

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 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 EU growing countries in the 1990s. New technologies 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 the EU, can (also) be associated to the diverse pace of adoption of new technologies across countries.

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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 and communication technologies (ICT) 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 their contribution was not equally significant everywhere. Over the 1990s, the contribution of new technologies to growth was substantial in the UK and the Netherlands 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 word 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 US-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 (see Council on Competitiveness, 2000).

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 did invest and accumulate fewer resources in new technologies than the US. Moreover, they also

significantly lag behind other front-runners in the EU (the UK, the Netherlands, Sweden) and outside the EU (Australia, New Zealand). In 1997, ICT spending and investment in Italy and Spain reached 4.5 and 2.0% of their GDP. Hence their spending and investment in new technologies fell short of the values recorded for the same items in the US and in other non-European countries by, respectively, some 3 and 1.5 percentage points of their GDP. This gap has actually widened over time.

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 0.7 percentage points of GDP growth in the 1990s are explained by capital accumulation in new technologies. In the EU, the same applies to the UK and the Netherlands. In these countries, GDP growth rates were also high relatively to the EU average. Over the same period, Italy and Spain show much lower contributions of ICT to growth (0.23 and 0.30 points) and a modest overall growth performance as well. Germany, France, Belgium and the Nordic countries are in between, with average growth contributions close to 0.40 points.

Similar results also obtain when decomposing growth performances over time, with the important exceptions of Finland, Ireland and Denmark. In these countries, new technologies explained very little at the beginning of the decade. The contribution of new technologies expanded rapidly over time, however, and reached 0.9, 0.7 and 0.7 percentage points, respectively, by 1997. In parallel, aggregate growth accelerated too.

I conclude that the growth gaps between the EU and the US, as well as within the EU, can (also) be associated to the diverse pace of adoption of new technologies.

The only other systematic cross-country studies of this type I am aware of are Schreyer (2000) and Bassanini, Scarpetta and Visco (2000), where the same primary data source as here is employed (WITSA/IDC) and broadly similar questions asked. In these papers, however, the contribution of new technologies is not computed for the business sector only, and software is left out of the capital stock. Both things lead to underestimate the contribution of information technology to growth.

The structure of this paper is as follows. In Section 2, the size of the 'new economy' in different countries is evaluated. In Section 3, data (investments, price deflators, capital stocks, capital income shares) for the growth accounting exercise in Section 4 are obtained. Section 4 contains a description of the accounting exercise and its main results. Section 5 concludes.

2 The depth of the ‘new economy’

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 nominal-valued variables provide the scope for separating prices and quantities - a necessary condition to analyze the economics of any phenomenon.²

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 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

² 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.

source I am relying on here is WITSA/IDC (1998). In their Report, WITSA ³ and IDC ⁴ 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 value, are obtained by adding up various items, such as information technology hardware, software and related external and internal services, 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. The sample includes eleven EU countries, the US and a composite ‘control’ group of countries inclusive of Norway, Switzerland, Canada, Japan, Australia and New Zealand. ⁵ 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. ⁶ 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 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.

³ WITSA is for World Information Technology and Services Alliance - a consortium of 32 information technology industries associations around the world.

⁴ IDC is for International Data Corporation – a research and consulting company on hi-tech industries.

⁵ 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.

⁶ 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.

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 the recent ‘On-line banking’ Survey in the *Economist* magazine).

To sum up, Europe as a whole (and the bulk of the large countries in the EU, in particular) lag 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 ICT investment and capital

In the previous section, some evidence on the penetration of ICT technologies in a sample of OECD countries 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) and come up with the most plausible proxies for investment spending of the business sector in new technologies. This makes the outcome of the numerical exercise in this and the next section not strictly comparable with the results from previous studies on the US.

3.1 ICT 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. I examine the issues relative to each capital good separately.

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 at 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 total ICT investment for the 18 OECD countries in the sample in 1992-1997.

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.

US data compares with much lower figures for most European countries. In 1997, Italy and Spain invested around 2% of their GDP, and most other countries in Continental Europe invested less than 2.5%. The Netherlands, Finland and Sweden were instead close to 3% and the UK close to 4% of its GDP - the highest investment share in the sample.

Yet **Table 2** contains another element to consider. It was emphasised 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 investment across countries are often not closely associated to remarkable differences in the propensities to invest in ICT. As shown in the second row of the ‘1992’ and ‘1997’ columns, 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. Yet 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 ICT 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, when national statistical offices employ different methods to construct such price indexes. The problem here is that the BEA employs hedonic

price techniques ⁷ for the US, while most countries in the Industrial world do not, in particular none does that in Europe. ⁸

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 for 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, communication 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 exists 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 can be 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 .

⁷ 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.

⁸ Note, however, that the price indices for software and communications recently published by the BEA are only partially computed using hedonic techniques. 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 in BEA figures for both software and communications equipment.

Obviously, the real world is possibly far off from the assumptions implied by the weak law of one price referred to 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 ICT price dynamics across countries is exaggerated by this procedure. Suppose that computer markets are less competitive in Europe than in the US. If this is the case, the sharp fall in US computer prices in the 1990s is unlikely to have translated into correspondingly high deflation rates for the computers sold in Europe. The law of one price would imply instead a full pass-through of US prices into EU or Japanese prices, once allowance is made for differences in investment good inflation.

Consequently, for a given trend in nominal investment, wrongly assuming that the law of one price holds, when it does not, may in fact exaggerate 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**. Figures in these Tables are computed under the 'weak law of one price' assumptions.

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 hardware⁹ 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.

3.3 ICT 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.¹⁰ As long as quality improvements are accounted for on the price side, each new vintage of capital is effectively the same as the previous ones. 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 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 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.

There are 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,¹¹ depreciation rates are assumed constant, though different across goods. In particular, software, hardware and communications equipment are assumed to depreciate at yearly rates of 44%, 32% and 15%, respectively, much faster than

⁹ 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.

¹⁰ 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.

¹¹ 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).

the aggregate capital stock, whose depreciation rate is 7.5% per year.¹² 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* 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 drawing on the business sector capital stocks constructed by the BEA for the US and by the OECD (Economic Outlook data base) for the other countries in the sample. 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 the loss of efficiency of each capital good is consistent with the assumed rule for its depreciation.¹³

Now, suppose that investment at time t enters the capital stock immediately at the end of time t .¹⁴ 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 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.

¹² 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.

¹³ 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 undepreciated equals the fraction of the initial efficiency left after the age-related loss has occurred.

¹⁴ 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.

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 communications equipment and 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, except for 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).

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:

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

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,¹⁵ 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). 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 proposed by Oliner and Sichel (1994, 2000). Expression (1) requires imputation of depreciation rates, rates of inflation/deflation and nominal capital-

¹⁵ Note that r is non-indexed, which implies the existence of well functioning capital markets.

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. Capital-output ratios obtain from the perpetual inventory method, once nominal rather than real investment is used. 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: $s_K = s_{COM} + s_{HW} + s_{SW} + s_{OTK}$.¹⁶ Once the aggregate share s_K is computed from aggregate data, each of the four shares depends on one unknown only, the net rate of return r , which 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 0.054, about one sixth of the economy-wide income share of all capital. The implied net rate of return was about 3.5 percentage points.¹⁷ 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 Is growth an information technology story everywhere?

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. The hallmark of 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

¹⁶ *I.e.* that the aggregate share of capital equals the sum of the shares of the three ICT capital plus the share of all other capital goods.

¹⁷ Most countries in the sample show net (nominal) rates of return in 1997 ranging between 3.5% (USA) and 9% (Italy). The implied net rate of return is close to zero for Japan, Switzerland and New Zealand, and close to 13% for Ireland.

categories of non-ICT capital. The decomposition of growth contributions by input, under the standard assumptions of constant returns to scale and perfect competition, is the following:

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

where $s_K = s_{COM} + s_{HW} + s_{SW} + s_{OTK}$ is the capital income share averaged over time t and $t-1$ (the other shares in (2) being calculated in the same fashion); dotted q , l , k_{COM} , k_{HW} , k_{SW} , k_{OTK} , a are, respectively, the growth rates of output, employment, capital in communication equipment, hardware, software, and 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 are taken from the OECD Economic Outlook. All of these variables refer to the business sector. Given the short length of the period examined, I do not make any attempt at distinguishing between trend and cyclical components of GDP, and just use actual GDP. Due to the unavailability of reliable measures for hours worked and capital utilization, I am also not controlling for the cyclical variations in factor utilization.¹⁸

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, finally, the difference between the growth rates in the two sub-periods is presented.

As shown in **Table 8**, the 1990s were times of moderate but sustained growth for most OECD countries. Real GDP in the eighteen countries in the sample grew at an 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 the GDP grew at rates equal or bigger than 2.5% per year, and Ireland, with its astonishing 6.7%.

In the second half of the decade, the business-cycle swing turned more favorable than in the first half in all countries: the average growth rate went up to 3.2% in 1996-97 from 1.5% in 1991-95. Yet the growth acceleration of 2 percentage points experienced by the US in 1996-97 was the biggest in the sample, except for Ireland and Finland. The rest of the countries in the sample enjoyed a moderate increase in their growth rates over time, but no radical turnaround.

¹⁸ This may lead to exaggerate the computed contribution of employment to growth for those countries, such as the Netherlands, where a large fraction of the newly created jobs were part-time jobs.

The cross-sectional and time series heterogeneity in the growth performance of EU countries provides separate testing grounds for the key issue in this paper, *i.e.* whether capital accumulation in new technologies numerically explains growth.

Table 9 and **Table 10** provide some elements to address this question along a cross-sectional dimension. In this Table, GDP growth rates in 1991-97 are decomposed into their employment, capital, and Solow residual components in the eighteen OECD countries in the sample. In **Table 10**, the contribution of capital is further distinguished into the separate growth contributions of hardware, software and communications equipment (altogether adding up to ICT capital) and other capital.

In some countries in the sample, the splitting of GDP growth into its main factor contributions is relatively balanced. In the US, for instance, the average growth rate of 2.6 is accounted for by employment for 0.85 points, capital for 0.73 points, and the Solow residual for 1.02 points. In other words, disentangling capital accumulation in new technologies from overall capital accumulation does not by itself reduce the entity of the Solow residual. The same applies to Canada, Australia, Japan, although capital appears to have contributed relatively more to growth in these countries than in the US.¹⁹

How about Europe ? Strikingly, in eight of the eleven EU countries in the sample, the contribution of employment to GDP growth was negative or close to zero in the 1990s. This was particularly the case in the first part of the decade, and much less so in the second half of the nineties. This is still impressive, mostly when compared to employment contributions to growth of 0.6 points in Canada, 0.85 points in the US and, in spite of the recession, 0.45 points in Japan. The only, perhaps expected, exceptions in Europe were the UK, the Netherlands and Ireland, with employment accounting for 0.6, 1.3 and 1.8 percentage points of GDP growth respectively.

In **Table 10** the contributions of capital in new technologies within the overall contribution of capital to growth are singled out. ICT capital positively contributed to growth in any OECD country in 1991-97. Yet the growth contribution of information technology in Continental Europe was usually consistently smaller than the ones recorded for other OECD countries.

The most sizable growth contributions from ICT (close or slightly bigger than 0.7 percentage points) in the 1990s are observed in the US, Australia, and Canada, and, within the EU, in the UK and the Netherlands. In these countries, capital accumulation in new technologies appears to partially crowd out, in terms of growth contributions, capital accumulation in the 'old economy' sectors. At the other end of the spectrum, new technologies contributed little to

growth in Italy and Spain (0.23 and 0.30, respectively). Correspondingly, capital accumulation in ‘other capital’ continues to provide a major contribution - and the bulk of the contribution of capital - to growth in these countries. France, Belgium, Ireland, Germany, Denmark, Finland and Sweden lie somewhere in between these two extremes, in terms of both the contribution of ICT and non-ICT capital.

Contrasting the summary data on GDP growth in **Table 8** and the results from growth accounting in **Table 9** and **10**, it is just natural to infer that the modest growth of Italy and Spain in the 1990s (1.3 and 1.8, respectively) is also associated to the delayed adoption of new technologies experienced in these countries. The gaps between Italy and Spain and the US in the growth contribution from new technology adoption account for, respectively, about 36% and 50% of their growth gaps with respect to the US in the 1990s.

Cross-country differences in the contribution of new technologies can also be paralleled to the different growth performances of Germany, France, Sweden and Finland, on one side, and the US, on the other side. In these other EU countries, the growth contribution of new technologies was not substantial, and they also fared worse than the US in terms of GDP growth. The ICT accumulation gaps explain, though, rather small shares (25% or less) of the overall growth gaps between these countries and the US.

Another interesting feature of the figures in **Table 9** and **10** is that, in the cross section, there seems to be no special ‘growth dividend’ to Sweden, Denmark and Finland arising from capital accumulation in new technologies. In spite of the rapid introduction of new technologies witnessed in these countries, average GDP growth rates in Sweden and Finland were not extraordinary. This is hardly surprising, considering that 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.²⁰ As made clear below, though, in the second part of the decade, the growth contribution of new technologies has risen a lot in Finland and Denmark (less so in Sweden). This has taken place in parallel with the return of Finland to growth and a further upward correction in the already high GDP growth rate in Denmark.

How do these results compare with findings in previous studies ? The ICT contribution computed in **Table 10** for the US closely match Oliner and Sichel’s results, once 1996 and 1997 are taken out (see their Table 1). My estimates of the contribution of non-ICT capital in **Table 9** to growth are instead clearly lower than theirs. This may have to do with the

¹⁹ Bassanini, Scarpetta and Visco (2000) successfully relate cross-country differences in TFP growth in OECD countries to differences in their labor and goods market institutions.

²⁰ 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).

somewhat less accurate measure of the capital stock I am using here.²¹ The estimates in **Table 9** are also definitely larger than those obtained in Schreyer (2000), where the contributions to growth of ICT capital in the G7 range between 0.1 and 0.25 percentage points in 1991-96.²²

Another important question dealt with in previous studies is whether the ICT contribution has been rising over time in the 1990s. It might be that a moderate contribution of new technologies to growth along the cross-sectional dimension is the result of an initially very low contribution rapidly increasing over time thereafter. This is indeed the case for Finland and Ireland. Oliner and Sichel (2000) and most other people working with US data found evidence of a rapidly increasing importance of capital accumulation in new technologies over time in the 1990s. I find the same for the US, for most countries in the EU, and for the other OECD countries in the sample as well. This is documented in **Table 11**, column [2]-[3].

Splitting the 1991-97 period into two sub-periods (1991-95 and 1996-97), the evidence points to a rise over time in the absolute contribution of ICT to growth in 17 out of 18 countries (Italy being the only exception).

In the US, the growth contribution of new technologies went up from 0.58 to 1.04 percentage points. This implies that about one fourth of the US growth acceleration of two percentage points is explained by the increased contribution of ICT to growth. In other non-EU countries (such as Australia, Canada, New Zealand and Japan), increases of 0.4-0.5 percentage points in the contributions of information technology to growth from one sub-period to the other were not uncommon as well.

Countries in the European Union show a scattered picture. In the group of front-runners, the growth contribution of new technologies in the UK has reached the same size as in the US, rising to 1.1 percentage points per year from 0.51 in 1991-95. This is more than one third of the UK GDP growth rate in 1996-97. In the Netherlands, the rise of the ICT contribution over time was less sharp, but still quantitatively relevant, going up from 0.59 to 0.82 percentage points.

No doubt, while starting low, Finland, Ireland and, slightly less evidently, Denmark caught up in the second half of the 1990s. The contributions of information technology to growth in these countries were very low (Finland, Ireland) or low (Denmark) in the first part of the

²¹ As mentioned above, the aggregate capital stocks of countries different from the US are taken from the OECD Economic Outlook.

²² While tracing the ultimate source of these differences may be hard, here is a list of the main differences between the two papers. He took WITSA/IDC data for granted, while I made the corrections mentioned in Section 2 and 3 to match recently published data for the US. He left software out of ICT investment, while I included it in line with the recent orientation of BEA. His aggregate capital stocks are more carefully constructed than mine, though, drawing on a finer disaggregation among six types of capital goods, which I have not undertaken.

decade. But then rapid accumulation of ICT capital led new technologies to account for, respectively, 0.90, 0.67 and 0.71 percentage points of GDP growth by 1996-97. This is still smaller than the US, Canada, Australia and the UK, but much closer to their values rather than to the values observed for Italy and Spain and other countries in Continental Europe. Over the same period, in fact, the contributions of information technologies have increased only moderately in Spain (+0.07), Germany (+0.08), Belgium (+0.16), Sweden (+0.16) and France (+0.17), and slightly decreased in Italy.

Overall, the 1990s evidence from **Table 9**, **10** and **11** suggests that the UK and the Netherlands experienced the quantitatively most relevant contribution of new technologies to growth in the EU. However, given their rapid and effective adoption of new technologies in the second half of the decade, Finland, Ireland and Denmark are the next likely front-runners.

A third question often discussed about in the past – for instance by Oliner and Sichel (1994) - is whether computers are the driving force of the ‘information technology & growth’ story. Their conclusion, restated in substantially unaltered form in their 2000 paper, is that computers are the main, but not the only part, of the information technology and growth story. 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.

Both **Table 10** and **11** present evidence supportive of this view, by showing that, on average, in 1991-97 computers and peripherals accounted for 0.3-0.4 percentage points of GDP growth, a fraction often close to 50% of total ICT contribution to growth. where the overall ICT contribution is large. This applies to the US, Canada, Australia, Norway, Switzerland, New Zealand and, within the EU, to the UK, Finland, Sweden, Denmark and the Netherlands. In countries, such as Italy, Spain, France and Germany, where, as just shown, the contribution of new technologies to growth was smaller, the contribution of computers as well fell short of 0.25 percentage points. In these countries, instead, communications equipment contributed to growth comparatively more. This is even reinforced when looking at growth contributions along the time series dimension. **Table 11** (column [2], [3], [5], [6]) shows that about half of the increase in the information technology contribution to growth between 1991-95 and 1996-97 stems from computers in practically all of the countries.

It seems just fair to conclude that computers account for a large fraction of the ‘information technology & growth’ story outside the US too.

5 Conclusions

In the end, is growth an information technology story in Europe too ? My findings suggest that, in the 1990s, capital accumulation in information technologies did make a contribution to growth in Europe too, although not equally everywhere.

EU countries can be broadly split into 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. This is pretty similar to what happened in the US in the same years. The return to growth in Finland, the continuation of the economic boom in Ireland and the strenghtening of the favorable upswing in Denmark throughout the late 1990s can also be associated to a sharply increasing contribution of new technologies to growth.

Countries like 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.

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.

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.

A final, though crucial, question concerns data collection. The sense that further progress in the understanding of the role of new technologies across countries be deeply intertwined with progress in data collection techniques is hard to escape. In the US, the national accounts

revision in the last few years did not fall from heaven. It was instead, among other things, the result of fruitful collaboration between private and public institutions. Would anything alike be conceivable in Europe ? Will national and international statistical offices and leading companies like Nokia, Ericsson, Tiscali, and other EU high-tech champions collaborate in the process of data collection and in the construction of the price indices needed to measure the 'new economy' ?

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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 – ICT investment in the OECD

	1992	1993	1994	1995	1996	1997
Germany	2.8 (51.2)	2.5	2.3	2.2	2.4	2.5 (44.4)
France	1.9 (33.3)	2.1	1.9	2.2	2.1	2.3 (35.3)
UK	2.4 (34.0)	2.4	2.4	2.9	3.5	3.9 (49.7)
Italy	2.4 (64.7)	2.1	1.9	1.7	1.8	1.9 (42.6)
Spain	2.2 (56.7)	2.0	2.2	2.0	2.2	2.1 (49.6)
Netherlands	2.5 (38.3)	2.5	2.5	2.9	2.8	3.0 (41.2)
Belgium	2.3 (40.3)	2.3	2.2	2.3	2.5	2.3 (37.0)
Ireland	1.9 (35.3)	1.8	1.8	1.9	2.4	2.5 (43.0)
Denmark	2.0 (32.2)	1.9	1.9	2.2	2.4	2.4 (35.7)
Sweden	2.5 (33.5)	2.5	2.6	2.8	2.7	2.8 (33.3)
Finland	2.2 (46.3)	2.0	2.2	2.2	2.8	2.9 (47.3)
Norway	2.3 (40.7)	2.0	1.9	2.4	2.4	2.6 (44.7)
Switzerland	3.1 (41.4)	2.8	2.9	3.1	3.1	3.3 (42.1)
Japan	2.0 (35.9)	2.0	2.0	2.2	2.7	2.7 (35.8)
Australia	2.6 (36.4)	2.8	3.1	3.3	3.7	3.9 (46.7)
N. Zealand	3.7 (41.5)	3.2	2.9	3.1	3.6	3.4 (39.7)
Canada	2.5 (37.4)	2.5	2.5	2.6	2.9	3.3 (43.0)
USA	2.6 (36.4)	2.6	2.9	3.0	3.2	3.4 (44.3)
EU11	2.3 (42.1% of total ICT)	2.2	2.2	2.3	2.5	2.6 (41.6% of total ICT)
OECD 18	2.5 (40.6% of total ICT)	2.3	2.3	2.5	2.7	2.9 (41.7% of total ICT)

Nominal shares over GDP, current values, percentage points.

Second row in '1992' and '1997' columns: 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	3,3	24,8	12,8	2.5
France	2,1	20,2	12,6	2.2
UK	6,4	25,7	14,0	2.5
Italy	1,7	18,7	7,5	2.6
Spain	3,8	20,7	6,2	3.9
Netherlands	5,8	22,5	13,8	2.2
Belgium	2,3	21,2	7,7	2.8
Ireland	4,4	22,4	12,9	2.6
Denmark	3,1	24,1	11,6	2.7
Sweden	3,7	22,0	10,4	2.1
Finland	3,7	22,6	10,8	0.3
Norway	3,6	19,6	9,8	1.6
Switzerland	3,8	22,7	12,6	2.9
Japan	9,3	21,9	12,3	4.3
Australia	7,4	28,2	9,1	3.4
N. Zealand	3,5	24,4	12,5	1.3
Canada	5,2	25,0	15,9	3.3
USA	5,1	25,7	12,6	2.2

Table 7 – ICT capital-output ratios and capital income shares

1997	Capital-output ratios				Income shares			
	TLC	Hardware	Software	ICT	TLC	Hardware	Software	ICT
Germany	0,085	0,023	0,026	0,134	0,019	0,013	0,013	0,046
France	0,059	0,022	0,027	0,108	0,014	0,013	0,014	0,041
UK	0,058	0,035	0,042	0,135	0,013	0,020	0,021	0,054
Italy	0,072	0,015	0,019	0,106	0,016	0,009	0,010	0,034
Spain	0,094	0,016	0,013	0,123	0,023	0,010	0,007	0,040
Netherlands	0,055	0,030	0,041	0,127	0,014	0,019	0,022	0,056
Belgium	0,044	0,024	0,037	0,104	0,010	0,014	0,018	0,042
Ireland	0,062	0,021	0,016	0,099	0,016	0,013	0,009	0,038
Denmark	0,042	0,031	0,026	0,100	0,008	0,017	0,012	0,037
Sweden	0,066	0,041	0,028	0,134	0,013	0,014	0,013	0,041
Finland	0,069	0,030	0,024	0,123	0,017	0,018	0,012	0,047
Norway	0,052	0,028	0,025	0,105	0,020	0,021	0,021	0,063
Switzerland	0,095	0,034	0,040	0,168	0,019	0,019	0,019	0,057
Japan	0,086	0,029	0,015	0,130	0,017	0,016	0,007	0,040
Australia	0,101	0,037	0,031	0,169	0,024	0,022	0,016	0,062
N.Zealand	0,089	0,037	0,042	0,168	0,010	0,016	0,012	0,038
Canada	0,072	0,032	0,034	0,139	0,016	0,019	0,017	0,052
USA	0,055	0,039	0,041	0,135	0,012	0,022	0,020	0,054

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 (*)	1,71	1,53	2,07	0,54
France	1,33	1,04	2,05	1,02
UK	2,85	2,64	3,37	0,73
Italy	1,31	1,27	1,41	0,13
Spain	1,79	1,30	3,01	1,71
Netherlands	2,54	2,21	3,38	1,17
Belgium	1,54	1,24	2,29	1,05
Ireland	6,74	5,82	9,04	3,22
Denmark	3,05	2,85	3,54	0,69
Sweden	1,35	1,02	2,16	1,14
Finland	1,15	-0,49	5,26	5,76
Norway	3,12	3,26	2,77	-0,49
Switzerland	0,11	-0,23	0,97	1,20
Japan	1,97	1,46	3,26	1,79
Australia	3,44	3,24	3,95	0,71
N. Zealand	3,04	2,55	4,25	1,69
Canada	2,12	1,79	2,96	1,17
USA	2,61	2,05	4,01	1,96

Source: OECD Economic Outlook

(*) Data for Germany refer to 1992-1997

Table 9: Decomposition of real GDP growth into factor contributions

1991-97, percentage points

	[1]	[2]	[3]	[4]
	GDP	EMPLOYMENT	CAPITAL	TFP
Germany *	1.71	-0.46	0.86	1.30
France	1.33	-0.25	0.85	0.72
UK	2.85	0.61	0.77	1.47
Italy	1.31	-0.50	0.92	0.91
Spain	1.79	-0.32	1.37	0.74
Netherlands	2.54	1.28	0.84	0.43
Belgium	1.54	0.10	0.92	0.52
Ireland	6.74	1.85	0.82	4.07
Denmark	3.05	-0.02	0.98	2.09
Sweden	1.35	-1.28	0.69	1.93
Finland	1.15	-1.87	0.12	2.91
Norway	3.12	1.58	0.58	0.97
Switzerland	0.11	-0.15	0.96	-0.70
Japan	1.97	0.47	1.22	0.28
Australia	3.44	0.74	1.33	1.38
N. Zealand	3.04	0.38	0.52	2.14
Canada	2.12	0.61	1.01	0.51
USA	2.61	0.85	0.73	1.02

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

*: Data for Germany refer to 1992-1997.

Table 10: The contribution of capital to growth through the looking glass

	[1]	[2]	[3]	[4]	[5]	[6]
	CAPITAL	TLC	Hardware	Software	ICT	Other K
Germany *	0.86	0,06	0,25	0,13	0,45	0,42
France	0.85	0,03	0,22	0,13	0,39	0,47
UK	0.77	0,08	0,38	0,23	0,68	0,08
Italy	0.92	0,03	0,14	0,07	0,23	0,68
Spain	1.37	0,09	0,17	0,04	0,30	1,07
Netherlands	0.84	0,08	0,34	0,24	0,66	0,18
Belgium	0.92	0,02	0,24	0,13	0,39	0,53
Ireland	0.82	0,07	0,24	0,09	0,40	0,42
Denmark	0.98	0,03	0,33	0,13	0,48	0,49
Sweden	0.69	0,05	0,29	0,12	0,47	0,23
Finland	0.12	0,06	0,31	0,11	0,47	-0,36
Norway	0.58	0,07	0,35	0,18	0,60	-0,02
Switzerland	0.96	0,08	0,35	0,20	0,62	0,33
Japan	1.22	0,14	0,29	0,08	0,51	0,71
Australia	1.33	0,17	0,44	0,11	0,71	0,61
N. Zealand	0.52	0,04	0,31	0,14	0,49	0,03
Canada	1.01	0,09	0,37	0,21	0,66	0,34
USA	0.73	0,06	0,43	0,22	0,71	0,02

Notes

- Column [1] reports the contributions of capital to growth from Table 9, column [3]. It can be decomposed into the sum of column [5] and column [6].
- Each cell (i,k) in column [2]-[6] represents the contribution of capital good k to GDP growth in country i .
- The values of **ICT** (Information and Communication Technologies) in column [5] are the sums of the values in column [2]-[4].

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

Table 11 – Growth contributions of ICT capital over time
1991-97, 1991-95, 1996-97. Percentage points

	ICT 1991-97	ICT 1991-95	ICT 1996-97	Hardware 1991-97	Hardware 1991-95	Hardware 1996-97
	[1]	[2]	[3]	[4]	[5]	[6]
Germany*	0,45	0,41	0,53	0,25	0,19	0,38
France	0,39	0,34	0,51	0,22	0,18	0,34
UK	0,68	0,51	1,11	0,38	0,29	0,61
Italy	0,23	0,24	0,20	0,14	0,12	0,19
Spain	0,30	0,26	0,39	0,17	0,13	0,27
Netherlands	0,66	0,59	0,82	0,34	0,25	0,57
Belgium	0,39	0,35	0,51	0,24	0,17	0,40
Ireland	0,40	0,30	0,67	0,24	0,20	0,35
Denmark	0,48	0,39	0,71	0,33	0,25	0,52
Sweden	0,47	0,42	0,58	0,29	0,24	0,44
Finland	0,47	0,31	0,90	0,31	0,20	0,59
Norway	0,60	0,53	0,77	0,35	0,30	0,47
Switzerland	0,62	0,55	0,82	0,35	0,26	0,55
Japan	0,51	0,38	0,83	0,29	0,21	0,49
Australia	0,71	0,57	1,08	0,44	0,36	0,62
N. Zealand	0,49	0,35	0,83	0,31	0,22	0,55
Canada	0,66	0,54	0,97	0,37	0,29	0,57
USA	0,71	0,58	1,04	0,43	0,34	0,67

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