$

i.e. the product of the gross rate of return on capital (the term in parentheses) and the capital-output ratio in nominal terms. In turn, *r* is the nominal market rate of return on investment,[16] δ_k is the depreciation rate of good *k*, dotted p_k is the capital gain or loss on the possess of capital good *k*, and P_k equals the purchasing price of a new capital good (and p_k being its log).

[16] Note that *r* is non-indexed, which implies the existence of well functioning capital markets.

Overall, the expression in parentheses times P_k is the user cost of capital, *i.e.* the rental price charged if capital good *k* were to be rented for one period. This rental price (and the implied gross rate of return) is supposed to be high enough to compensate an asset holder for the opportunity cost of not investing elsewhere, plus the loss due to depreciation less asset price inflation.

Can the value added shares of capital be computed from the pieces of information put together so far? Yes, following the method used by Oliner and Sichel (1994, 2000) and first suggested by Hall and Jorgenson (1967). Expression (1) requires imputation of depreciation rates, rates of inflation/deflation and nominal capital-output ratios for each of the capital good. Depreciation rates are known from above. The rates of change of P_k can be approximated by three-year moving averages of the growth rates of each investment deflator. Both P_k and, as shown below, *r* are specified in nominal terms. Capital-output ratios obtain from the perpetual inventory method, once nominal rather than real investment is used. Wherever needed, the 'other capital' item is computed residually. Capital stocks data for hardware - evaluated, following Schreyer (1998)[17], at quality-unadjusted prices - and communications equipment are thus subtracted out of aggregate capital stocks, and the 'other capital' item obtains. [18]

Having done so, only the net rate on return on investment *r* remains to be calculated. One possibility is to plug a market rate of return, such as the yearly growth rate of the share prices in the stock market, into (1). Here, instead, I follow Oliner and Sichel once again. The net rate of return obtains, under the restriction that the same rate of return *r* be earned on all types of capital onto the identity: $s_K = s_{COM} + s_{HW} + s_{OTK}$. [19] Once the aggregate share s_K is computed from aggregate data, each of the three shares depends on one unknown only. Then the net rate of return *r* can be computed right away.

In turn, once the net rate of return is calculated, the gross rate of return on each capital good and its income share can be derived as well. **Table 7** presents summary evidence on OECD capital output ratios and income shares in information and communication technologies in 1997. The ICT capital-output ratio in the US was 0.135 and the income share of information technology capital in the economy was 0.053, about one sixth of the economy-wide income share of all capital. The implied net rate of return was about 5.7 percentage points in nominal terms (see the last column in **Table 7**) and 4.1 in real terms, quite close to the value of 4.4

[17] Schreyer (1998, Box 1, p.10) surveys the studies aimed at quantifying the difference between quality-adjusted and unadjusted price indices for computers in the US, concluding that 10 percentage points is a plausible lower bound for such difference. I concur with his conclusion and accordingly compute a new real investment series for hardware, to be used to obtain the 'other capital' residual item.

[18] Software is not subtracted out, for it was not included in the OECD measure of aggregate capital stock either.

[19] *I.e.* that the aggregate share of capital equals the sum of the two ICT capital shares (with software left out) plus the share of all other capital goods.

computed by Oliner and Sichel. The overall gross rates of return tend instead to take on large values, the more so the higher the depreciation rate of the capital good and the capital loss anticipated by capital owners. Hence, as a result of a depreciation rate of 44%, the gross (nominal) rate of return on software was 51.1%, while the gross return on hardware reached 61.3%, since a depreciation rate of 32% cumulated to an expected capital loss of 23.6%.

Within the EU, the UK and the Netherlands exhibit very similar figures to those obtained for the US. The rest of the countries in the EU show lower capital-output ratios and income shares. Yet, while the levels of such ratios and shares may be subject to measurement error, one robust feature in the data is that *all* such ratios and shares steadily increased over time in the 1990s.

4. Growth accounting evidence on the 'new economy' in Europe

Since Solow (1957), growth accounting exercises have been routinely employed to decompose the growth rates of total or per-capita output into their components (usually: capital, labor, technical change) at various levels of disaggregation. Initially, starting with Solow's paper, most authors found that growth was predominantly explained by technical change, *i.e.* the fraction of GDP growth unexplained by factor accumulation. But then Jorgenson and Griliches (1967) showed that a finer disaggregation of capital and labor input, allowing for changes in the qualitative composition of each input over time, may go a long way re-absorbing the bulk of the (unexplained) TFP growth within the (explained) factor accumulation component.

The exercise conducted here consists of decomposing the contribution of capital accumulation to growth into three components (communications equipment, hardware and software) related to information technology, and a residual item 'other capital', which lumps together the various categories of non-ICT productive capital. The decomposition of growth contributions by input, under the standard assumptions of constant returns to scale and perfect competition, is the following:

(2) $$\dot{q} = (1 - s'_K)\dot{l} + s_{COM}\dot{k}_{COM} + s_{HW}\dot{k}_{HW} + s_{SW}\dot{k}_{SW} + s_{OTK}\dot{k}_{OTK} + \dot{a}$$

where s_C is the capital income share of capital good C (C= COM, HW, SW, OTK) averaged over time t and t-1; s'_K is equal to s_K, the capital share computed from national accounts, plus

s_{SW}, the software share[20]; dotted q, l, k_{COM} , k_{HW}, k_{SW}, k_{OTK}, a are, respectively, the growth rates of output, total hours worked, capital in communication equipment, quality-adjusted hardware, software, and other (non-ICT) capital, and the well known 'Solow residual', a residual item supposed to measure disembodied technical change. GDP, employment, aggregate capital and the capital income shares s_K for the business sector are taken from the OECD Economic Outlook. The average number of hours worked is from Scarpetta, Bassanini, Pilat and Schreyer (2000, Table A.13, p.83).

Table 8 summarizes the evidence on real GDP growth rates in the European Union and other OECD economies in the 1990s. In the first column, the average growth rate in 1991-97 is presented. In the second and the third column, the average growth rates over the two sub-periods are also shown. In the fourth column, the differences between the growth rates in the two sub-periods are presented.

The 1990s were times of moderate but sustained growth for most OECD countries, except for Ireland, which experienced an extraordinary period of rapid growth. Real GDP in the eighteen countries in the sample grew at an (arithmetic) average rate of 2.3% per year. Within the EU, GDP rose by less than two percentage points per year in most countries, except for Denmark, the UK and the Netherlands, where growth rates of 2.5% per year or more were observed. Ireland stands out with its 6.3%.

Moreover, in the second half of the decade, a few countries markedly improved their growth performances compared to the first part of the decade. The celebrated growth acceleration in the US (+1.9% compared to 1991-95, even more if the time horizon extends to the end of the decade) was not unique. Spain, New Zealand and Japan enjoyed a growth acceleration of about the same entity. Finland and Ireland saw their GDP rising faster by 5 percentage points per year or more.

The growth accounting exercise developed here ultimately investigates whether these (admittedly still short-lived) developments can be associated to diverging trends and profitability of accumulation of capital in new technologies across countries and over time.

The decomposition of the 1991-97 GDP growth rates of the 18 OECD countries in the sample into their employment, capital, and Solow residual components is first shown in **Table 9**. Then, the contribution of capital to GDP growth is further distinguished into the growth contribution of information and communication technologies and the contribution arising from the 'other capital' item in **Table 10**. In turn, **Table 11** further breaks down the contribution of new technologies to growth into the separate contributions of hardware,

[20] As mentioned above, software was not accounted as an investment good until recently. This implies that the

software and communications equipment – the three key components of capital in new technologies.

4.1 The growth contribution of labor, capital and TFP

The main features of the capital, labor and TFP decomposition of GDP growth in the 1990s documented in **Table 9** are three.

First, the contribution of labor to growth was negative or close to zero in eight of the eleven EU countries in the sample. This was clearly the case in the first part of the decade, and less so in the second half of the nineties. It remains nevertheless impressive, when compared to yearly employment contributions to growth of 0.54 points for Canada, 0.72 for Australia, 0.97 for the US and 1.88 for New Zealand over the same period of time. The only, perhaps expected, exceptions in Europe were the UK, the Netherlands and Ireland, where employment accounted for 0.5, 1.3 and 1.2 percentage points of GDP growth respectively. Spain in the second half of the decade is another exception.

The negative growth contribution of labor reflects both the comparatively low creation of employment in most EU countries – a well known fact - and the fall in the value added labor shares occurred in most European countries in the eighties documented by Blanchard (1997). That labor does not positively contributes to growth in Europe is however not a novel feature in macro-economic data. In their growth accounting study of the G-7, Dougherty and Jorgenson (1996, Table 2, p.26) found that the contribution of labor to growth was negative already in France, Germany, the UK and Italy over the period 1960-89 as well. If anything, the growth contribution of labor became less negative in the 1990s than in the past.

Now move to column [4] in the same Table. The second notable feature of **Table 9** is the comparatively large growth contribution of total factor productivity – the so called 'Solow residual', a proxy for technical change and other elements not captured by factor accumulation[21] – observed in Nordic countries (Denmark, Sweden, Finland and Norway), the UK and Ireland. According to the calculations reported in **Table 9**, in the 1990s, TFP the yearly growth rates of TFP reached 4.1% in Ireland, 2.7% in Finland, 1.9% in Norway, 1.7% in Denmark, and 1.2% in Sweden and the UK. In most other countries in the OECD, TFP growth stayed below 1% per year (well below in Belgium, France and the Netherlands),

capital stocks reported in the OECD Economic Outlook do not include software.

[21] A reminder is appropriate here. The TFP computed here also absorbs the changes in the composition of the labor force, which was instead appropriately separated out in other studies, such as Oliner and Sichel's and Jorgenson and Stiroh's.

reaching 1% in the US. The only country where TFP grew more than 1% per year was Italy (+1.1%).

The third highlight from **Table 9** concerns the growth contribution of capital, which, unlike the labor and TFP components just described, exhibits greater similarity across countries, in particular within the EU. The growth contributions of capital in the US and in nine of the eleven EU countries in the sample range between 1 and 1.2 percentage points. In Europe, Spain is the upward exception, with an overall capital contribution of almost 1.5 points per year, and Finland is the downward exception with a very small overall contribution of capital (a bare 0.35, up to 0.50 in 1996-97).

4.2 The growth contribution of 'new economy' and 'old economy' capital

The available data constructed as described in section 3 can shed some light on the relation between the *use* of information technologies and growth. The growth contributions of aggregate capital presented in **Table 9** can be broken down into capital in new technologies and other 'old economy' capital. This allows one to separately evaluate their growth contributions. This breakdown is presented for 1991-97, as well as for the 1991-95 and 1996-97 sub-periods, in **Table 10**. If the 'new economy' is for real, one expects to find a sizable and increasing role of informational capital in boosting growth rates.

This is indeed what is in the data, though not equally everywhere. ICT capital positively contributed to growth in any OECD country in 1991-97, and increasingly so over time. Yet the growth contribution of information technology in Continental Europe was usually consistently smaller than the ones recorded for other OECD countries.

The biggest contribution of new technologies to growth (close to two thirds of a percentage point of GDP) in the 1990s is observed, as expected, in the US (see column [1] in **Table 10**). In the same column, however, one reads that Canada and Australia reached very similar figures as well. **C**olumn [4] and [6] also show that the ICT contributions to growth have been steadily going up over time in these countries, from some 0.5 in the early 1990s to 0.9 or more in 1996-97. Oliner and Sichel (2000, Table 1) report a 1996-99 average growth contribution of 1.1 percentage points for the US, which is consistent with these findings.

In Europe, the UK and the Netherlands exhibit the highest ICT growth contributions (0.59 percentage points per year, slightly smaller than the US, Canada and Australia). In the UK, too, the contribution of ICT has become much bigger over time (rising from 0.46 in 1991-95 to 0.94 - the same as in the US - in 1996-97). The increase was there in the Netherlands too, but of a more moderate entity (from 0.54 to 0.71 percentage points).

The average growth contribution from ICT capital accumulation was much smaller in Finland (0.41) throughout the 1990s, but its 1991-97 figure in fact averages a modest growth contribution in the first half of the decade (0.27) and a spectacular increase to 0.74 in 1996-97. By 1996-97, new technologies equally contributed to growth in Finland and the Netherlands.

At the other end of the spectrum, new technologies contributed little to growth in Italy and Spain (0.23 and 0.30, respectively) and in Ireland, France and Belgium (0.32, 0.34, 0.34). In these countries, the total contribution of capital to growth was very similar (Italy, France, Belgium, Ireland) or clearly bigger (Spain) than that of the US (see column [1] in **Table 10**). Yet, ‘old economy’ capital made the bulk (75-80%) of this overall capital contribution in EU countries, while the share of ‘old economy’ capital was one half - or less – of the growth contribution of capital in the US, the UK and the Netherlands. This also marks the key difference between these countries and the UK, the Netherlands and Finland.

In turn, as shown in column [4] and [6] in the same Table, the contributions of ICT capital did not rise much in Italy and Spain throughout the 1990s (in Italy it even decreased from 0.25 to 0.17), while France, Belgium and, most of all, Ireland did experience sizable increases of ICT capital contributions in the second half of the decade. As a result of this acceleration, new technologies are reported to make a bigger contribution to growth in Ireland (0.52) than in Germany and France (0.46), not to mention Italy and Spain.

In between these two groups, Denmark, Sweden and Germany exhibit growth contributions of ICT capital of 0.40-0.45 – this average being usually the result of moderate (0.1-0.2) increases of growth contributions over a starting point of 0.35-0.40 from the first to the second half of the decade.

Hence, the UK and the Netherlands benefited the most from new technologies throughout the decade. By the end of the decade, however, these growth gains extended to Finland and, to a lesser extent, Denmark and Ireland.

Table 10 also suggests that, as a rule, the emergence of a more sizable role of new technologies in the process of economic growth cannot be closely associated to an *absolute* reduction of the growth contribution of the ‘old economy’ capital. This is the case in some countries (Germany, France, the UK, Belgium), but not in the US, Sweden, Ireland and, outside the EU, Norway, New Zealand and Australia, where the reverse instead happened.

In general, the data in **Table 10** bear two distinct, but connected, implications for the relation between new technologies and growth.

First, by contrasting the summary data on GDP growth in **Table 8** and the results from growth accounting in **Table 9** and **10,** one is driven to draw a parallel between the modest growth of Italy, France, Belgium and Spain in the 1990s (1.3, 1.2, 1.7 and 1.8% per year, respectively) and the delayed adoption of new technologies in these countries. The gaps in the growth contribution from new technology adoption between these countries and the US account for about one third of their GDP growth gaps with respect to the US in the 1990s. Slightly less evidently, the same holds to Germany, Sweden and Finland, where only 15% of the 1990s growth gaps with respect to the US are accounted by ICT capital accumulation.

Second, comparing the data on investment and spending in new technologies with the growth accounting results in **Table 9** and **10**, there seems to be no special 'growth dividend' to Sweden and Finland arising from new technologies. In spite of the rapid introduction of new technologies witnessed in the Nordic countries (see **Table 1** and **2**), average GDP growth rates, at least in Sweden and Finland were not extraordinary in the 1990s. This is, in part, hardly surprising. Both countries went through severe recessions in the early 1990s for a variety of reasons not having to do with the introduction of new technologies.[22] In addition to that, though, the growth contribution of new technologies has risen a lot in the second half the decade, at least in Finland and Denmark - less so in Sweden - and this has taken place in parallel with the return to growth to Finland and a further upward correction in the already high GDP growth rate in Denmark. Thus, even in these countries, a relation between effective adoption of new technologies and growth may be envisaged. To a lesser extent, this can be applied to Ireland as well. Sure, the outstanding Irish growth performance is only marginally accounted for by capital accumulation in new technologies. Yet the further growth acceleration in the second half of the decade took place in parallel with an increase in the growth contribution of ICT capital in Ireland as well.

4.3 The growth contribution of hardware, software and communications equipment

A question often discussed about in the past – for instance by Oliner and Sichel (1994) and Jorgenson and Stiroh (1995) - is whether computers are the driving force of the 'information

[22] The main causes of the Finnish recession are discussed in Honkapohja and Koskela (1999). A comprehensive evaluation of the Swedish problems in the early 1990s is in Lindbeck (1997).

technology & growth' story. Their conclusions, restated in substantially unaltered form in their already quoted 2000 papers, is that computers are indeed the main part of the story, but by no means the only one. This implies that either leaving computers out or exclusively focusing the attention on them would mislead the overall evaluation of the effects of 'new economy' activities on growth.

Table 11 presents evidence supportive of this view for the US and other countries than the US and, in particular, for European countries.

It is known from the mentioned previous studies that in the United States:

(a) the contribution of computers was about 0.20-0.25 percentage points – about 45% of the total contribution of ICT to growth – in the first half of the 1990s;

(b) the contribution of computers rose substantially in the second half of the decade, reaching about 60% of the total contribution of ICT to growth.

These pieces of US evidence are by and large replicated in my growth accounting exercise (see column [3] and [4] of **Table 11**). I have computed a slightly bigger value of 0.27 over the same period of time, equivalent to 53% of the total growth contribution from ICT capital in 1991-95. The growth contribution of computers more than doubles as of 1996-97, reaching 0.57, about 60% of the total growth contribution of information technologies.

In most countries in the sample (but not generally in the EU), computers and peripherals accounted for 0.20 (or more) percentage points of GDP growth in 1991-95. In the EU, instead, the average contribution of hardware was of 0.15 points, with Italy and Spain stuck at 0.09 and 0.10. In the second part of the decade, when the US underwent the sharp growth acceleration which drove computers to contribute for 0.57 points, in all OECD countries in the sample the contribution of hardware to growth at least doubled in terms of percentage points (in Finland it tripled). Everywhere the computers made up for more than 50% of the total ICT contribution to growth. In Italy, the contribution of computers almost entirely exhausted the (tiny) ICT contribution to growth.

No such clear-cut worldwide trends can be detected for software and communications equipment. The growth contributions of communications equipment stagnated or changed little upwards and downwards in most countries over the 1990s. In Europe, in the UK, Denmark and Finland, it rose from almost nothing to respectively 0.17, 0.07 and 0.14 percentage points per year in the second half of the decade. The contribution of software went up by about one tenth of a percentage point in the US and other non-European OECD countries. In Europe, instead, the growth contribution of software stagnated, with the only exception of the United Kingdom and, marginally, Finland.

This, however, suggests a possibly important lesson. The only two countries in Europe where the growth contributions of information technologies increased by almost half a percentage point from the first to the second part of the 1990s (*i.e.* Finland and the UK), did engineer such a big leap forward by taking advantage of capital accumulation in *all* of the three dimensions of information technology, *i.e.* hardware, software and communications equipment.

5. Comparison with previous studies

The object of this section is to contrast the figures presented in section 4 with the results of previous comparable studies. The results for the US are compared to the findings due to Oliner and Sichel (OS, 2000) and Jorgenson and Stiroh (JS, 2000). The results for the G-7 are contrasted with the results obtained by Schreyer (2000). No other study exists for non-G-7 countries.

Table 12 and **13**, respectively, provide the main elements for the comparison. Unfortunately, the tables can only refer to the first half of the 1990s (1990-95 and 1990-96, respectively), not to the last few years.

Starting with the US evidence, the two papers by OS and JS present a pretty similar view of the role of new technologies in the US. As mentioned in the Introduction, both papers acknowledge that IT were a key engine underlying the 1990s acceleration of growth in the United States. The similarities between these two papers do not end here. As documented in the first two columns of **Table 12**, the decomposition of GDP growth in the two papers is very similar too. The biggest difference concerns the numerical value attributed to the overall growth contribution of information technologies, 0.57 in OS and 0.40 in JS. Sichel, in his discussion of JS at the Brookings Panel, argued that this difference is likely to originate from the different measurement conventions employed in the two papers. In short, Oliner and Sichel follow the Bureau of Labor Statistics conventions, while Jorgenson and Stiroh use a broader concept of output, which includes consumer durables and housing. This would lead, for given ICT spending, to reduce the value added share and, consequently, the measured growth contribution of ICT goods. The growth contribution of durables reported by JS more than offsets the reduced role attributed by them to new technologies.

The narrow concept of output that I use in this paper (taken from the OECD Economic Outlook) is closer to the one used by OS. Unsurprisingly, my findings are closer to theirs than to JS's.

My exercise presents an important omission compared to both studies. The only heterogeneity allowed for in the growth accounting exercise in Section 4 is the one due to the process of changing composition of capital from longer-lived structures and equipment (lumped together into the ‘other capital’ item) to shorter-lived information technology and communications equipment. I have not controlled, though, for educational attainments and skills of the labor force. In other words, I am assuming complete labor homogeneity.

How important is this omission ? As quantified by OS and JS (once again, the two studies produce remarkably similar answers), the changing composition of the labor force accounts for another 0.44 percentage points. Expectedly, a less fine decomposition results into a larger computed value for the Solow residual. I obtain a Solow residual equal to 0.77, against values of 0.48 in OS and 0.36 in JS.

Finally, despite that I am using the same BEA data for ICT investment and prices as OS, I do not quite exactly replicate OS’s results on the three separate growth contributions of hardware, software and telecommunications. It is to consider, however, that other implementation details make my study different from theirs, such as the exact shape of the age-efficiency profile of the three ICT investment goods and the formula that adds investment to the stock of capital. This is probably the reason of why the growth contribution of software, hardware and communications equipment are respectively 0.20, 0.27 and 0.04 percentage points in this paper, as opposed to 0.25, 0.25 and 0.07 in OS.

I can also compare my growth accounting results with the findings of Paul Schreyer (2000) on the G-7, which are a subset of the sample of countries included in this paper.

While the methodology of analysis and the primary source of the data are the same here as in his study (I even borrowed his assumption on price harmonization in Section 3.2), some details differ. First, Schreyer’s definition of information and communication technology is narrower than mine, for he leaves software out of the capital stock. Instead, I considered it part of ICT investment, in line with the recent orientation of the BEA. Second, we both rely on WITSA/IDC data for hardware. But he takes their hardware data for granted, while I correct them downwards by about one third, to match recently published data for the US. Third, he takes WITSA/IDC telecommunications data, inclusive of public and private services and investment, and cut them off by 70% to obtain the investment item to be used for growth accounting purposes. He then goes backwards in time (WITSA/IDC data stop in 1992) by using OECD industry data, which I did not have access to. I decided to discard WITSA/IDC data for telecommunications altogether and use instead an OECD Telecommunications database, which unfortunately only provides data for public investment but goes back to 1980.

Then, as described in section 3.1, I compared BEA data for private investment and OECD data for public investment in the US, computing a correction factor employed to correct upwards the OECD data for the other countries in the sample. Altogether, I have telecommunications data ranging between 30% and 45% of the total spending in telecommunications provided by WITSA/IDC.

Summing up, I end up using smaller figures for hardware and bigger figures for communications equipment than Schreyer does. There may be other differences in the assumed shaper of the age-efficiency profile of hardware and communications equipment, which I cannot evaluate. Finally, he has West Germany in his sample, while I have unified Germany. I doubt this makes a big difference.

How do my results compare to his, after all ? A comparison of the key numbers is provided in **Table 13**. In spite of the implementation differences just mentioned, it turns out that our results are not too far apart. In the upper panel of **Table 13**, the computed ICT contributions to growth in both studies are reported. In the lower panels, the income shares and the growth rates of real investments for hardware and communications[23] are also shown. They help disentangle the source of differences and similarities in the upper panel.

Given the different treatment of software, it is hardly surprising that my growth contributions reported in row [2] of **Table 13** are always bigger than his, reported in row [1]. Taking software out of my figures, however, makes the comparison of findings more insightful. The numbers in row [1] and [3] clearly show that my results do *not* systematically overstate Schreyer's results. In particular, our results are almost identical for France and the UK; mine are bigger for Germany, Japan and Canada, and smaller for Italy and the US.

Bigger ICT contributions growth are, among other things, the result of higher ICT income shares or higher growth rates of investments. Based on the data in the lower panels of **Table 13**, it can be argued that the discrepancies for Germany, Japan and Canada are seemingly due to differences in the computed ICT income shares (mine are bigger by 1.5-2.0 percentage points) rather than to differences in the growth rates of investments. The result for Italy is instead possibly due to the lower growth rates of investment coming out of my calculations. Finally, Schreyer's numerical estimate of the ICT growth contribution for the US (0.42) is bigger than mine (0.36), which, in turn, is close to the evaluation of OS, but definitely bigger than JS. Schreyer's result is mainly due to his reportedly high growth rate of hardware investment.

[23] Schreyer does not report the growth rates of capital stocks. He reports instead the growth rates of real investment spending, which are clearly related to the growth of capital stocks. This is why I concentrate on investment rather than on capital.

In conclusion, while some differences between my results and findings from previous studies cannot be denied, similarities are many and plausible rationales can be offered for such differences.

6. More conservative estimates

Preliminary to the calculation of nominal investment spending of the business sector from WITSA/IDC data on total spending, in section 3.1 I assumed that WITSA/IDC data for hardware and software and OECD data for telecommunications would bias actual data by some coefficient of proportionality. The size of the coefficient was assumed fixed over time and equal across countries; smaller than one for hardware, and bigger than one for software and communications. It was computed taking the latest release of the US BEA data on hardware, software and communications equipment as a benchmark, assuming that the multiplicative bias present in the US data in 1992-97 would be the same for other OECD countries as well.

This is not necessarily appropriate, in particular given the comparatively larger role played by public sectors in Europe than in the US.[24] In 1992-97, US government spending represented, on average, about 32% of GDP, five points bigger than Japan but smaller (often substantially smaller) than the other OECD countries in my sample. In the same yeas, in Europe, the ratio between government spending and GDP was smaller than 40% just in Ireland and Spain (36% and 39%, respectively), with the UK slightly bigger than 40%, Germany close to 45%, France, Belgium and Italy close to 50%, Denmark, Finland and Sweden ranging between 55% and 62%. This is evidence of the bigger government size in Europe with respect to the US. Bearing these figures in mind, it is hard to believe that business sector investment in new technologies represents the same share of total ICT investment in the US as elsewhere in the OECD.

Accordingly, I modified the correction factor (CF) so as to take into account the relative size of the various public sectors, and then I checked how growth accounting results change. The revised correction factors (CF’) are computed as follows:

(3) $$CF'_c = CF \frac{GOV_{USA}}{GOV_c}$$

[24] I am thankful to Francesco Caselli for this suggestion.

where GOV_{USA} and GOV_c are, respectively, the US and country *c*'s shares of current government spending over GDP. Since in all countries in the sample (except for Japan), the ratio between GOV_{USA} and GOV_c is less than one, this amounts to making nominal investments in information and communication technologies smaller than in the benchmark case. Note, moreover, that, since the same correction applies at all dates, this translates into a level, not in a growth rate effect. In other words, nominal investment flows, capital-output ratios and the implied rates of return change, but not the growth rates of capital stocks.

The results from the growth accounting exercise run using this revised set of data are reported in **Table 14**, which duplicates the structure of **Table 10** with new figures appended. As expected, the contribution of new technologies to growth is now quantitatively smaller for most countries (except for Japan) and correspondingly a larger fraction of GDP growth goes now into both 'other capital' and TFP growth. But the qualitative implications of the benchmark exercise stay essentially unchanged.

First, the growth contributions of information technology in the UK and the Netherlands are now, respectively, 0.47 and 0.40 (while they were both 0.59). Yet they are still the EU countries obtaining the most – in terms of growth - from new technologies. Second, the big jump of Finland and Ireland between the first half and the second half of the decade is still there: in both countries, the growth contributions of ICT capital go up from some 0.20 to 0.45 percentage points or more. Third, the disappointing performances of Italy and Spain in the high tech and the moderate rise in the ICT contributions in France and Germany are still there. Much like in previous sections, Italy fared worse, in terms of the adoption of new technologies, in 1996-97 than in 1991-95. The only possibly relevant difference is that France, Belgium and Denmark experience a smaller increase in the growth contributions of new technologies in the second half of the decade vis-a-vis the first half than in the benchmark case.

Overall, once contributions are scaled down by 0.15-0.20 percentage points per year, nearly any conclusion drawn from the analysis of the benchmark case remains essentially unchanged.

7. Conclusions

In the 1990s, capital accumulation in information technologies did make a contribution to growth in Europe too, although not equally everywhere. Wherever significant, the contribution of information technology to growth was not simply numerically positive in the first part of the nineties, but also grew bigger over time. This was prominently due to the expanding role of computers. Overall, the main message conveyed by the paper is in line with the thrust of previous results for both the US and the G7, and does not crucially depend on the details of how the data set was put together.

EU countries can be split into three groups in terms of the contribution of new technologies to growth.

Countries like the UK and the Netherlands invested a large amount of resources in new technologies and this was associated to high GDP growth rates. The return to growth in Finland, the continuation of the economic boom in Ireland and the strengthening of the favorable upswing in Denmark throughout the late 1990s can also be associated to a sharply increasing contribution of new technologies to growth.

Italy and Spain, instead, invested much less and, perhaps unsurprisingly, in these countries the contribution of new technologies to growth has been very limited so far. In parallel, these countries were also among the slow growers in the 1990s.

Finally, in a third group of countries - inclusive of France, Germany, Belgium and Sweden - resources were indeed channeled into new technologies, sometimes heavily like in Sweden. Yet the contributions of new technologies to growth in these countries have so far been lower than the ones computed for the UK and the Netherlands in the EU, and the US, Canada, and Australia outside Europe.

Altogether, much of the evidence in this paper is suggestive that at least a fraction of the growth gaps between the US and the EU and within the EU can be associated to existing differences in the use and adoption of new technologies.

Whether it is the successful adoption of new technologies to *bring about* growth (as most observers, politicians and businessmen appear inclined to think), or instead ICT capital accumulation to come about *as a result of* high growth rates, is, however, something beyond the scope of this paper and, more generally, of the growth accounting framework. This is anyway an important question that forthcoming, more ‘structural’, research will have to address.

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Table 1: The use of information and communication technologies in the OECD. Nominal ICT spending as a share of GDP. Percentage points.

	1992	1997	1998
Germany	5.4	5.7	5.9
France	5.8	6.5	6.7
UK	7.1	7.8	7.6
Italy	3.7	4.4	4.5
Spain	3.9	4.3	4.2
Netherlands	6.6	7.3	7.3
Belgium	5.8	6.2	6.3
Ireland	5.5	5.9	NA
Denmark	6.4	6.8	6.8
Sweden	7.6	8.4	8.9
Finland	4.7	6.2	6.2
Norway	5.6	5.8	6.5
Switzerland	7.6	7.9	8.1
Japan	5.7	7.6	NA
Australia	7.2	8.5	NA
N. Zealand	9.0	8.7	NA
Canada	6.8	7.7	NA
USA	7.1	7.7	8.1
EU11 (*)	5.7	6.3	NA
OECD18 (*)	6.0	6.7	NA

Sources
1992-1997: WITSA/IDC for ICT spending in local currency; OECD National Accounts for GDP in local currency.
1998: Morgan Stanley (2000) estimates

(*) Arithmetic averages

Table 2 – Business sector investment in information technology and total investment in the OECD (GDP shares)

	ICT business investment		Total fixed investment	
	[1]	[2]	[3]	[4]
	1992	1997	1992	1997
Germany	2.8 (51.2)	2.5 (44.4)	22.0	21.9
France	1.9 (33.3)	2.3 (35.3)	17.9	20.2
UK	2.4 (34.0)	3.9 (49.7)	15.3	14.9
Italy	2.4 (64.7)	1.9 (42.6)	20.9	18.1
Spain	2.2 (56.7)	2.1 (49.6)	20.3	21.4
Netherlands	2.5 (38.3)	3.0 (41.2)	16.9	20.7
Belgium	2.3 (40.3)	2.3 (37.0)	21.3	20.8
Ireland	1.9 (35.3)	2.5 (43.0)	19.9	18.0
Denmark	2.0 (32.2)	2.4 (35.7)	23.0	19.6
Sweden	2.5 (33.5)	2.8 (33.3)	19.9	23.3
Finland	2.2 (46.3)	2.9 (47.3)	24.0	21.4
Norway	2.3 (40.7)	2.6 (44.7)	30.5	28.4
Switzerland	3.1 (41.4)	3.3 (42.1)	16.5	20.2
Japan	2.0 (35.9)	2.7 (35.8)	16.5	16.7
Australia	2.6 (36.4)	3.9 (46.7)	21.5	23.5
N. Zealand	3.7 (41.5)	3.4 (39.7)	20.5	18.0
Canada	2.5 (37.4)	3.3 (43.0)	18.5	19.2
USA	2.6 (36.4)	3.4 (44.3)	15.6	17.7
EU11	**2.3** (42.1)	**2.6** (41.6)	**20,1**	**20,0**
OECD 18	**2.5** (40.6)	**2.9** (41.7)	**20,1**	**20,2**

Nominal shares over GDP, current values, percentage points.
Second row in column [1] and [2]: share of ICT investment over total ICT spending.
Primary sources: Bureau of Economic Analysis for US data. My calculations from WITSA/IDC (1998) and OECD (1999) for other OECD countries.

Table 3 – Equipment and software price indices in the US

	Equipment & software: all	Information equipment	Hardware	Software	Communications
1988	1,4	-0,9	-7,4	1,1	1,3
1989	1,5	-1,6	-6,9	-2,4	1,3
1990	1,4	-2,1	-9,7	-1,4	1,2
1991	1,5	-1,6	-10,7	0,6	1,2
1992	-0,7	-4,8	-15,6	-5,9	0,9
1993	-0,5	-3,3	-15,9	0,3	0,4
1994	-0,3	-3,6	-12,6	-2,3	-0,3
1995	-0,8	-4,7	-18,1	0,3	-1,2
1996	-2,1	-7,6	-27,2	-1,9	-0,6
1997	-2,7	-7,3	-25,5	-2,6	-0,4
1998	-3,5	-8,6	-30,1	-2,0	-1,1
1999	-2,6	-6,7	-26,5	0,5	-1,0
Compounded rates of change					
1990-93	0,4	-2,9	-12,2	-1,6	0,9
1993-99	-2,0	-6,2	-20,8	-1,3	-0,8
1993-97	-1,5	-5,6	-18,8	-1,6	-0,6
1997-99	-3,0	-7,4	-24,6	-0,7	-1,0

Source: US Bureau of Economic Analysis, www.bea.doc.gov, April 2000

Table 4 – ICT price inflation in OECD countries

	1990-1995			1996-1997		
	Communication Equipment	Hardware	Software	Communication Equipment	Hardware	Software
Germany	0.7	-11.5	-0.3	-2.0	-23.1	-0.9
France	-0.8	-13.0	-1.9	-1.8	-22.9	-0.7
UK	-1.1	-13.4	-02.2	-0.3	-21.4	0.8
Italy	1.9	-10.3	0.9	1.5	-19.6	2.6
Spain	2.2	-10.1	1.1	0.6	-20.5	1.7
Netherlands	-0.5	-12.7	-1.5	-0.9	-21.9	0.3
Belgium	0.2	-12.0	-0.9	-1.1	-22.2	0.0
Ireland	-0.4	-12.6	-1.4	2.0	-19.1	3.1
Denmark	-2.1	-14.4	-3.2	-1.7	-22.7	0.5
Sweden	-0.3	-12.5	-1.4	-1.7	-22.7	-0.5
Finland	0.4	-11.9	-0.7	-1.6	-22.7	-0.5
Norway	0.4	-11.9	-0.7	0.5	-20.5	1.7
Switzerland	-1.8	-14.1	-2.9	-6.2	-27.3	-5.1
Japan	-1.6	-13.8	-2.7	-4.8	-25.9	-3.7
Australia	-1.2	-13.4	-2.3	-3.0	-24.1	-1.9
N. Zealand	-0.5	-12.7	-1.5	-5.3	-26.3	-4.1
Canada	-2.8	-15.1	-3.9	-2.1	-23.1	-0.9
USA	-0.7	-12.9	-1.7	-2.5	-23.6	-1.4

Source: BEA for US data, my own calculations for other OECD countries

Table 5 – ICT investment: prices and quantities in the OECD 1992-97, average rates of change, percentage points

	Communication Equipment		Hardware		Software	
	Price	Quantity	Price	Quantity	Price	Quantity
Germany	-1,7	-4,1	-17,6	25.6	-0.8	11.1
France	-2,2	6,7	-18,0	22.0	-1.3	12.5
UK	-0,4	23,2	-16,6	29.7	0.5	13,9
Italy	1,6	-5,4	-14,9	18,6	2,5	2,9
Spain	1,1	3,2	-15,3	21,6	2,0	1,0
Netherlands	-1,2	1,6	-17,2	26,0	-0,3	13,7
Belgium	-1,1	-2,6	-17,1	24,2	-0,2	4,6
Ireland	1,5	18,5	-15,0	23,5	2,4	11,4
Denmark	-2,4	13,2	-18,2	27,2	-1,5	10,3
Sweden	-1,3	2,7	-17,3	24,7	-0,4	8,4
Finland	-1,0	11,6	-17,1	30,3	-0,1	12,2
Norway	-0,4	9,4	-16,6	27,1	0,5	9,3
Switzerland	-5,3	3,2	-20,7	25,0	-4,4	11,7
Japan	-4,5	14,5	-20,0	23,0	-3,6	12,1
Australia	-2,4	14,8	-18,1	33,8	-1,5	19,0
N. Zealand	-3,9	-0,1	-19,5	24,4	-3,0	14,7
Canada	-1,4	6,8	-17,4	27,5	-0,5	16,6
USA	-2,1	10,9	-18,0	31,4	-1,2	13,4

Source: BEA for US data, my own calculations for other OECD countries

Table 6 – ICT and aggregate capital stocks in OECD countries 1991-97, average rates of change, percentage points

	Communication equipment	Hardware	Software	All capital goods (business sector)
Germany	4,0	24,8	12,8	2.5
France	1,6	20,2	12,6	2.2
UK	5,7	25,7	14,0	2.5
Italy	3,0	18,7	7,5	2.6
Spain	5,4	20,7	6,2	3.9
Netherlands	6,7	22,5	13,8	2.2
Belgium	2,6	21,2	7,7	2.8
Ireland	3,0	22,4	12,9	2.6
Denmark	2,5	24,1	11,6	2.7
Sweden	3,6	22,0	10,4	2.1
Finland	3,4	22,6	10,8	0.3
Norway	2,3	19,6	9,8	1.6
Switzerland	4,1	22,7	12,6	2.9
Japan	8,7	21,9	12,3	4.3
Australia	6,9	28,2	9,1	3.4
N. Zealand	5,0	24,4	12,5	1.3
Canada	5,5	25,0	15,9	3.3
USA	4,6	25,7	12,6	2.2

Table 7 – ICT capital-output ratios, capital income shares and net rates of returns

1997	**Capital-output ratios**				**Income shares**				**Net rates of return**
	TLC	Hardware	Software	**ICT**	TLC	Hardware	Software	**ICT**	**r**
Germany	0,085	0,023	0,026	**0,134**	0,019	0,011	0,013	**0,043**	0,051
France	0,059	0,022	0,027	**0,108**	0,014	0,011	0,014	**0,039**	0,067
UK	0,058	0,035	0,042	**0,135**	0,012	0,017	0,021	**0,050**	0,061
Italy	0,072	0,015	0,019	**0,106**	0,016	0,007	0,010	**0,033**	0,088
Spain	0,094	0,016	0,013	**0,123**	0,023	0,008	0,007	**0,038**	0.105
Netherlands	0,055	0,030	0,041	**0,127**	0,014	0,015	0,022	**0,051**	0.042
Belgium	0,044	0,024	0,037	**0,104**	0,009	0,011	0,018	**0,038**	0.047
Ireland	0,062	0,021	0,016	**0,099**	0,015	0,010	0,008	**0,033**	0.112
Denmark	0,042	0,031	0,026	**0,100**	0,008	0,014	0,012	**0,034**	0,015
Sweden	0,066	0,041	0,028	**0,134**	0,013	0,014	0,013	**0,041**	0,033
Finland	0,069	0,030	0,024	**0,123**	0,017	0,015	0,012	**0,044**	0,074
Norway	0,052	0,028	0,025	**0,105**	0,010	0,013	0,012	**0,035**	0,054
Switzerland	0,095	0,034	0,040	**0,168**	0,019	0,019	0,019	**0,057**	0,012
Japan	0,086	0,029	0,015	**0,130**	0,018	0,014	0,008	**0,040**	0,010
Australia	0,101	0,037	0,031	**0,169**	0,024	0,018	0,016	**0,058**	0,052
N.Zealand	0,089	0,037	0,042	**0,168**	0,019	0,018	0,021	**0,058**	0,015
Canada	0,072	0,032	0,034	**0,139**	0,018	0,016	0,018	**0,052**	0,079
USA	0,055	0,039	0,041	**0,135**	0,013	0,019	0,021	**0,053**	0,057

Notes: All variables are in *nominal* terms.

Table 8 – GDP growth rates in the 1990s
Business sector, percentage points

	[1]	[2]	[3]	[4]
	1991-97	1991-1995	1996-1997	[3]-[2]
Germany (*)	1,53	1,60	1,41	-0,19
France	1,18	0,95	1,75	0,79
UK	2,84	2,64	3,35	0,71
Italy	1,43	1,44	1,41	-0,03
Spain	1,81	1,29	3,11	1,82
Netherlands	2,63	2,23	3,64	1,41
Belgium	1,70	1,51	2,18	0,67
Ireland	6,31	4,92	9,81	4,89
Denmark	3,11	3,00	3,37	0,37
Sweden	1,34	1,04	2,11	1,07
Finland	1,21	-0,46	5,39	5,85
Norway	3,02	2,45	4,44	2,00
Switzerland	0,15	-0,24	1,13	1,38
Japan	1,97	1,46	3,26	1,79
Australia	3,65	3,35	4,41	1,06
N. Zealand	3,12	3,25	2,80	-0,45
Canada	2,22	1,79	3,31	1,52
USA	3,08	2,54	4,41	1,86

Source: OECD Economic Outlook

(*) Data for Germany refer to 1992-1997

Table 9: Decomposition of GDP growth into labor, capital and TFP contributions

1991-97, percentage points

	[1]	[2]	[3]	[4]
	GDP	**LABOR**	**CAPITAL**	**TFP**
Germany *	1.53	-0.48	1.10	0.92
France	1.18	-0.53	1.09	0.62
UK	2.84	0.49	1.12	1.23
Italy	1.43	-0.70	1.04	1.10
Spain	1.81	-0.38	1.49	0.70
Netherlands	2.63	1.28	1.21	0.15
Belgium	1.70	-0.31	1.15	0.86
Ireland	6.31	1.18	1.00	4.13
Denmark	3.11	0.16	1.22	1.73
Sweden	1.34	-0.82	0.97	1.20
Finland	1.21	-1.80	0.35	2.66
Norway	3.02	0.13	0.94	1.94
Switzerland	0.15	-0.44	1.30	-0.71
Japan	1.97	-0.41	1.42	0.96
Australia	3.65	0.72	1.57	1.36
N. Zealand	3.12	1.88	0.77	0.47
Canada	2.22	0.54	1.37	0.32
USA	3.08	0.97	1.12	0.99

Notes: Column [1] presents GDP growth rates in 1991-97. Column [2]-[4] present the contributions of employment (hours worked), capital and total factor productivity to GDP growth.

*: Data for Germany refer to 1992-1997.

Table 10: The growth contributions of ICT and non-ICT capital

	[1]	[2]	[3]	[4]	[5]	[6]	[7]
	1991-97			1991-95		1996-97	
	K	**ICT**	Other K	**ICT**	Other K	**ICT**	Other K
Germany (*)	1.10	**0,41**	0,69	**0,38**	0,78	**0,46**	0,50
France	1.09	**0,34**	0,75	**0,29**	0,82	**0,46**	0,59
UK	1.12	**0,59**	0,53	**0,46**	0,60	**0,94**	0,36
Italy	1.04	**0,23**	0,81	**0,25**	0,75	**0,17**	0,95
Spain	1.49	**0,30**	1,18	**0,29**	1,21	**0,34**	1,13
Netherlands	1.21	**0,59**	0,61	**0,54**	0,59	**0,71**	0,68
Belgium	1.15	**0,34**	0,82	**0,30**	0,89	**0,43**	0,64
Ireland	1.00	**0,32**	0,68	**0,24**	0,63	**0,52**	0,81
Denmark	1.22	**0,40**	0,82	**0,33**	0,82	**0,58**	0,81
Sweden	0.97	**0,46**	0,51	**0,41**	0,47	**0,58**	0,61
Finland	0.35	**0,41**	-0,06	**0,27**	0,01	**0,74**	-0,23
Norway	0.94	**0,41**	0,53	**0,30**	0,37	**0,69**	0,93
Switzerland	1.30	**0,56**	0,74	**0,50**	0,81	**0,69**	0,56
Japan	1.42	**0,45**	0,97	**0,33**	1,10	**0,74**	0,65
Australia	1.57	**0,61**	0,96	**0,49**	0,92	**0,90**	1,09
N. Zealand	0.77	**0,55**	0,22	**0,51**	0,11	**0,64**	0,52
Canada	1.37	**0,64**	0,72	**0,53**	0,73	**0,91**	0,72
USA	1.12	**0,64**	0,48	**0,52**	0,44	**0,94**	0,58

Notes

- Column [1] reports the contributions of capital to growth in 1991-97. The figures are the same as in **Table 9**, column [3]. It can be decomposed into the sum of column [2] and column [3].
- Column [2], [4], and [6] report the values of the growth contributions of capital in new technologies (ICT), respectively, in 1991-97, 1991-95 and 1996-97.
- Column [3], [5], and [7] report the values of the growth contributions of 'other' capital (i.e. capital originated not from investment in new technologies), respectively, in 1991-97, 1991-95 and 1996-97.

(*) Data for Germany refer to 1992-1997.

Table 11: The contributions of hardware, software and communications equipment to growth

	[1]	[2]	[3]	[4]	[5]	[6]
	1991-95	1996-97	1991-95	1996-97	1991-95	1996-97
	TLC	TLC	Hardware	Hardware	Software	Software
Germany*	0,09	0,05	0,15	0,30	0,15	0,11
France	0,02	0,04	0,14	0,28	0,13	0,14
UK	0,02	0,17	0,23	0,49	0,20	0,28
Italy	0,08	-0,01	0,09	0,16	0,08	0,02
Spain	0,13	0,09	0,10	0,22	0,05	0,02
Netherlands	0,10	0,05	0,20	0,46	0,24	0,20
Belgium	0,02	0,03	0,13	0,32	0,15	0,08
Ireland	-0,01	0,18	0,15	0,28	0,10	0,06
Denmark	0,00	0,07	0,20	0,41	0,14	0,10
Sweden	0,05	0,04	0,23	0,44	0,13	0,10
Finland	0,02	0,14	0,16	0,48	0,10	0,12
Norway	0,00	0,09	0,17	0,45	0,13	0,15
Switzerland	0,09	0,07	0,21	0,45	0,21	0,17
Japan	0,10	0,22	0,17	0,41	0,06	0,11
Australia	0,10	0,28	0,29	0,51	0,10	0,12
N. Zealand	0,11	0,05	0,23	0,38	0,16	0,21
Canada	0,10	0,12	0,25	0,49	0,19	0,29
USA	0,04	0,10	0,27	0,57	0,20	0,28

(*) Data for Germany refer to 1992-1997.

Table 12: US growth accounting in a small cross-section of studies

1990-95	Oliner & Sichel	Jorgenson & Stiroh	This paper
GDP growth	2.75	2.74	2.54
Contributions from:			
Capital	1.01	0.91	0.96
ICT Capital	0.57	0.40	0.52
Hardware	0.25	0.19	0.27
Software	0.25	0.15	0.20
Communications	0.07	0.06	0.04
Other capital	0.44	0.51	0.44
Labor hours	0.82	0.81	0.82
Labor quality	0.44	0.37	n.a.
Durables	n.a.	0.29	n.a.
TFP	0.48	0.36	0.77
Other figures (for reference)			
Income shares:			
Hardware	1.4	1.0	1.7
Software	2.0	1.5	1.2
Communications	1.9	1.1	1.3
Growth rates of inputs:			
Hardware	17.5	18.7	22.4
Software	13.1	10.0	12.1
Communications	3.6	5.5	3.6

Sources: Figures in column [1] are from Table 1 in Oliner and Sichel (2000). Figures in column [2] are from Table 2 and 5 in Jorgenson and Stiroh (2000), except for the growth rates of inputs, which are inferred from information in Table 2 and 5 as well.

All figures in percentage points.

Table 13: Accounting for the contribution of information technologies to growth in the G-7

1990-96	GER*	FRA	UK	ITA	JAP	CAN	USA
ICT contribution							
[1]: Schreyer	0.19	0.17	0.29	0.21	0.19	0.28	0.42
[2]: This paper	0.39	0.31	0.52	0.22	0.40	0.59	0.58
[3] = [2] - software	0.25	0.18	0.30	0.16	0.33	0.38	0.36
ICT income shares							
[1]: Schreyer	0.8	0.9	1.3	0.9	0.8	1.5	1.5
[3]: This paper	2.7	2.4	2.2	2.4	2.4	3.1	2.6
Growth of real investment spending							
Hardware							
Schreyer	18.6	11.0	17.6	12.9	14.5	17.6	23.8
This paper	17.3	12.1	19.8	9.6	15.3	19.1	20.4
Communications equipment							
Schreyer	3.4	2.1	2.2	9.2	15.0	4.3	5.1
This paper	4.5	6.2	10.9	-3.8	14.5	2.7	7.3

Source: Schreyer (2000). In particular, ICT contributions are from Table 4, real investment spending from Table 1, ICT income shares from Table 3.

All figures in percentage points.

(*) Germany is West Germany in Schreyer's study and unified Germany in this paper.

Table 14: The growth contributions of ICT and non-ICT capital: more conservative estimates

	[1]	[2]	[3]	[4]	[5]	[6]	[7]
	1991-97			1991-95		1996-97	
	K	**ICT**	Other K	**ICT**	Other K	**ICT**	Other K
Germany (*)	1,04	**0,30**	0,74	**0,28**	0,82	**0,34**	0,57
France	1,01	**0,22**	0,79	**0,19**	0,84	**0,30**	0,65
UK	1,05	**0,47**	0,58	**0,36**	0,63	**0,73**	0,47
Italy	0,99	**0,15**	0,84	**0,16**	0,79	**0,11**	0,97
Spain	1,47	**0,25**	1,22	**0,24**	1,24	**0,28**	1,17
Netherlands	1,08	**0,40**	0,69	**0,37**	0,64	**0,48**	0,79
Belgium	1,07	**0,21**	0,86	**0,19**	0,91	**0,27**	0,73
Ireland	0,98	**0,29**	0,69	**0,21**	0,64	**0,47**	0,84
Denmark	1,11	**0,23**	0,88	**0,19**	0,85	**0,33**	0,96
Sweden	0,84	**0,24**	0,60	**0,22**	0,54	**0,30**	0,75
Finland	0,25	**0,24**	0,01	**0,16**	0,04	**0,43**	-0,04
Norway	0,86	**0,29**	0,58	**0,21**	0,39	**0,48**	1,04
Switzerland	1,21	**0,41**	0,80	**0,37**	0,86	**0,51**	0,65
Japan	1,46	**0,53**	0,93	**0,39**	1,07	**0,88**	0,57
Australia	1,56	**0,57**	0,99	**0,46**	0,93	**0,85**	1,12
N. Zealand	0,72	**0,46**	0,26	**0,43**	0,14	**0,54**	0,56
Canada	1,24	**0,42**	0,82	**0,35**	0,80	**0,59**	0,87
USA	1,12	**0,64**	0,48	**0,52**	0,44	**0,94**	0,58

Notes

- Column [1] reports the contributions of capital to growth in 1991-97. The figures are the same as in **Table 9**, column [3]. It can be decomposed into the sum of column [2] and column [3].
- Column [2], [4], and [6] report the values of the growth contributions of capital in new technologies (ICT), respectively, in 1991-97, 1991-95 and 1996-97.
- Column [3], [5], and [7] report the values of the growth contributions of 'other' capital (i.e. capital originated not from investment in new technologies), respectively, in 1991-97, 1991-95 and 1996-97.

(*) Data for Germany refer to 1992-1997.