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BY FOCCO VIJSELAAR AND RONALD ALBERS[1]

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1 *Economists, Directorate Economic Developments, European Central Bank.* *We thank Bart van Ark, Neale Kennedy, Gerard Korteweg, Ad van Riet, Marcel Timmer and two anonymous referees for their comments. All errors and omissions remain ours, of course. We thank Erikos Velissaratos for his help in acquiring data on investment in ICT and Colin Webb for providing us with the OECD STAN database.* *This paper represents the views of the authors and does not necessarily reflect the views of the European Central Bank.*

Address	**Kaiserstrasse 29**
	D-60311 Frankfurt am Main
	Germany
Postal address	**Postfach 16 03 19**
	D-60066 Frankfurt am Main
	Germany
Telephone	**+49 69 1344 0**
Internet	**http://www.ecb.int**
Fax	**+49 69 1344 6000**
Telex	**411 144 ecb d**

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Abstract

This paper provides an overview of the currently available evidence on the importance of information and communication technologies (ICT) for developments in productivity growth in the euro area. On the basis of the available data, there is evidence of an increased contribution of ICT to economic growth both in terms of production and investment in the second half of the 1990s. However, there is little, if any, evidence of significant positive spillover effects from the use of ICT to overall productivity growth. This implies that there is no reason to believe that potential output growth in the euro area has increased significantly in recent years on account of new technologies.

JEL classification: E22, L63, L86, O3, O47

Key words: Information and communication technologies, average labour productivity, sectoral developments, growth accounting, capital stock, euro area, measurement issues

Non-technical summary

In the period from the mid-1990s to 2000, the macroeconomic performance of the United States was remarkable. For instance, over this period, average labour productivity (ALP) growth - i.e. the increase in output per person employed or, preferably, the increase in output per hour worked - for instance, clearly increased, while employment continued to grow at a steady rate. In explaining this performance, the focus of recent research has mainly been on the revolution in information and communication technologies (ICT).

An important question in this respect is whether these new technologies have also had an impact on productivity growth in the euro area. In contrast to the United States, there is only scant evidence for the euro area of the impact of the new technologies on economic developments. The aim of this paper is to partly redress the balance by studying the importance of ICT for productivity growth in the euro area. To our knowledge, this is the first contribution that focuses on the euro area as such.

Growth in ALP can be the result of an increase in the amount of capital available per hour worked (capital deepening) or of an increase in the overall efficiency of the economic process, as measured by the gain in total factor productivity (TFP). In other words, TFP growth can be interpreted as that part of overall productivity growth that cannot be accounted for by higher capital or labour input. ICT could lead to higher ALP growth trough capital deepening and, if the use of ICT improves the efficiency of the economic process, also through an increase in TFP growth. However, it is difficult to disentangle the forces driving TFP growth. As opposed to ALP, TFP growth cannot be measured directly and is difficult to estimate in practice.

This paper follows two approaches to gauge the importance of ICT for euro area productivity growth. First, it directly accounts for the contribution of ICT capital to ALP growth and estimates developments in TFP growth in the euro area by applying a standard growth accounting framework, which decomposes the sources of output growth. Second, it examines in more detail the developments in ALP growth at the sectoral level, focusing on sectors producing and intensively using ICT.

The main findings may be briefly summarised as follows.

The results of the growth accounting exercise suggest that the importance of ICT capital accumulation for economic growth in the euro area has increased in the second half of the 1990s. The euro area is thus experiencing positive growth effects of ICT through capital deepening. However, TFP growth has been declining rather than accelerating in the course of the last decade. This casts doubt on a significant positive impact of the use of ICT on the increase in efficiency of the economic process in the euro area.

Output and ALP growth in ICT *producing* sectors in the euro area have clearly been higher than in other sectors of the economy. This points to a positive impact of ICT on economic growth. However, the size of these sectors is relatively small implying that there has so far been only a limited impact on overall economic developments. Nevertheless, the aggregate contribution of ICT sectors to total ALP growth was noticeable in the euro area in the period 1991-1998. The fact that the growth rates of ALP in the ICT *using* sectors did not rise appreciably faster than in the non-ICT using sectors again casts doubt on the existence of a positive impact from the use of ICT on TFP growth.

The conclusion can thus be that ICT was of increasing importance for economic growth in the euro area over the 1990s. At the same time, there is no reason to believe that the significant rise in ICT investment in the course of the last decade has led to a significant rise in economy-wide TFP growth. These findings do also not support the notion that ICT has raised potential output growth in the euro area.

Finally, a further interesting result is that the contribution of ICT capital to output growth has not been much different in the euro area than in the United States, if one attempts to allow for the effects of different deflation techniques – contrary to conventional wisdom. This suggests that other factors are likely to account for the largest part of the observed difference in TFP growth, including differences in production structure and possibly also in the flexibility of product, labour, and financial markets.

I Introduction

In the period from the mid-1990s to 2000, the macroeconomic performance of the United States was remarkable. Over this period, average labour productivity (ALP) growth in the United States, for instance, clearly increased, while employment continued to grow at a steady rate. In explaining this performance, the focus of recent research has mainly been on the revolution in information and communication technologies (ICT). In some studies it is argued that it is mainly the ICT producing sector that has been responsible for the increase in productivity growth (Jorgenson and Stiroh 2000; Jorgenson 2001; Stiroh 2001a, 2001b), while others argue that in addition the use of ICT goods and services has contributed to the acceleration in productivity (Oliner and Sichel 2000; Bailey and Lawrence 2001; Nordhaus 2001).[2]

An important question in this respect is whether these new technologies have also had an impact on productivity growth in the euro area. In contrast to the United States, there is only scarce evidence for the euro area of the impact of the new technologies on economic developments. Thus, even though in recent years the (policy) debate on the impact of ICT on productivity growth has raged on both sides of the Atlantic Ocean, to date the vast majority of empirical studies has remained limited to the United States. The aim of this paper is to partly redress the balance by studying the importance of ICT for productivity growth in the euro area. To our knowledge, this is the first paper that focuses on the euro area as such.

Moreover, the present paper has a broader scope than the relatively few empirical studies on individual euro area countries. First, this study presents evidence on sectoral developments in ALP. Taking this perspective, it is important to distinguish increases in productivity growth resulting from developments limited to the ICT producing sectors from increases due to the spreading use of ICT in other sectors of the economy. Arguably, only if ICT has the character of a so-called general-purpose technology would it result in a more rapid sustained increase in the overall efficiency of the economic process, which would imply that the economy has a higher rate of growth of potential output.[3] Second, this paper focuses on a decomposition of the sources of productivity growth rather than limiting itself to an estimate on the contribution of ICT capital to output growth as is done

[2] The alleged revolutionary character of ICT has not been undisputed. Gordon (2000), for instance, remains sceptical about the importance of ICT, arguing that it does not measure up to the great inventions of the past – in particular electricity and the internal combustion engine - in affecting productivity and the quality of life.

[3] Note however, that there is no clear-cut definition of what are the defining elements of a general-purpose technology. The historical experience shows that the impact of major technological breakthroughs on macro-economic productivity developments has not been comparable across technologies, which makes any comparison with previous episodes hazardous (Wellink and Albers 2001). Furthermore, in theory it would be sufficient for ICT production and investment to increase at a sufficiently high rate to raise potential output and increase in the growth rate of output, without necessarily being spread widely over the economy

in most studies on individual euro area countries. This approach does allow for making inferences about potential spillover effects of the use of ICT.

Productivity growth is most often measured in terms of ALP, i.e. as the increase in output per person employed or, preferably, the increase in output per hour worked. Growth in ALP can be the result of an increase in the amount of capital available per hour worked (capital deepening) or of an increase in the overall efficiency of the economic process, as measured by the gain in total factor productivity (TFP). An acceleration in ALP due to an increase in TFP growth could be a sign of the general-purpose character of ICT. However, as opposed to ALP, TFP growth cannot be measured directly and is difficult to estimate in practice.

As mentioned, this paper uses two approaches to gauge the importance of ICT for euro area productivity growth. First, it directly accounts for the contribution of ICT capital to ALP growth and estimates developments in TFP growth in the euro area by applying a standard growth accounting framework. This framework has been widely applied in studies on aggregate data on the United States, in particular. However, most recently the emphasis in the analysis of economic effects of ICT has shifted from aggregate-level to industry-level studies (e.g. Stiroh 2001a, McKinsey Global Institute 2001, Van Ark 2000 and 2001). As data on ICT investment by industry is still largely unavailable for euro area countries, it is not possible to undertake a sectoral growth accounting exercise. Therefore, a second focal point will be on developments in ALP growth in sectors producing and intensively using ICT. Due to data constraints this study largely limits itself to developments in the 1990s. While the emphasis is clearly on the euro area, comparisons with the United States are drawn to add a comparative perspective.

The remainder of the paper is structured as follows. Section 2 discusses the relevant literature on the importance of ICT for economic growth in euro area countries. Section 3 presents the results of the analysis on sectoral developments, while section 4 presents the results of the growth accounting exercise. Section 5 concludes. The appendices provide details on data sources and estimation methods, on individual country results, and on the likely sources of measurement error and the overall impact of using alternative (US based) deflators for IT equipment to the euro area estimates.

2 Related literature

So far, only a few studies have considered the impact of ICT on economic growth in euro area countries. This is mainly due to a relative dearth of national accounts data on investment in ICT. Most studies have therefore used private sector data sources on ICT expenditure to construct investment series for euro area countries. These have the disadvantage that they are not consistent with national accounts methodologies and thus are not directly comparable to the available official statistics. This study, however, uses official data on both the production of and investment in ICT.

Turning to the related literature, Schreyer (2000) used data for G7 countries from a private data source (International Data Corporation) on ICT expenditure and computed the contribution to growth of ICT capital by applying a standard growth accounting framework. He estimated that ICT capital contributed some 0.4 percentage point per annum on average to economic growth in the United States in the period 1990-1996, compared to about 0.2 percentage point in Germany, France and Italy over the same period. Schreyer made no estimates of TFP growth.

Daveri (2001) and Colecchia and Schreyer (2001) extended the work of Schreyer (2000) and updated the estimates to 1999. Daveri's study covered all EU countries (with the exception of Luxembourg) as well as the United States. An important extension is the incorporation of investment in software. This, together with a different method to construct investment series from the expenditure data, led to higher estimates of investment in ICT in EU countries. With software included the contribution of ICT capital to real GDP growth in EU countries varied from 0.3 to 0.6 percentage point in the period 1991-1999, compared to 0.9 percentage point in the United States over the same period. In most countries, the contribution to growth in real business sector output was found to have increased from the first to the second half of the 1990s. Daveri also estimated TFP growth, which he found to have increased in five smaller euro area countries only.

Colecchia and Schreyer (2001) derived estimates of contributions of ICT capital to output growth in the business sector on the basis of official data for three euro area countries (France, Germany, and Italy). In addition, they constructed some estimates for Finland. They estimated the contribution of ICT to business output growth to vary from 0.2 to 0.3 percentage point using national deflators and from 0.3 to 0.6 percentage point using alternative US based deflators in the period 1995-1999. With the notable exception of Germany, they found a clear increase in the contribution of ICT to output growth from the first to the second half of the 1990s. The study did not provide estimates of TFP growth.

In appendix 2 the results of Colecchia and Schreyer are presented in more detail and compared with the results of this study.

Using another private sector data source on ICT expenditure (Reeds), Roeger (2001) presented different scenarios for the contribution of ICT capital to output growth in EU countries. In particular he used various assumptions as regards the price deflators for ICT goods and the price elasticity of ICT capital. The estimated contributions of ICT to output growth varied from 0.2 to 0.3 percentage point in the years 1992-1994, and from 0.3 to 0.6 percentage point in the period 1995-1999 – with an increase in the contribution in each case between the earlier and the later period. Moreover, in estimating the effect of ICT on aggregate TFP growth, Roeger concluded that there was little evidence of substantial spillovers on account of the use of ICT.

Three further papers draw on national accounts data to make bilateral comparisons with the United States. Mairesse et al. (2000) compared France with the United States. They found that for France the contribution of ICT (including software) to output growth increased from 0.2 percentage point in the period 1989-1995 to 0.3 percentage point in the period 1995-1999. This contribution has continued to grow in recent years, to reach 0.4% in 1999. Two papers (CPB 2000, Van der Wiel 2001) focused on the contribution of ICT to aggregate and sectoral ALP growth in the Netherlands. CPB (2000) found that ICT (excluding software) contributed 0.2 percentage point to growth in ALP in both the periods 1991-1995 and 1996-1999. Van der Wiel (2001) presented additional estimates of the contribution of software to ALP growth in the Netherlands, which increased from 0.1 percentage point in the first period to 0.2 in the second. In a study on Finland, Jalava and Pohjola (2001) concluded, using data on ICT expenditure rather than national accounts data, that the contribution of ICT capital to output growth in Finland increased from 0.3 percentage points in the early 1990s to 0.7 percentage point in the late 1990s, mainly on account of investment in communication equipment.

A paper by Van Ark (2001) differs from the studies mentioned above in that it highlights the production side rather than the investment side of ICT, by analysing developments in ICT producing and ICT using sectors in ten major OECD countries. The main finding of Van Ark was that the differences in ALP growth between the United States and most European countries are partly explained by a larger and more productive ICT producing sector in the United States, and also by a higher contribution to productivity in the United States from ICT using industries and services. This notwithstanding, in general ALP growth in the ICT producing sectors accelerated from the first to the second half of the 1990s.

All in all, these previous studies suggest that ICT has had some positive effect on economic growth in the euro area, that this effect tended to increase over the 1990s, but remained relatively limited. The literature reviewed, however, gives no clear verdict as regards the existence of positive spillover effects.

3 Sectoral developments

To assess the importance of ICT for the production side of the economy in the euro area, this section examines developments in output and productivity growth at the sectoral level, in the ICT sector in particular. The ICT sector as a whole is defined as consisting of ICT producing and ICT using sectors (see Table 1). The classification of ICT producing industries closely follows that of the OECD (2000a), while the classification of ICT using industries follows that of Van Ark (2000, 2001).[4] It is relevant to identify ICT using sectors, because any positive spillover effects from the use of ICT should become apparent in sectors other than those producing ICT. ICT using sectors are defined as those which have a relatively high ratio of ICT investment to industry output and a relatively high share in the overall ICT capital stock. This is admittedly somewhat arbitrary. Indeed, 'non-ICT using' sectors will also use ICT to some extent, and it could be argued that even a limited use of ICT could cause a clear improvement in the efficiency of the production process. The ICT using sectors distinguished here might thus be seen as only a rough measure for assessing the importance of ICT use in the economy as a whole.

Table 1: Classification of ICT producing and using industries

ICT producing sector, manufacturing
Office, accounting and computing machinery (code 30) and radio, television and communication equipment (code 32).
ICT producing sector, services
Post and telecommunications (code 64) and computer and related activities (code 72).
ICT using sector, manufacturing:
Chemicals and chemical products (code 24), electrical machinery and apparatus, not elsewhere classified (code 31), and medical, precision and optical instruments (code 33).
ICT using sector, services:
Financial intermediation (code 65), insurance and pension funding (code 66), activities related to financial intermediation (code 67), renting of machinery and equipment (code 71), research and development (code 73), and 'other business activities' (code 74).

Note: codes in brackets are from the international standard industry classification, revision 3. Only about half of the category 'other business services' qualifies as ICT using. Therefore a 50% split was applied for this category.

A shift share analysis has been carried out in order to determine the contribution of a given sector to overall productivity growth more precisely. This method implies that ALP for the total economy (P) can be written as the sum of the ALP contributions of individual sectors (i) weighted with their labour share ($L_i/L=S_i$):

$$P = Y/L = \sum_i (Y_i/L_i)(L_i/L) = \sum_i (P_i{*}S_i) \qquad (1)$$

In a time perspective this equation can be rewritten as:

$$\Delta P_{(t)} = (\sum_i (\Delta P_{i(t)} * S_{i(t-1)}) + \sum_i (P_{i(t-1)} * \Delta S_{i(t)}) + \sum_i (\Delta P_{i(t)} * \Delta S_{i(t)}) \qquad (2)$$

where Δ takes differences across time. The first term on the right hand side of the equation is the so-called 'within' effect. It measures the contribution of the ALP growth *within* the individual sector to overall productivity growth. It can be interpreted as the counterfactual rate of productivity growth in the absence of changes in the production structure. The second and third terms represent the contribution of productivity growth from changes in the employment shares between sectors. A shift of employment from sectors with low productivity levels to sectors with high productivity levels will show a positive 'static' effect (the second term). The third term measures the contribution of a shift in employment shares of a sector multiplied by its productivity growth. This so-called 'dynamic' effect will be positive if the share of a sector that shows above average productivity growth increases. The total contribution of any sector to overall ALP growth is obtained by summing the separate components for the sector.

Data on gross value added and employment (in persons) at a detailed sectoral level are available for five euro area countries: Germany, France, Italy, the Netherlands, and Finland (comprising about 81% of euro area gross value added). The data from these five countries are used to construct an estimate for gross value added and employment by sector for the euro area (see Appendix 1 on data sources and aggregation methods for more information).[5] Unfortunately, data for all five countries are available only for the period 1991 to 1998. Due consideration should be given to the fact that the results may be influenced by the particular cyclical position of countries in these years.

[4] The classification used here is somewhat less detailed in that both the OECD and Van Ark distinguish sectors at the three-digit sectoral level.

[5] The euro area economic structure may differ from the structure implicit in the euro area estimate presented here, which is based on only a subset of countries. Arguably, the availability of statistics correlates positively with the degree of countries' economic development, which in turn could apriori be assumed to positively correlate with the degree of ICT penetration in the economy. This would imply that there might be an upward bias in the estimates of the contribution of ICT to ALP growth. However, here, and especially in the growth accounting exercise, important euro area producers of ICT (Ireland and Finland) are not taken into account – due to lack of data. Furthermore, the aggregation of gross value added is not fully harmonised across euro area countries, as use is made of both chain-weighted and fixed-weight aggregates. Moreover, considerably different price indicators are used, including hedonic deflators. Here (and in the following subsection) these factors are not taken into account. All this implies that there is probably a bias in the euro area estimate as presented in this study, the precise size and direction of which are however unknown.

Table 2 presents for the euro area, for each ICT sector, the output share and output growth, the employment share and employment growth, as well as ALP growth. The manufacturing and business services sectors as well as the total economy have been added as benchmarks for the developments in the ICT sectors. Appendix 2 gives an overview of the individual country results. Table 3 presents the contributions to overall ALP growth of the ICT sectors.

Table 2 Sectoral developments in the euro area[1]

	Share in nominal value added		Growth in real value added		Share in employment		Growth in employment		Growth in ALP	
	1991	1998	1991-1998	1995-1998	1991	1998	1991-1998	1995-1998	1991-1998	1995-1998
ICT producing sectors, manufacturing	1.0%	0.8%	6.6%	12.3%	0.9%	0.6%	-5.2%	-1.8%	12.5%	14.3%
ICT producing sectors, services	3.3%	3.8%	5.9%	8.9%	2.4%	2.4%	-0.2%	0.9%	6.0%	7.9%
ICT using sectors, manufacturing	4.2%	3.6%	0.9%	1.3%	3.6%	2.9%	-3.0%	-1.2%	4.0%	2.4%
ICT using sectors, services	10.5%	11.2%	2.4%	3.3%	6.8%	8.1%	2.2%	3.2%	0.1%	0.1%
Manufacturing	23.3%	20.8%	0.8%	1.5%	23.9%	20.2%	-2.4%	-0.6%	3.4%	2.1%
Business services	44.2%	47.7%	2.3%	3.0%	34.9%	38.3%	1.2%	2.1%	1.1%	0.9%
Total economy	100.0%	100.0%	1.6%	2.0%	100.0%	100.0%	-0.1%	0.6%	1.7%	1.3%

[1] estimate based on Germany, France, Italy, the Netherlands, and Finland comprising about 81% of euro area gross value added
Source: own calculations using data from STAN OECD database, Groningen University ICT database, and Statistics Netherlands
Note: due to the rapid decline of measured prices in the ICT producing manufacturing sector its share in nominal value added declined, despite high rates of growth in real value added.
Manufacturing and business services include the ICT sectors.

Table 3 Contribution to average labour productivity growth in the euro area[1]
(as percent of total ALP growth)

	Overall contribution		Within effect		Static shift effect		Dynamic shift effect	
	1991-1998	1995-1998	1991-1998	1995-1998	1991-1998	1995-1998	1991-1998	1995-1998
ICT producing sectors, manufacturing	3.4%	7.5%	7.5%	9.5%	-1.8%	-1.4%	-2.3%	-0.7%
ICT producing sectors, services	12.6%	23.0%	12.7%	22.0%	-0.1%	0.8%	0.0%	0.2%
ICT using sectors, manufacturing	2.3%	1.8%	10.0%	7.2%	-5.8%	-5.0%	-1.8%	-0.4%
ICT using sectors, services	16.0%	22.0%	0.8%	1.2%	15.1%	20.7%	0.1%	0.1%

[1] estimate based on Germany, France, Italy, the Netherlands, and Finland comprising about 81% of euro area gross value added
Source: own calculations using data from STAN OECD database, Groningen University ICT database, and Statistics Netherlands

Table 2 shows that the *ICT producing sectors*, both in manufacturing and services, were highly dynamic in terms of growth rates of real value added and ALP. Moreover, there was a clear pick-up in the growth rates of both variables in the second half of the 1990s. However, the size of the ICT producing sectors is small, with a share of less than 5% in total nominal value added and roughly 3% in total employment, implying that their impact on activity developments in the euro area as a whole is limited. Nevertheless, the contribution to overall ALP growth is noticeable, being about one sixth (0.3 percentage point) of total euro area ALP growth over the period 1991-1998, and even one third (0.4 percentage point) in the years 1995-1998 (see Table 3).[6] The own dynamics of the sector

[6] Strictly speaking a shift share analysis can not be applied to chain-weighted data, as chain-weighted data are not additive over the sectors (see e.g. Whelan 2000). In our sample the data for France are chain-weighted, however, as explained in footnote 3, in the euro area aggregate this has not been taken into account, implying that the euro area estimates used here are additive over the sectors.

(the 'within' effect) have been paramount in explaining this contribution. Shift effects played only a minor role and even reduced the total contribution of the ICT producing manufacturing sector.

As to the *ICT using sectors*, there has been no clear increase in the growth rates of real value added or ALP. In the ICT using services sector measured ALP growth has even been close to zero during the 1990s. The ICT using services sector has also been the one with the highest employment growth, reaching somewhat over 3% in the second half of the 1990s. Indeed, ICT producing sectors and the ICT using manufacturing sector had hardly any or even negative employment growth over the same period. The absence of stronger dynamics in the ICT using sectors than on average in the manufacturing and the business services sectors suggests that over the period examined positive spillover effects from the use of ICT have been limited if present at all. As to its contribution to overall ALP growth, the within effect in the ICT using manufacturing sector has been substantial. However, due to the decline in employment share, the overall contribution of this sector has been small. By contrast, the ICT using services sector has mainly contributed to overall productivity growth on account of a substantial increase in the employment share of this sector over time.

A direct comparison of the results for the euro area with those for the United States (shown in Table 4) reveals the following.[7] First, the growth rates of ALP of the ICT producing manufacturing sectors in the euro area seem roughly comparable to those in the United States. This should be seen against the background of statistical problems, which adds to the measured difference between the euro area and the United States on account of more rapidly declining deflators for ICT producing manufacturing sectors in the United States. The hedonic method used in the United States to separate price and quality changes tends to lead to lower measured price increases and higher measured output growth than the approaches used in most euro area countries, where only France uses the hedonic approach (see also appendix 4 'Measurement problems related to productivity'). In the period 1995-1998, for example, the decline in the value added deflator for the ICT producing manufacturing sector was 12.5% per year on average in the United States and 7.2% in the euro area. The difference of more than 5 percentage points, being a rough measure of the possible impact of measurement errors clouding the comparison, almost completely accounts for the differences in measured ALP growth. Bearing in mind this

[7] The construction of ICT producing services sector data for the United States was hampered by classification problems. A direct comparison with the euro area data therefore seemed not justified. Moreover, no shift-share analysis for the United States is presented here, as the use of chain-weighted indices makes such an analysis impossible without the introduction of fairly restrictive assumptions. See also footnote 6.

caveat is important in interpreting Tables 3 and 4, which show ALP as measured by the currently available statistics, in an attempt to let these data 'speak for themselves'.

Second, in the United States the high ALP growth was accompanied by an above average increase in employment in the ICT producing manufacturing sector. This contrasts sharply with developments in the euro area over this period. This could be indicative of structural impediments to growth in the euro area, such as barriers to the creation of firms, for example resulting from the regulatory framework or the relative dearth of venture capital, to inflexible labour markets or to a lack of human capital in the ICT producing manufacturing sector.

Third, the share of the ICT producing manufacturing sector in total nominal value added in the US is at 1.8% in 1998 more than twice as high as the corresponding share in the euro area. This implies that the impact of this dynamic sector on economy-wide developments is clearly stronger in the United States than in the euro area. Moreover, the output share of all ICT (producing and using) sectors taken together clearly increased in the United States from 19.6% in the first half of the 1990s to 22.8% in the second half, whereas it was more or less stable in the euro area at 19.0% and 19.4% respectively.

Fourth, in the United States, as in the euro area, the dynamics of the ICT using sectors in terms of value added and ALP appear not to be particularly strong when compared with the benchmark sectors (total manufacturing and total business services respectively). However, in the United States there has been an increase in ALP growth in the ICT using sectors from the first to the second half of the 1990s, which was larger than the increase in the benchmark sectors. This is consistent with the finding of Stiroh (2001a, 2001b) that the industries in the United States which recorded an acceleration in ALP in the second half of the 1990s were more intensive users of ICT capital.

Table 4 Sectoral developments in the US

	Share in nominal value added		Growth in real value added		Share in employment		Growth in employment		Growth in ALP	
	1991	1998	1991-1998	1995-1998	1991	1998	1991-1998	1995-1998	1991-1998	1995-1998
ICT producing sectors, manufacturing	1.5%	1.8%	20.9%	25.6%	1.0%	0.9%	1.4%	3.5%	19.2%	21.3%
ICT producing sectors, services	4.8%	5.2%	4.9%	5.4%	3.0%	3.3%	3.0%	4.1%	1.9%	1.2%
ICT using sectors, manufacturing	3.4%	3.1%	3.0%	4.2%	2.2%	1.8%	-0.9%	0.2%	3.9%	4.0%
ICT using sectors, services	9.9%	12.7%	4.6%	7.4%	8.4%	9.3%	3.3%	4.4%	1.3%	2.8%
Manufacturing[1]	17.4%	16.3%	4.5%	4.0%	14.9%	13.4%	0.3%	0.6%	4.1%	3.4%
Business services[1]	49.1%	53.2%	4.7%	6.4%	43.8%	45.9%	2.5%	2.9%	2.1%	3.4%
Total economy	100.0%	100.0%	3.5%	4.1%	100.0%	100.0%	1.8%	2.1%	1.7%	2.0%

[1] Manufacturing and business services include the ICT sectors.
Source: own calculations using data from STAN OECD database, Groningen University ICT database, and Statistics Netherlands

Overall, one may conclude that output and ALP growth in ICT *producing* sectors in the euro area were clearly higher than in other sectors of the economy. This points to a positive impact of ICT on economic growth. However, the size of these sectors is relatively small implying that there has so far been only a limited impact on overall economic developments. Nevertheless, the aggregate contribution of ICT sectors to total ALP growth was noticeable in the euro area in the period 1991-1998. The fact that the growth rates of ALP in the ICT *using* sectors did not rise appreciably faster than in the non-ICT using sectors casts doubt, for the time being, on the existence of positive spillover effects from the use of ICT in the euro area. Moreover, the relatively low growth rates of employment in the ICT producing sectors in the euro area could be indicative of a lack of flexibility in the product, labour, and financial markets.

4 Contribution of new technologies to economic growth

To assess the contribution of ICT capital to economic growth and to estimate the development of TFP, a standard growth accounting exercise has been carried out. The growth accounting framework was pioneered by Solow (1957) and further developed by Jorgenson and associates (e.g. Jorgenson and Griliches, 1967; Jorgenson et al 1987). The framework used here is similar to that used in Oliner and Sichel (2000). In a growth accounting framework, the growth rate of output ($\dot{Y}$) is equal to the weighted growth rates of labour input ($\dot{L}$) and capital input ($\dot{K}$), plus growth in total factor productivity ($\dot{TFP}$). The following formula has been used here:

$$\dot{Y} = \alpha_L \dot{L} + \sum_i \alpha_{Ki} \dot{K}_i + \dot{TFP} \qquad (3)$$

Time subscripts have been suppressed for simplicity of notation. Labour input growth is measured in total hours worked (Appendix 1 provides a more detailed overview of the data used). The share of labour (α_L) can be calculated from the wage share in gross value added (which can be directly extracted from the national accounts) adjusted for the imputed wage income of the self-employed and varies over time. Due to data limitations, no adjustment has been made for the quality of labour in this exercise. As to capital inputs, a distinction is made between the contribution of ICT capital and of other, non-ICT capital to output. In all, six categories of capital have been distinguished. ICT capital consists of the stock of information equipment (including computers), the stock of software, and the stock of communications equipment. Non-ICT capital consists of the stocks of 'other machinery and equipment', transport equipment and non-residential construction. Capital stock estimates have been constructed using the perpetual inventory method, which uses the past pattern of real investment together with assumptions on service lives and age-efficiency patterns of the different types of capital goods (see also Appendix 1). The sum of the shares of the various types of capital is assumed to be equal to 1- α_L, a standard assumption in this kind of exercise reflecting constant returns to scale. The shares of the different types of assets in total capital input are based on the user cost of capital, i.e. the gross rate of return that must cover the internal rate of return (assumed common to all capital)[8], the depreciation rate, and the capital gain/loss of the specific capital good. Tax considerations were not taken into account, but the impact of taxes on the user cost of capital is assumed to be captured by the internal rate of return.

It is important to mention the following caveats. First, the growth accounting exercise used here relies on the Cobb-Douglas framework, with all production factors entering as mutually complementary. ICT is thus treated as just another capital good, one that is not different from others in terms of its impact on production. However, some observers have argued that ICT will have more fundamental implications for the organisation of work, making ICT a substitute of rather than a complement to other types of capital. Extending the framework to allow for ICT being a substitute is however beyond the scope of this paper.

Second, TFP growth as estimated here reflects a Hicks-neutral shift of a production possibility function over time. The estimates of TFP growth would be biased to the extent that technical progress is not neutral.

Third, the implicit assumption made here is that ICT affects economic growth immediately. However, some have argued that the benefits of ICT for economic growth will only be observed with a lag (e.g. David 1990).

Fourth, the growth accounting framework departs from the assumption of maintained equilibrium. In periods of structural changes, this assumption does not hold. Arguably, the increased use of ICT could be seen as such a structural change. Kiley (2000), for instance, has tried for the United States to incorporate costs of adjustment and concluded that the inclusion of adjustment costs can have large effects on the growth-accounting exercise when a new investment good is introduced - such as ICT. The contribution of ICT to economic growth could consequently be constrained for a prolonged period by the large adjustment costs required to incorporate a new investment good into the economy's

[8] This assumption is not consistent with the views of some, who argue that ICT accounts for exceptionally high returns to investment.

capital stock. Eventually, however, the impact of ICT boosts long-run growth in his model as well.

Fifth, ideally TFP growth as derived here (i.e. as a residual term) should reflect the increase in efficiency in the economic process. Hence, any positive spillover effects from ICT investment should result in an increase in the estimate of TFP growth.[9] However, as TFP growth is a residual term it captures all elements not included in the growth rates of capital and labour input, and thus also reflects the impact of omitted variables such as the quality of labour and any biases due for example to measurement problems.[10] It is therefore difficult to draw any firm conclusions from changes in measured TFP growth for the development of overall efficiency.

Using equation (3), the contribution of ICT capital to output and ALP growth has been determined and estimates have been made of TFP growth for the period 1991-1999. Usually TFP growth shows a pro-cyclical pattern. However, in view of the difficulties to separate trend from cycle, especially over short time periods, no attempt has been made to distinguish trend productivity growth from cyclical effects. Rather, the focus is on actual developments in the course of the 1990s.[11] For the euro area, there is a scarcity of national accounts data on ICT investment. However, the euro area estimates presented below are based on national accounts data from four countries (Germany, France, Italy and the Netherlands) which together comprise almost 80% of euro area gross value added.[12]

Table 5 shows the decomposition of growth of total real value added for the euro area estimate (using the implicit deflators from national data). Appendix 3 provides an overview of the individual country results. Table 5 presents absolute contributions to output growth as well as relative contributions, which represent the contribution relative to total growth. It appears that the relative contribution of ICT capital to growth has increased from 13% in the first half of the 1990s to 21% in the second half, largely due to software and, to a lesser extent, to information equipment. By contrast, the contribution of communications equipment investment has been remarkably stable over time. The increased contribution of ICT capital to the growth of real value added has been accompanied by a decline not only in the relative but also in the absolute contribution of

[9] Some researchers suggested on the basis of US data that technological change that is embodied in new ICT capital goods, which is not adequately reflected in the official price indices, would bias downward the measured growth of effective ICT capital stock (e.g. Sakellaris and Wilson 2001). In the current analysis, the effect of such embodied technological change is not identified and should show up in the overall estimate of TFP growth.

[10] As Triplett (2001) pointed out "if output and computer inputs are correctly measured, the new things that computers do will not show up in economic statistics in the form of an enhanced growth of [T]FP",

[11] With the notable exception of Gordon (2000), this has been the approach taken in most of the US literature as well. For instance, Stiroh (2001b) noted: "It is important to point out that there is no attempt to cyclically adjust the data; all analysis is done using actual data as reported by BEA. [...], it is quite difficult to separate trend and cyclical components, particularly when the data end in the middle of the cycle, as is currently the case."

[12] See footnote 3.

non-ICT capital. The contribution of total hours worked to output growth has turned positive in the second half of the 1990s to 22% in relative terms, following a substantial decrease in hours worked in the first half of the decade. The estimates give no indication of an increase in TFP growth in the course of the 1990s. On the contrary, TFP growth declined markedly in both absolute and relative terms from the first to the second half of the decade. In this context, it should be noted that the measure of TFP growth used here implicitly also includes the impact of changes in the quality of labour. In a situation of increasing labour market flexibility accompanied by increasing employment also of relatively low-skilled and inexperienced workers, the quality of labour input may grow at a slower pace than in a situation in which these people would not have entered employment. Hence, the decrease in measured TFP growth in the euro area in the second half of the 1990s is not necessarily a negative sign as it probably also partly reflects the absorption of previously unused supply of labour.

Table 5 Decomposition of euro area output growth[1]

	Absolute contribution to growth (percentage points)		Relative contribution to growth (as a percent of total)	
	1991-1995	1996-1999	1991-1995	1996-1999
ICT capital	0.20	0.40	13	21
- *Information equipment*	0.09	0.15	*6*	*8*
- *Software*	0.05	0.18	*4*	*9*
- *Communications equipment*	0.06	0.07	*4*	*3*
Other capital	0.57	0.47	37	24
Total hours worked	-0.66	0.43	-43	22
TFP	1.41	0.63	92	33
	annual average percentage growth			
Gross real value added	1.5	1.9	100	100

[1] estimate based on Germany, France, Italy, and the Netherlands, comprising about 79% of euro area gross value added
Source: own calculations based on data from OECD and national accounts

A closely related exercise focuses on the decomposition of ALP growth, whereby the growth in total hours worked is subtracted from the growth in output and from the growth in the various inputs. In this decomposition, ALP growth reflects increases in the amount of capital available per hour worked (capital deepening) and in the growth rate of TFP. Table 6 presents the results. According to these estimates, ALP growth decreased from 2.4% in the first to 1.3% in the second half of the 1990s. This decrease can be attributed to both a decline in TFP growth, and to a decrease in the rate of capital deepening of non-ICT capital. By contrast, ICT capital deepening accelerated over the same period from 10% to 28% in terms of relative contributions.

Table 6 Decomposition of euro area average labour productivity growth[1]

	Absolute contribution to growth (percentage points)		Relative contribution to growth (as a percent of total)	
	1991-1995	1996-1999	1991-1995	1996-1999
ICT capital deepening	0.25	0.36	10	28
- *Information equipment*	*0.11*	*0.14*	*4*	*11*
- *Software*	*0.07*	*0.16*	*3*	*13*
- *Communications equipment*	*0.07*	*0.06*	*3*	*4*
Other capital deepening	0.77	0.32	32	24
TFP	1.41	0.63	58	48
	annual average percentage growth			
ALP	2.4	1.3	100	100

[1] estimate based on Germany, France, Italy, and the Netherlands, comprising about 79% of euro area gross value added
Source: own calculations based on data from OECD and national accounts

Table 7 compares the results of this study with those of similar studies for the United States, attempting to take into account the methodological differences with regard to price deflators.[13] In particular, for the euro area estimate the US deflator for information equipment is substituted for the national one. Comparisons are further hampered by differences in the output concept used: while this study focuses on GDP, the studies on the United States cited refer to private sector output. Nevertheless, some interesting results appear.

It appears that the differences in the contribution of ICT capital to growth between the euro area and the United States are not very different, contrary to conventional wisdom. Table 7 suggests that the most significant difference between the euro area and the United States is in the development of TFP growth, which decreased in the euro area, but increased in the United States. To some extent the deceleration in TFP in the euro area may be explained by a deceleration in labour quality, as explained above. However, according to the studies cited in Table 7, in the United States the contribution of labour quality to output growth also declined slightly (about 0.1 percentage point) from the first to the second half of the 1990s. The results from the comparison are consistent with the finding of Stiroh (2001b) that increased ICT-use did not cause TFP to accelerate in the case of the United States (even though a positive impact of ICT-use on ALP is discernible at the sectoral level). However, he did find that TFP growth increased above average in the ICT producing sector. This suggests that the larger size of this sector in the United

[13] Because of the use of US-based alternative deflators, the growth contributions for the euro area in Table 7 differ from the results in Table 5. See appendix 4 for a discussion of the many methodological and statistical difficulties surrounding international productivity comparisons.

States is one of the explanations for the difference in TFP growth between the euro area and the United States.

Admittedly, the adjustment made here to the euro area estimate is rather crude. Whilst it is true that different approaches to quality adjustment may significantly impact on information equipment deflators, a number of other factors also need to be taken into account. For instance, the price indices in each country may reflect a different mix of investment goods, which suggests that using a US-based alternative deflator is far from ideal. Moreover, especially when investment goods are imported, a currency conversion could be warranted. Note also that adjustment of the deflators for information equipment could have an impact on GDP and ALP. However, the analysis in appendix 4 suggests that any such impact on the growth rate of aggregate output is only very limited (even though the effect on GDP expenditure components and measured real value added in individual sectors likely is much more substantial).

Table 7 Comparison of this study with studies on the United States
absolute contribution to growth (percentage point)

	Country	Period	Contributions to output growth[1]			
			IT equipment[2]	Software	Comm. equipment	TFP growth[3]
This study	euro area	1991-1995	0.26	0.05	0.06	1.24
		1996-1999	0.49	0.18	0.07	0.29
Oliner/Sichel	United States	1991-1995	0.25	0.25	0.07	0.92
		1996-1999	0.63	0.32	0.15	1.47
Jorgenson/Stiroh	United States	1990-1995	0.19	0.15	0.06	0.73
		1995-1998	0.46	0.19	0.10	1.24

[1] This study: GDP; Oliner/Sichel: nonfarm business sector output; Jorgenson/Stiroh: private domestic output
[2] Using an alternative US based deflator for IT equipment to increase comparability
[3] Including changes in labour quality

In summary, the results of the standard aggregate growth accounting exercise suggest that the importance of ICT capital accumulation for economic growth in the euro area has increased in the second half of the 1990s. The euro area is thus experiencing positive growth effects of ICT. The size of the contribution even appears to be not very different to that in the United States if one attempts to allow for the difference in price deflators for IT equipment. However, the data available do not point in the direction of significant positive spillover effects of ICT investment on the rest of the economy in the euro area, since, according to the estimates presented here, TFP growth has been declining rather than increasing in the course of the last decade.

5 Concluding remarks

The analysis of output and productivity developments in the euro area undertaken in this paper suggests that in the period up to 2000 there were only very limited, if any, positive spillover effects of the use of ICT on overall efficiency in the economic process. Hence, there is no reason to believe that the growth rate of potential output of the euro area would have risen significantly in recent years as a result of ICT developments. However, the data do show clear evidence of an increased contribution of ICT to overall economic growth. It has often been argued that the effects of ICT on TFP may occur with a certain delay. Looking forward, it thus might be that the forces of technological change are already discretely operating in the background. This would also imply that the uncertainties surrounding estimates of medium-term developments in potential output growth might have become skewed to the upside.

Many observers have attributed the differences in measured productivity growth (whether it is ALP or TFP growth) between the euro area and the United States in the second half of the 1990s, to a large degree to differences in the contribution of ICT capital. However, the contribution of ICT capital to output growth has not been much different in the euro area than in the United States, if one attempts to allow for the effects of different deflation techniques. This suggests that other factors are likely to account for the largest part of the observed, substantial, difference in TFP growth, including differences in production structure and possibly also flexibility of product, labour, and financial markets.

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Appendix 1 Data sources and aggregation methods

Data for sectoral developments

The main data source used is the OECD STAN database, which contains data on a detailed (two-digit ISIC rev.3) sectoral level for gross value added and employment. This database is still under development and as yet not published (see http://www.oecd.org/dsti/sti/stat-ana/stats/). In some cases, data from this database are not available or not sufficiently detailed. In those cases, the ICT database of Groningen University (see http://www.eco.rug.nl.GGDC/) has been used as an additional source of information. Moreover, for the Netherlands, use has been made of detailed employment accounts and supply and use tables of Statistics Netherlands. Employment includes self-employed persons in all cases.

Data for growth accounting

Labour hours: total employment data (in persons) were taken from the OECD (2000b) and average working hours from Scarpetta et al (2000). The series on average working hours was extended by one year (to 1999) on the assumption that the trend of the three preceding years was sustained.

Labour share: The share of labour (α_L) is calculated from the national accounts, by adding to the share of the employees (which can be directly read from the national accounts) the share of the self-employed, assuming that the share of the latter is proportionally equal to the share of the employees.

Capital stocks: To construct the capital stocks the following formula has been used:

$$K_{it} = \sum_{b=0}^{b=t} \Phi_{itb} I_{ib}$$

Where I_{ib} represents real investment at time b of capital good i, and Φ_{itb} the economic efficiency at time t of investments at time b of capital good i. Φ_{itb} in turn is calculated from the formula:

$$\Phi_{itb} = (m_i - a_i) / (m_i - \beta_i a_i)$$

with m_i the average service lifes set equal to those of the US Bureau of Economic Analysis (1999), a_i being the age of the vintage, and β_i the decay parameters set at 0.95 for ICT capital and 0.8 for other types of capital, following CPB (2000) on the assumption that the decay in efficiency of ICT is relatively very limited until the asset is retired at the end of the service life. However, assuming a common decay parameter to all types of capital (including ICT capital) does not significantly alter the results. Note that the service life for software has been set at 4 yours, based on assumed service lifes for pre-packaged and own account software in Oliner and Sichel (2000).

The investment data necessary to build capital stocks are based on national accounts (ESA95) of Germany, France, Italy, and the Netherlands. In the case of Germany, the ICT investment series had to be backcast by assuming that the growth pattern of the other three countries was representative for Germany as well. In addition, the structural break due to German re-unification has been corrected by applying West-German growth rates to all German levels back in time. Moreover, in the case of non-ICT investment, some series had to be backcast by applying growth rates of ESA79 data to the ESA95 time series in order to construct long-enough time series. The investment data were aggregated to yield estimates of euro area investment in the different types of capital goods distinguished.

Share of capital: The income share for each type of capital is calculated from the following equation:

$$\alpha_{Kit} = (c_{it}\, K_{it}) \,/\, (p_{yt}\, Y_t)$$

where Y is real gross value added, and c_{it} the user costs of capital, which are calculated by using the following formula:

$$c_{it} = (r_t + \delta_{it} - \pi_{it})\, P_{kit}$$

where δ_{it} represents the depreciation rate, which is taken from the tables of the US Bureau of Economic Analysis (1999) as in Oliner and Sichel (2000), π_{it} is the expected capital gain/loss and is calculated as a three-year moving average of the annual price change of the capital good (following CPB 2000 and Oliner and Sichel 2000), P_{kit} is the price of the respective capital good, r represents the nominal rate of return and is assumed to be equal over all types of stocks of capital goods. The depreciation rate for software has been derived in a consistent manner with BEA's depreciation estimates for the other types of capital goods. The rate of return is thus calculated for each year as the ex post return from the equation:

$$\sum_i ((\, r_t + \delta_{it} - \pi_{it})\, P_{kit}\, K_{it}\,) \,/\, (p_{yt}\, Y_t) = 1 - \alpha_{Lt}$$

Aggregation methods

Where appropriate, purchasing power parities were used to compute euro area aggregates, in accordance with standard practices for cross-country comparisons of economic growth

(Van Ark 1996). 1996 purchasing power weights as calculated by the OECD (1999) were applied here. In particular, the expenditure PPPs were matched to the particular sector and investment category distinguished (the so-called 'proxy' PPP approach). This choice is motivated by the need for a conversion factor which takes cross-country differences in price levels and relative price differences among expenditure categories into account. However, the alternative of applying one common conversion factor, such as the weights used by Eurostat or those used in the Area-Wide model for the euro area (Fagan et al. 2001), does not change the results significantly. The alternative of conversion at current exchange rates is not appropriate, as it does not allow for difference in price levels among countries. Moreover, current exchange rates are volatile and affected by a number of factors, such as capital movements, trade flows, and the sentiment of financial markets, which makes them unsuitable to compare fluctuations in real economic activity across countries.

Appendix 2 Sectoral developments in individual euro area countries

The individual country results of the sectoral analysis are presented below (see Tables a2.1 and a2.2). In interpreting the data the following has to be borne in mind.

1. The differences in measured ALP in the ICT producing manufacturing sector are mainly due to differences in price deflators (see Table a2.3), which are probably mainly caused by methodological differences in the measurement of real output rather than by real economic differences. The use of hedonic deflators by France, for example, explains the relatively high productivity growth in the ICT producing manufacturing sector according to the French national data. The 'distortionary' effects of the use of different price deflators becomes apparent when a common deflator based on the United States is substituted for the national deflators of the euro area countries studied. These alternative calculations show high productivity growth in France comparable to those in the other euro area countries (see Table a2.4). Note in this context, that the national deflator in France is declining even more rapidly than that in the United States, implying that measured productivity growth is even slightly reduced in the case of France when using a common US-based price index.

2. The country tables show that in the course of the 1990s the share of ICT sectors only did increase in the case of Finland. The share has been more or less stable in the other euro area countries. Note that value added shares are calculated with current prices and thus are directly comparable across countries. The relatively high share of ICT producing sectors in value added is one of the factors explaining the faster overall productivity growth in Finland vis-à-vis the other euro area countries.

3. Moreover, the structure of the economy differs from country to country. For example, Finland has a large ICT producing manufacturing sector. In fact, it is even larger than that of the United States in relative terms. However, within the United States there are also large regional differences. In this context, it is interesting to note that Finland started relatively early with the liberalisation of its telecom market, as stressed by Colecchia and Schreyer (2001), which may be one of the reasons behind the rapid take-off of ICT production in Finland in the course of the 1990s. In this regard, it can also be noted that those countries that are commonly thought to have been among those that made most progress with labour market reforms in the euro area (namely Finland and the Netherlands), also show the largest overall employment growth.

Table a2.1 Share in value added

	period	Finland	France	Germany	Italy	Netherlands
ICT producing sectors, manufacturing	1991	0.6%	0.8%	1.3%	0.8%	1.6%
	1998	3.6%	0.8%	0.7%	0.5%	1.2%
ICT producing sectors, services	1991	3.2%	3.6%	3.3%	3.1%	2.8%
	1998	4.0%	3.8%	3.9%	3.7%	3.9%
ICT using sectors, manufacturing	1991	2.3%	3.3%	5.8%	3.2%	2.8%
	1998	3.0%	3.3%	4.5%	3.1%	2.3%
ICT using sectors, services	1991	6.5%	11.2%	10.1%	10.5%	11.1%
	1998	6.0%	10.9%	11.1%	11.3%	13.4%

Source: own calculations using data from STAN OECD database, Groningen University ICT database, and Statistics Netherlands

Table a2.2 ALP growth

	period	Finland	France	Germany	Italy	Netherlands
ICT producing sectors, manufacturing	1991-1998	22.8%	24.0%	9.8%	-0.1%	5.9%
	1995-1998	21.1%	26.9%	11.8%	-1.9%	3.3%
ICT producing sectors, services	1991-1998	7.1%	3.7%	8.7%	5.3%	2.6%
	1995-1998	9.6%	5.8%	12.1%	5.0%	3.1%
ICT using sectors, manufacturing	1991-1998	5.5%	4.4%	3.8%	3.0%	5.8%
	1995-1998	4.5%	3.1%	2.5%	1.3%	1.0%
ICT using sectors, services	1991-1998	3.1%	-1.3%	0.5%	0.7%	0.7%
	1995-1998	3.0%	-1.6%	1.7%	-0.8%	0.1%

Source: own calculations using data from STAN OECD database, Groningen University ICT database, and Statistics Netherlands

Table a2.3 Change in implicit value added deflator

	period	Finland	France	Germany	Italy	Netherlands
ICT producing sectors, manufacturing	1991-1998	-2.4%	-15.4%	-3.6%	-0.5%	-2.0%
	1995-1998	-2.4%	-18.0%	-2.1%	0.3%	-1.6%
ICT producing sectors, services	1991-1998	-0.2%	-0.7%	-0.6%	2.3%	1.1%
	1995-1998	0.3%	-2.3%	-3.5%	3.1%	-2.4%
ICT using sectors, manufacturing	1991-1998	2.3%	0.5%	0.5%	2.2%	-1.4%
	1995-1998	0.3%	0.2%	0.1%	0.8%	-3.8%
ICT using sectors, services	1991-1998	1.7%	2.8%	1.2%	3.2%	3.5%
	1995-1998	1.2%	2.3%	-0.6%	3.2%	2.0%

Source: own calculations using data from STAN OECD database, Groningen University ICT database, and Statistics Netherlands

Table a2.4 ALP growth on the basis of US deflator

	period	Finland	France	Germany	Italy	Netherlands
ICT producing sectors, manufacturing	1991-1998	33.1%	16.4%	17.5%	10.4%	15.3%
	1995-1998	35.0%	18.8%	25.0%	12.3%	16.1%

Source: own calculations using data from STAN OECD database, Groningen University ICT database, and Statistics Netherlands

Appendix 3 Growth accounting for individual countries

The results of the growth accounting analysis for the individual euro area countries covered in this study are shown below, along with the results of other studies which made use of official data (see Tables a3.1 and a3.2). From Table a3.1, it can been seen that the contribution of ICT capital to ALP growth increased in all countries except Italy. Italy has also been lagging in terms of the ICT contribution at the sectoral level. Furthermore, all countries studied experienced a deceleration of TFP growth, with the exception of France. However, French TFP growth was already relatively low at the beginning of the 1990s. From Table a3.2 it emerges that in qualitative terms the estimates from this study and other related studies tend to yield a similar picture, especially on the increased importance of ICT for economic growth over the 1990s. However, the following caveats should be borne in mind in interpreting the quantitative estimates, which do differ somewhat from one study to the other.

1. This study focuses on growth rates of real GDP whereas most other studies tend to use real business sector output. The use of GDP in this study was motivated most importantly by the fact that the data on investment for three of the four countries are available for the total economy only and not for the private sector. In this study it was chosen to use these data directly, whereas for example Colecchia and Schreyer (2001) constructed their own estimates of business sector investment on the basis of the data on total economy investment in the cases of Germany and Italy, to enhance comparability with the United States. As the main focus of this study is to consider the importance of ICT for the euro area and not to establish results which are comparable with estimates for other economies, such an adjustment - which necessarily involves some arbitrary decisions and possibly creates (further) biases in the data – was considered unjustified in this case.

2. A comprehensive framework to calculate ICT contributions to output and productivity growth is used here. A comprehensive framework allows for a cross-check with the contribution of labour to output growth and for TFP estimates. The importance of such cross-checking emerges from a closer look at the study by Mairesse et al. (2000) for France. In particular, in this study the share of capital goods (excluding construction) adds up to 12.1% on average over the period 1995-1999. The total share of capital was 31.7% in that period according to the national accounts. The difference of 19.6 percentage points seems too much to be attributable to the exclusion of construction.[14] The shares of capital assumed affect the estimates of the level of contributions of ICT capital to output growth (but not the pattern over the years). This probably leads to an

[14] In our calculations the share of construction was 13.7%.

underestimate of contributions of ICT capital to output growth in the study of Mairesse et al.

3. The depreciation rate for software used in this study is higher than the depreciation rate used in some of the other studies. This is probably due to a different interpretation of the right concept of depreciation, an issue which is not straightforward to settle on theoretical grounds. The System of National Accounts (1993) defines depreciation as "the decline, during the course of the accounting period, in the current value of the stock of fixed assets owned and used by a producer as a result of physical deterioration, normal obsolescence, or normal accidental damage".[15] It thus relates to economic depreciation as well as physical depreciation. In the presence of rapid technological change, high residual values of assets at the end of their assumed service lives are not consistent with a high rate of economic obsolescence. In particular, the net value of an intangible asset such as software can be expected to be close to zero at the end of its service life. This implies a relatively large declining balance rate and thus a relatively high depreciation rate. The depreciation rate used affect the size of the estimated contribution of software to output growth, with higher depreciation rates implying higher contributions. The depreciation rate for software used in this study allows for a depreciation to about 5% of the original value at the end of the service life, while the depreciation rate used in other studies tend to leave software at much higher residual values at the end of its service life (in the order of 25%). Consequently, other studies find lower contributions of software to output growth. The pattern of an increased contribution from the first to the second half of the 1990s is, however, not affected by this difference.

[15] Note in this respect, that changes in the acquisition prices of assets, which are also part of the formula for user cost of capital, reflect revaluation – not depreciation. See Fraumeni (1997) for an alternative view. In particular, she argues that price changes reflect also obsolescence, which would overlap with the definition of depreciation from SNA.

Table a3.1 Decomposition of ALP growth
(percentages for ALP, percentage points otherwise)

	period	France	Germany	Italy	Netherlands
ALP	1991-1995	**1.79**	**2.70**	**2.95**	**1.96**
	1996-1999	**1.37**	**1.53**	**0.86**	**0.53**
Capital deepening					
ICT	1991-1995	**0.26**	**0.20**	**0.19**	**0.34**
	1996-1999	**0.45**	**0.27**	**0.21**	**0.47**
Information equipment	*1991-1995*	*0.14*	*0.10*	*0.03*	*0.22*
	1996-1999	*0.18*	*0.12*	*0.03*	*0.26*
Software	*1991-1995*	*0.08*	*0.07*	*0.03*	*0.08*
	1996-1999	*0.21*	*0.13*	*0.09*	*0.20*
Communications equipment	*1991-1995*	*0.04*	*0.03*	*0.13*	*0.04*
	1996-1999	*0.06*	*0.01*	*0.09*	*0.01*
Other capital	1991-1995	**1.08**	**0.98**	**1.26**	**0.84**
	1996-1999	**0.39**	**0.62**	**0.47**	**-0.25**
TFP	1991-1995	**0.45**	**1.52**	**1.49**	**0.78**
	1996-1999	**0.52**	**0.64**	**0.18**	**0.30**

Source: own calculations based on data from OECD and national accounts

Table a3.2 Comparison of this study with other studies on individual euro area countries

France					
	Period	**Contributions to output growth** (percentage points) [1]			
		IT equipment	**Software**	**Comm. equipment**	**TFP growth**
This study	1991-1995	0.14	0.07	0.03	0.45
	1996-1999	0.19	0.23	0.08	0.52
Colecchia/Schreyer	1990-1995	0.11 (incl. com. eq.)	0.02	NA	NA
	1995-1999	0.19 (incl. com. eq.)	0.08	NA	NA
Mairesse et al.	1989-1995	0.09	0.05	0.03	NA
	1995-1999	0.13	0.09	0.05	NA

German					
	Period	**Contributions to output growth** (percentage points)[1]			
		IT equipment	**Software**	**Comm. equipment**	**TFP growth**
This study	1991-1995	0.09	0.06	0.02	1.52
	1996-1999	0.12	0.13	0.01	0.64
Colecchia/Schreyer	1990-1995	0.16 (incl. com. eq.)	0.06	NA	NA
	1995-1999	0.14 (incl. com. eq.)	0.07	NA	NA

Italy					
	Period	**Contributions to output growth** (percentage points)[1]			
		IT equipment	**Software**	**Comm. equipment**	**TFP growth**
This study	1991-1995	0.02	0.01	0.11	1.49
	1996-1999	0.04	0.10	0.11	0.18
Colecchia/Schreyer	1990-1995	0.10 (incl. com. eq.)	0.01	NA	NA
	1995-1999	0.12 (incl. com. eq.)	0.04	NA	NA

Netherland					
	Period	**Contributions to labour productivity growth** (percentage points)[2]			
		IT equipment	**Software**	**Comm. equipment**	**TFP growth**
This study	1991-1995	0.22	0.08	0.04	0.78
	1996-1999	0.26	0.20	0.01	0.30
CPB	1991-1995	0.2 (total ICT excl. software)			0.7
	1996-1999	0.2 (total ICT excl. software)			1.3
Van der Wiel	1991-1995	0.2 (incl. com. eq.)	0.1	NA	0.5
	1996-2000	0.2 (incl. com. eq.)	0.2	NA	1.2

[1]This study; GDP; other studies: business sector output

[2]This study; GDP per hour worked; other studies: business sector output per employee fte

Appendix 4 Measurement problems related to productivity

The problem of measurement of macro-economic data has featured prominently in recent discussions on the impact of the new technologies on the economy. In particular, the techniques to account for quality changes of ICT production and expenditure in the national accounts have received particular attention. However, other measurement problems such as methods to take better account of changes in relative prices and those related to measuring services sector output may be as important in this regard. This appendix attempts to shed more light on these measurement issues.

4.1 The sensitivity of euro area real GDP to alternative deflators for ICT goods

As Wyckoff (1995) showed, the large differences in computer deflators between countries are at least partly due to methodological differences. In particular, conventionally constructed price indices would not fully capture quality improvements, as opposed to other indices such as those constructed applying the hedonic technique (i.e. a deflation technique based on a regression of the prices of a basket of goods on a set of qualities or characteristics of those goods, to identify price changes due to quality changes). Application of conventional price deflating techniques would thus lead to an overestimation of price changes and hence an underestimation of volume changes.[16]

As most euro area countries apply traditional techniques, it has sometimes been argued that measured real GDP growth in the euro area would be higher if prices of ICT goods were fully adjusted for quality improvements (e.g. Cecchetti 2000). The substitution of US price indices for ICT goods and services in the euro area national accounts has been advocated as a first step to enhance comparability between the growth rates recorded in the official statistics. Schreyer (2000) presents simulated effects on key economic variables (real output, private final consumption, government expenditure, investment, exports and imports) and productivity in five OECD countries, on the basis of such alternative (US based) price indices of ICT products. He concludes, however, that the impact of alternative price indices on real GDP growth tends to be small. Alternative (US based) deflators are applied below to the production side framework as presented in Section 3 of the main text.

[16] Although Aizcorbe et al (2000) show that in theory the particular methodology of construction of price indices should not necessarily matter, in practice, countries applying a more conventional technique record smaller price declines in ICT goods than countries applying the hedonic technique.

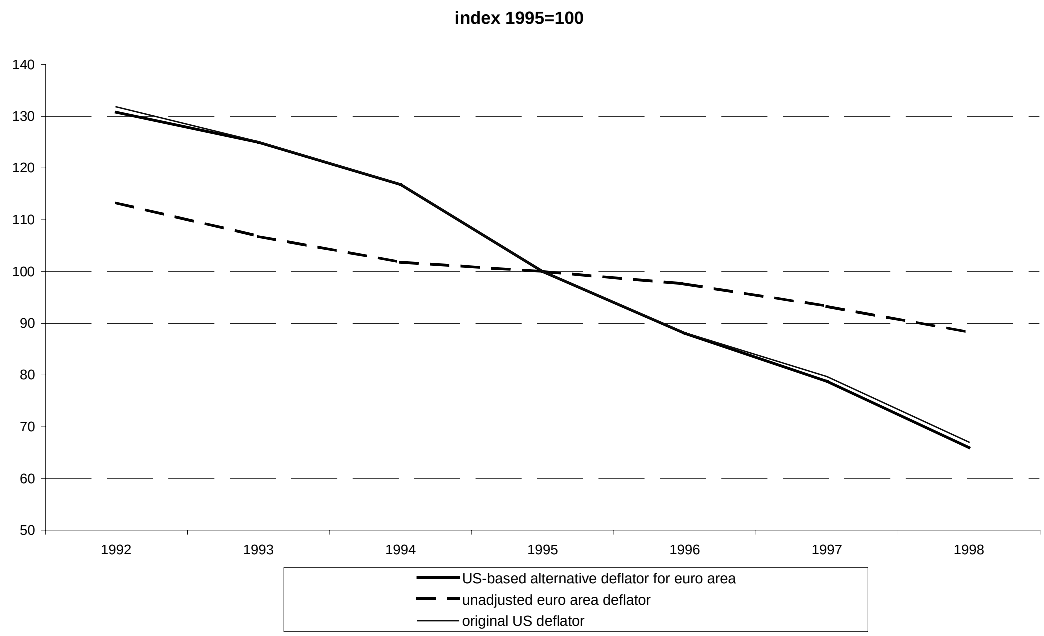
Since the rate of growth of aggregate GDP or value added is a weighted average of the growth rates of value added by industry, it would appear straightforward to compute adjusted real value added measures by adjusting the constant-price value added for the relevant industries (for instance those producing ICT equipment), using alternative deflators. Multiplying the alternative growth rate of real value added thus obtained for the industries concerned by their share in total value added would yield an alternative economy-wide estimate of real value added (or real GDP) growth. This is not a valid approach, however.

National accounts guidelines recommend price and volume indices for value-added to be based on the so-called 'double-deflation' method, combining deflators of gross output and intermediate inputs. In the present context, this point is of importance as many industries consume intermediate ICT products whose price changes may be overstated as well. Thus, both output and input prices have to be adjusted to assess the full impact on measured value added and on total gross value added. If prices are adjusted for a product in one industry that is delivered to another industry, real value added in both industries is affected and the adjustment goes in opposite directions. Hence, full and internally consistent estimates of inter-industry effects on input and output price and volume adjustments, and their final impact on overall value added (or GDP) have to be assessed using detailed input-output tables.

The detailed sectoral gross value added data from the OECD Stan database were combined with information from 1995 input-output tables in order to construct series of gross output and inputs for a total of 24 sectors. The focus is here on the ICT producing manufacturing sectors, 'office accounting equipment and computer machinery industry' (30 ISIC) and 'radio, TV and communications equipment industry' (32 ISIC). For euro area countries the US deflator was substituted for the national one, after a correction for differences in domestic inflation with the United States for non-ICT hardware goods in the period from 1992 to 1998. This correction is deemed necessary in order to make the alternative deflator for ICT equipment independent of changes in inflation that prevail in the different countries. However, applying the US deflator directly without correcting for differences in domestic inflation for non-ICT hardware goods does not lead to significant differences in the results.

Chart a4.1 shows the implicit price deflator for ICT equipment for the United States along with both the original and the alternative deflators for the euro area. Between 1992 and 1998 the alternative (US based) deflator for ICT equipment in the euro area decreased by 10.8% on average, compared to a 4.1% average decline for the original deflator, based on national data.

Chart a4.1 Price deflators for ICT equipment – euro area and United States



Source: own calculations based on OECD Stan database and Eurostat 1995 input-output tables

Table a4.1 summarises the results. The table shows a decomposition of the total effect of the use of an alternative (US based) ICT deflator on measured real GDP growth in the euro area, distinguishing the effects of using an alternative deflator for ICT equipment output and of an alternative price index for the use of ICT equipment as input.

Table a4.1 Impact on euro area real value added growth of using US based deflators for ICT equipment
(percentages for real value added, percentage points otherwise)

	1992	1993	1994	1995	1996	1997	1998	avg 1992-98
unadj.real value added growth	1.6	-0.7	2.2	2.1	1.3	2.0	2.6	1.6
adjustments due to								
ICT output adjustment	0.08	-0.02	0.02	0.26	0.21	0.18	0.37	0.16
ICT input adjustment	-0.03	0.03	-0.01	-0.17	-0.16	-0.13	-0.28	-0.11
total impact	0.05	0.01	0.01	0.09	0.06	0.05	0.09	0.05
adj.real value added growth	1.7	-0.7	2.2	2.2	1.4	2.0	2.7	1.6

Source: own calculations based on OECD Stan database, Groningen University ICT database, Statistics Netherlands, and Eurostat 1995 input output tables
Note: figures may not add up due to rounding

Since the effects computed are typically small, the intermediate results are presented to two decimal points in the table, even though the margins of error would probably only allow rounding to at most one decimal point. The effects of the use of alternative deflators for ICT equipment for the 1992-1998 period averages 0.16 percentage point per year for gross output growth (which has an upward effect) and 0.11 percentage point for the growth rate of intermediate inputs (which has a negative impact on the growth rate of real value added). The combined effect of the gross output and intermediate input corrections on the growth rate of real gross value added (and hence on real GDP) thus cancels out to a large extent. Between 1992 and 1998 the net effect on real value added growth is only visible at the two decimal point level, averaging a mere 0.05 percentage point. Furthermore, the adjustments show no clear pattern over time, although adjustments tend to be larger in the second half of the 1990s than in the first.

Thus, the estimates from the production side suggest that the mechanical net impact of alternative deflators for ICT equipment on real GDP growth in the euro area is relatively small (albeit with some variation across years).

4.2 Other measurement issues

The issue of ICT deflators can not be discussed in isolation. For example, a consistent use of aggregation procedures to arrive at area-wide aggregates would be required as well. At present, several countries within the euro area use chain-type indices with annually changing weights in their national accounts to compute growth rates of real GDP and components, as is done in the United States, while other euro area countries do not. Chain-type indices use adjacent period weights to allow for changes in relative prices and output over time. By contrast, some euro area countries use a fixed weight basis. The difference between the two methods is small as long as relative weights do not change significantly over time. However, in the event of strong changes in the relative weights the use of a fixed basis leads to a distortion of the price and growth measurement, and this bias increases with the distance from the base period. According to EU standards for national accounts (ESA95), the use of annually chain-weighted measures is to be completed by 2005.

Apart from the issue of ICT deflators and aggregation procedures, there are other sources of measurement error which influence measured output and productivity. In particular, distinguishing between price and quantity components of output has become increasingly difficult as the share of services in total value added has increased over time. Identifying volume and price changes in services sectors is difficult for a number of reasons. First, there is a relative dearth of primary statistics for the service sector. Second, it is often conceptually more difficult to define the quantity of a particular service delivered than the quantity of a tangible good. In many cases output in services sectors is estimated on the basis of inputs, which implies a probable under-recording of productivity growth. As the size of the services sector has increased over time, it is likely that the measurement error has increased as well. For instance, in the euro area the share of services (including government) in nominal value added increased from 56.9% in 1980 to 69.4% in 1999. To what extent this will impact on the international comparability of data is difficult to determine. In principle, any measurement problems associated with the increasing share of services in GDP would be common to all advanced economies. Nevertheless, the share of services may differ across countries. Moreover, and more generally, different accounting practices among statistical agencies could lead to a dissimilar impact. For instance, there are substantial differences in methodologies for distributing ICT expenditure, software in particular, over final and intermediate uses (Lequiller 2001, Oulton 2001, Bundesbank 2001).

In summary, differences in existing statistical practices among countries appear to hamper comparisons of output and productivity across countries and across sectors. However, the biases will affect the aggregate output and productivity measures less. Thus, while measurement errors do cloud the picture, it seems unlikely that they are the major explanation for the lower recorded productivity growth in the euro area in recent years.

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