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ICT INVESTMENT AND GROWTH OF OUTPUT AND PRODUCTIVITY

Information and communication technology (ICT) may well be the most important modern technology and certainly a core element of the knowledge-based society. Expenditure on, production shares of and investment in ICT have risen in the past decade, albeit at different rates of growth across EU countries and between the EU and the USA. ICT has had a significant impact on growth of GDP and productivity, although the scope of this impact and its direction are still subject to scientific controversy.

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In the 1990s, several causes combined to accelerate ICT diffusion and growth: technological change was coupled with massive price cuts, which made for a surge in digital technologies. An already existing predisposition of firms to exploit the opportunities of ICT, liberalisation of telecommunications and growth features of the Internet economy (economies of scale and network effects) have combined to create new vigour and an eagerness to invest in new technologies. In the USA, business investment in computers and peripheral equipment, measured in real terms, jumped more than fourfold between 1995 and 1999 (e.g., *Oliner – Sichel,* 2000). A rapid increase is also observable in Europe, though not at the same pace as in the USA.

Nevertheless, there are still divergent opinions on the overall importance of ICT for the economy, most notably on the productivity impact of ICT investment. The debate on the significance of the "new" economy primarily discusses the magnitude of the impact of ICT investment on economic development in non-ICT-producing sectors.

International trends in ICT spending and investment

The following chapters first report trends in ICT expenditure, production and investment and analyse country differences. Then we discuss the methodological issues related to the measurement of the output and productivity growth impact of information technology, and ICT expenditure and investment trends in Europe and the USA. We present studies which quantify the impact of ICT on aggregate growth, cyclical effects and spillovers on labour productivity. The final chapter provides a summary of the findings thus obtained.

ICT expenditure

The importance of ICT can be measured in terms of expenditure, production and investment[1]. All are increasing, though at different rates in different countries (Table 1). Expenditure in Europe seems to be more cyclical and, on average, lower than in the USA, but European developments are very heterogeneous at the country level. While Sweden and the UK spend as much on ICT as the USA, big EU countries, such as France, Germany, Italy and Spain, are lagging behind in terms of ICT spending.

[1] ICT expenditure measures the diffusion of computer hardware and peripherals, communications equipment and software. For Europe no official data are available, but figures are derived from surveys by private sources. The most frequently used data source is compiled by ICD (*WITSA,* 2000). The data collected by ICD is gathered both at the country level and from corporate headquarters. ICD is the only available source for European countries which allows systematic cross-sectional comparisons for the 1992-1999 period. As ICD does not publicly release information as to the size and structure of its sample, the degree of comprehensiveness of the data set remains hard to gauge. The situation in the USA is very different. The Bureau of Economic Analysis (BEA) maintains the "Tangible Wealth Survey" which provides information on 57 distinct types of capital goods in current and chain-weighted dollars for 62 industries from 1947 through 1996. The distinct types of assets for each industry can be aggregated to calculate capital stocks for computer hardware and communications equipment. Software investment is not included in this survey, but BEA started to publish data on aggregate investment in software in its 1999 revision (Source: *Stiroh,* 2001, *European Commission,* 2000, *WITSA,* 2000, *Oliner – Sichel,* 2000, *Landefeld – Grimm,* 2000).

ICT expenditure measures the diffusion of ICT goods and thus the absorption of ICT by businesses, private households and the government sector. Consequently, the readiness of firms to invest in these technologies and the willingness of private households and the government to use them impacts on the overall ranking of countries.

The available indicators of ICT spending reveal distinct differences in the level of expenditure between OECD countries. Sweden and the UK in Europe as well as Australia and the USA take the lead, spending about 8 percent of GDP in 1999, followed by the Netherlands and Denmark with expenditures close to 7 percent. France, Germany, Italy and Spain (the other large European countries) are grouped around or below the EU average (1999: 5.6 percent). The overall result is that the expenditure share in GDP is 2.5 percentage points or nearly one third lower than in the USA.

Table 1: International comparison of ICT investment and production

	Share of ICT in business sector employment	Share of ICT in business sector value added	ICT expenditure	
	1998	1998	1998	1992-1999
	In percent		As a percentage of GDP	
Belgium	4.3	5.8	5.7	5.6
Denmark	5.1	–	6.7	6.6
Germany	3.1	6.1	5.1	5.3
Greece	–	–	5.1	3.8
Spain	–	–	4.0	3.9
France	4.0	5.3	5.9	5.9
Ireland	4.6	–	6.4	5.9
Italy	3.5	5.8	4.5	4.2
The Netherlands	3.8	5.1	6.9	6.7
Austria	4.9	6.8	4.7	4.8
Portugal	2.7	5.6	5.1	4.5
Finland	5.6	8.3	5.7	5.6
Sweden	6.3	9.3	9.5	8.2
UK	4.8	8.4	9.0	8.1
EU [1]	4.0	6.4	6.0	5.6
Japan	3.4	5.8	6.2	6.0
USA	3.9	8.7	8.7	8.1
Switzerland	6.0	–	7.3	7.3
Australia	2.6	4.1	8.5	8.1
Canada	4.6	6.5	8.1	7.6

Source: *OECD* (2001A), *WITSA* (2000), WIFO calculations. – [1] Weighted average (with GDP 1990), WIFO calculations.

The European spending gap correlates with the smaller size of the ICT-producing sector (see *McMorrow – Roeger,* 2001) but is also due to less dynamic spending by the government sector and private households. Australia demonstrates that a large ICT sector is not a prerequisite for high ICT expenditure: the ICT-producing sector accounts for only 2.6 percent of overall business sector employment, even though Australia is among the big ICT spenders.

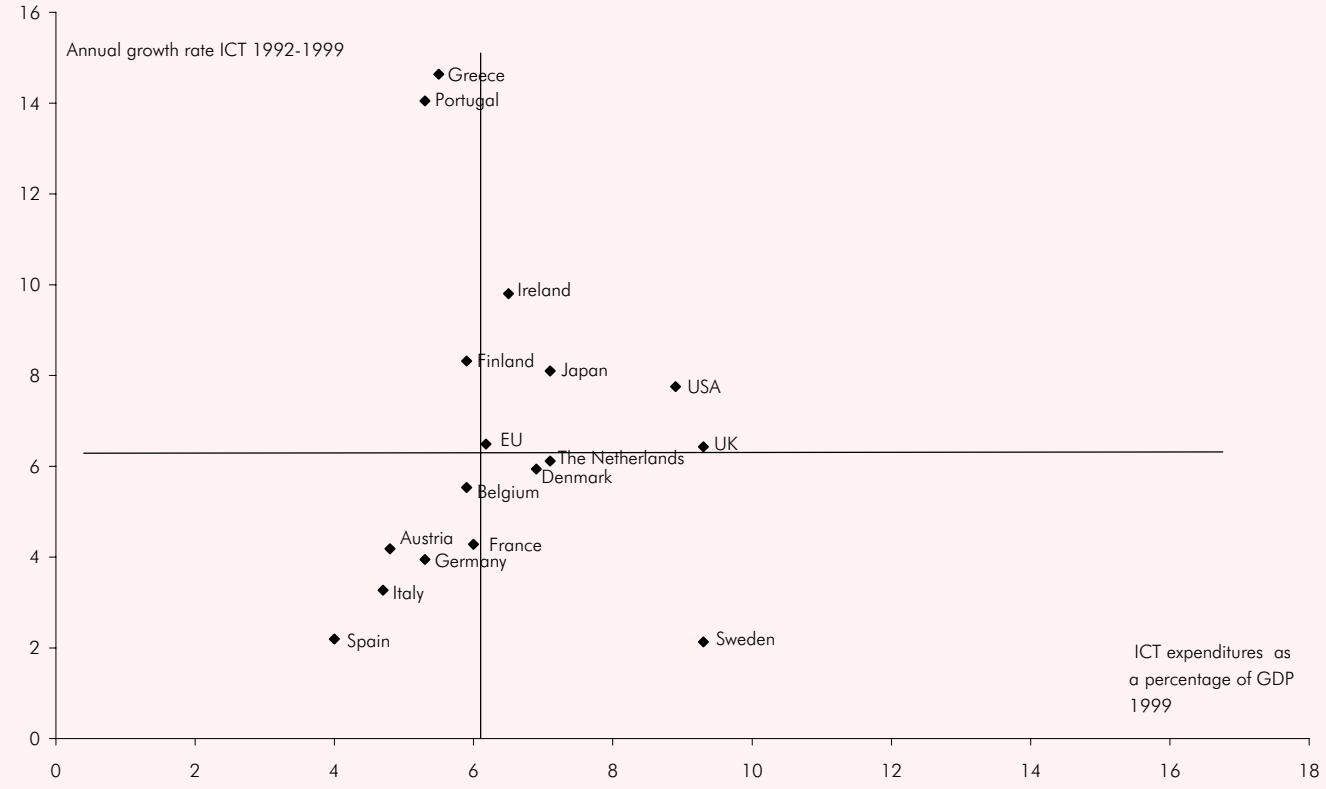
Throughout the 1990s, overall ICT spending increased both in Europe (+6.5 percent p.a.) and the USA (+7.8 percent p.a.), substantially accelerating in the second half of the decade (EU +3.7 percent p.a., USA 6.2 percent p.a.). ICT expenditure increased far more steadily in the USA than in Europe. The annual growth rates in Europe seem to be related to business cycle fluctuations, rising at above-average rates in periods of sound economic growth and stagnating or even declining in phases of low GDP growth. In the USA the overall growth performance and the growth of ICT expenditure are smoother but seem to be similarly coupled.

The gap between ICT shares in Europe and the USA has widened since 1992 (from 2.3 percentage points in 1992 to 2.7 percentage points in 1999). Since, however, GDP in the USA grew faster, the growth of ICT expenditure was more dynamic. Relative to US expenditure, European expenditure in ICT declined from 90 percent in 1992 to 75 percent in 1999.

The most dynamic European countries with respect to ICT expenditure growth were Greece, Portugal, Ireland and Finland (Figure 1). All of them increased their shares of ICT expenditure as percentages of GDP in the 1990s and are now above or close to the EU average. The same applies – although at a lower level – to the Netherlands, Denmark, Belgium and the UK. In contrast, countries like Spain, Italy, Austria, France and

Belgium showed below-EU-average growth of their ICT expenditures in the 1990s, and consequently a more or less stagnating share of GDP devoted to ICT. Germany and Austria even experienced a reduction of ICT expenditure as a percentage of GDP.

Figure 1: Growth rate of ICT expenditure and ICT expenditure as a percentage of GDP



Source: *WITSA* (2000), WIFO calculations.

Table 2: Nominal investment in ICT

	ICT investment			Total fixed investment		
	1992	1999	Change 1992-1999	1992	1999	Change 1992-1999
	As a percentage of GDP		Percentage points	As a percentage of GDP		Percentage points
Belgium	2.12	2.59	+0.47	21.29	20.99	–0.30
Denmark	2.04	2.72	+0.68	18.14	20.97	+2.83
Germany	1.74	2.17	+0.43	24.04	21.29	–2.76
Greece	0.75	1.80	+1.05	21.32	23.00	+1.69
Spain	1.52	1.58	+0.06	23.09	23.69	+0.60
France	1.70	2.05	+0.35	20.93	18.86	–2.07
Ireland	1.82	2.32	+0.50	16.59	24.13	+7.53
Italy	1.49	1.77	+0.28	20.47	18.43	–2.04
The Netherlands	2.23	3.09	+0.86	21.32	21.47	+0.15
Austria	1.61	1.89	+0.28	23.50	23.65	+0.15
Portugal	0.96	1.81	+0.85	25.01	27.48	+2.46
Finland	1.61	2.48	+0.87	19.61	19.28	–0.32
Sweden	2.49	3.64	+1.15	18.26	16.47	–1.79
UK	2.43	3.76	+1.33	16.53	17.97	+1.44
EU	1.81	2.37	+0.56	20.72	21.26	+0.54
USA	2.60	4.54	+1.94	17.01	20.33	+3.32

Source: *Daveri* (2001), WIFO calculations for EU average.

ICT investment

There are three countries which deserve special attention as they somewhat disturb the rather systematic pattern: Greece, Portugal and Sweden. Sweden maintained its high level of ICT expenditure over the 1990s, with its ICT expenditure increasing at about the same rate as the Swedish GDP but below the European average. It should be noted that the USA, which spends about as much on ICT as Sweden, had to increase its ICT spending level significantly to achieve this level of ICT as a percentage of GDP. In Greece and Portugal, the high growth rates were driven by heavy investment in telecommunication infrastructure – an investment which the majority of European countries had already made in the first half of the 1990s.

ICT expenditure includes expenditure by private households and the government sector. Nevertheless, it is the business sector investments which provides the relevant figures for estimating the ICT impact on output and productivity growth.

Nominal ICT investment[2] is about one third of nominal ICT expenditure. The main trends for investment are identical to those outlined above for ICT expenditure. The US investment level is higher, Europe's investment is growing cyclically and declining relative to the USA. However, none of the EU countries – contrary to the trend in ICT expenditure – reaches the US level of ICT investment. The latter may be due to the different weighting of the components (hardware, software, communications equipment) in the calculation of ICT investment for Europe.

The rapid diffusion of information technology is mirrored in the rising share of ICT investment goods in non-residential gross capital formation in the business sector. In 1999, about one third of all investments in Finland and the US business sector were devoted to ICT goods (Table 3; *OECD,* 2001A). In Australia, the corresponding share was about one fifth of business sector investment. In France, Germany, Italy and Japan – the other countries in the sample – the level of investment in ICT was about half as large as in the USA and in Finland. In the USA the rapid increase of ICT investment accounted for about 50 percent of the rise in investment in the US business sector.

Capital stocks and investment contain ever higher shares of ICT

The capital stocks of all ICT components have risen much faster than those of capital goods in general. The capital stock of communications equipment and software increased by about 10 percent annually in Europe, that of hardware by about 30 percent (unweighted averages). Compared to the USA, growth rates for capital stock of communications equipment were higher in Europe, about the same for hardware and lower for software.

Table 3: Nominal share of investment in ICT in total investment of the business sector

	IT equipment				Communications equipment				Software				ICT equipment and software			
	1980	1990	1995	1999	1980	1990	1995	1999	1980	1990	1995	1999	1980	1990	1995	1999
	In percent															
Germany	4.1	5.3	4.6	6.1	4.9	5.0	4.2	4.3	2.8	3.7	4.5	5.7	11.8	14.0	13.3	16.2
France	2.5	3.3	3.5	4.0	3.3	3.7	4.4	5.8	2.4	2.8	3.6	6.2	8.2	9.8	11.5	16.0
Italy	4.0	4.2	3.5	4.2	3.9	5.7	6.7	7.2	1.7	3.8	4.3	4.9	9.6	13.7	14.4	16.3
Finland	2.6	4.5	5.5	3.8	4.0	4.8	13.0	20.3	2.9	5.5	11.6	11.9	9.5	14.9	30.0	36.0
EU[1]	3.3	4.3	4.3	4.5	4.0	4.8	7.1	9.4	2.5	4.0	6.0	7.2	9.8	13.1	17.3	21.1
Japan	3.3	3.8	4.6	5.2	3.4	4.0	5.3	6.9	0.6	4.7	6.0	5.7	7.2	12.4	15.9	17.9
USA	5.1	7.0	8.7	8.5	7.1	7.5	7.3	8.2	3.0	8.0	10.1	15.0	15.2	22.5	26.1	31.7
Australia	2.2	5.4	8.0	6.5	4.4	3.9	5.2	5.6	1.0	4.4	6.1	8.7	7.6	13.7	19.3	20.8
Canada	4.5	5.8	7.9	7.6	3.2	4.0	4.4	5.3	.	.	.	.	.	.	.	.

Source: *OECD* (2001B). – [1] Unweighted average of the 4 countries.

[2] *Daveri* (2001) calculates investment data for Europe based on a comparison of WITSA figures for the USA with the official investment data from the Bureau of Economic Analysis. The relationship between WITSA expenditure and BEA figures for investment on hardware, communications equipment and software is used to calculate the share of business expenditure to investment in the overall figure. Under these assumptions, hardware investment in the USA is 58.6 percent of total hardware spending as reported by WITSA, communications equipment is 31.6 percent of WITSA expenditure and software investment (including own-account software) is about 212.5 percent of the WITSA software item, respectively. These coefficients are then multiplied by the corresponding WITSA spending items for EU countries to obtain nominal IT investment spending data for the 1992-1999 period.

This eagerness to invest in the new technology was somewhat surprising given the long-lasting discussion of the "productivity paradox" which "complains" about the missing productivity impact of investment in computing equipment. Managers obviously had a different perception of the impact of digital technologies on output and productivity growth. The dramatic drop of prices for these assets supported the trend and favoured substitution between different types of capital goods.

There are considerable differences between countries in investment and uptake of ICT, which are partly due to policy differences. Sufficient competition helps to lower costs, thus encouraging ICT investment and diffusion. Policy plays an important role in ensuring sufficient competition, e.g., through regulatory reform, effective competition policy and the promotion of market openness. The liberalisation of the telecommunications sector is of particular importance, as the use of ICT in networks relies to a considerable extent on the costs of communications (*OECD,* 2001A). Consequently, significant effects of the European liberalisation in telecommunications should be felt in the years not yet included in the data.

Table 4: Growth of ICT and aggregate capital stocks, 1991-1999

	Communications equipment	Hardware	Software	All capital goods (business sector)
		Percentage change		
Belgium	+10.3	+27.9	+8.4	+3.0
Denmark	+9.8	+26.6	+11.7	+2.9
Germany	+13.5	+29.6	+13.3	+2.6
Greece	+16.4	+42.6	+16.1	+2.7
Spain	+12.6	+25.2	+7.2	+4.0
France	+11.4	+24.0	+10.3	+2.3
Ireland	+13.2	+28.8	+15.9	+3.2
Italy	+11.1	+23.6	+5.1	+2.7
The Netherlands	+9.9	+32.1	+14.0	+2.3
Austria	+9.7	+29.9	+12.4	+4.3
Portugal	+24.6	+43.2	+11.1	+4.5
Finland	+8.8	+23.8	+9.7	+0.5
Sweden	+5.2	+25.0	+9.6	+2.1
UK	+7.8	+31.6	+14.3	+2.9
EU	+11.2	+27.6	+10.8	+2.7
USA	+4.9	+31.2	+17.4	+2.6

Source: *Daveri* (2001), WIFO calculations.

Measuring the impact of ICT investment

Investment in information technology impacts on economic output and productivity growth through three separable channels (*Stiroh,* 2001, *European Commission,* 2000, *McMorrow – Roeger,* 2001):

1. *Growth of labour productivity:* The primary effect of ICT use should be an increase in labour productivity through additional capital formation (ICT capital), which raises the productivity of labour (i.e., capital deepening).
2. *Increase in multi-factor productivity:* Technological progress allows the production of improved capital goods at lower prices, thus raising multi-factor productivity growth in the sector producing IT goods. The magnitude of this effect depends on both the speed of technological progress and the share of the ICT sector in overall production.
3. *Spill-overs:* ICT investment induces embodied technological change, thus increasing multi-factor productivity (MFP) growth outside the IT sector, generating production spill-overs or externalities[3].

The distinction between these forces is quite difficult and subject to severe measurement problems. Measurement of the impact of ICT on growth and productivity has a long history, and different methods are applied at the aggregate, sectoral and firm levels. The

[3] *OECD* (2001A) finds evidence that there is also a strong positive correlation between indicators of ICT use (e.g., numbers of secure servers, Internet host density, PC density and Internet access costs) and the pick-up in MFP growth in the second half of the 1990s. Countries that have experienced a substantial pick-up in MFP growth in this period typically have a higher diffusion of ICT technologies, as well as lower costs of ICT technologies.

recent studies of the impact of ICT investment on aggregate output growth – which will be at the centre of our interest – use the neo-classical growth-accounting methodology as pioneered by *Solow* (1957). Studies on the sectoral or firm level usually apply econometric models based on production functions to assess the impact of ICT use (for a survey see *Brynjolfsson – Yang,* 1996, *Brynjolfsson – Hitt,* 2000, *Stiroh,* 2001).

The economic impact of investment in ICT

The mainstream results for the USA and Europe

Despite the different approaches taken and the problems with data, there is unanimous agreement that ICT does significantly contribute to GDP and productivity growth, that this impact is larger in the USA than in Europe, and greater in the second half of the 1990s than the first.

The US economy was growing rapidly in the 1990s, especially in the second half. The EU economy also accelerated its growth rates, but at a lower level. Most studies underline that "there is no single factor that explains the divergence in growth performance" (*OECD,* 2001A). OECD countries that have improved performance in the 1990s have generally been able to draw more people into employment, have increased investment, and have improved multi-factor productivity (MFP).

One obvious candidate for explaining the strong performance of the US economy is the rapid diffusion of information technologies, which was fuelled by a steep decline in prices for ICT goods. The mainstream result of the studies[4] is that ICT investment explains about 0.4 to 0.5 percentage point in the first half and 0.8 to 1 percentage point of output growth in the second half of the 1990s (Table 5). Thus the importance of ICT for economic growth more than doubled compared to the first half of the past decade[5].

For EU countries there are basically two estimates on the growth impact of ICT investment available (*European Commission,* 2000, *Daveri,* 2001; Table 6). *OECD* (2001B) presents estimates for four European countries as part of a sample of eight countries. Estimates for European countries generally arrive at a lower contribution of ICT to output growth. On average, about 0.5 to 0.6 percentage point of output growth in Europe are due to ICT. The estimates in the two available studies for the full sample exhibit marked differences (Table 6). *Daveri* (2001) finds a considerably larger ICT growth contribution in the first and second halves of the 1990s, although the increase between the two periods is not as distinct as in other studies. His estimate of the growth contribution of ICT in the USA and some of the EU countries is substantially higher than in other studies[6].

In both the 1990s as a total and sub-periods of the decade, none of the EU countries had achieved a growth contribution of ICT investments comparable to that of the USA (Table 6). In the USA, about 0.9 percent percentage point of output growth in the 1990s are attributed to ICT investments. The UK achieved 0.76 percentage point due to investment in ICT and is thus the EU country with the highest contribution. Other big European ICT investors, such as the Netherlands, Sweden, Finland and Ireland, are well below this level but still ahead of the remaining European countries which show rather homogeneous ICT growth contributions of around 0.3 to 0.5 percentage point. The European average ICT growth contribution is dominated by low (and sometimes even declining) ICT growth contributions in countries such as Germany, France, Italy and Spain.

Compared to the USA, Europe seems to lose 0.3 to 0.5 percentage point of economic growth. The major cause for the lower contribution of ICT to aggregate growth in Europe is lagging investment in ICT. Other factors affecting the outcome of these growth-accounting exercises (price measurement and usage costs of capital) were as-

[4] *BLS* (2000), *European Commission* (2000), *Daveri* (2000, 2001), *Gordon* (2000), *Jorgenson – Stiroh* (2000), *Kiley* (1999), *OECD* (2001A, 2001B), *Oliner – Sichel* (2000), *Whelan* (2000).

[5] The major exception is *Kiley* (1999): he estimates a negative growth impact of ICT which is due to adjustment costs associated with the implementation of ICT. In his framework the effect of ICT would turn positive once investment in ICT is reduced or halted. Then adjustment costs would not cancel out the positive impact of ICT on output growth.

[6] Most growth-accounting studies calculate capital stocks for computer hardware, software and communications equipment and assess the impact of these components of ICT investment separately. This renders information on the relative growth impact of the different forms of information technology. In the USA, the largest contribution to output growth stems from hardware investments. In the second half of the 1990s, hardware investment raised output by 0.5 to 0.6 percentage point (Table 5). Software contributed about 0.2 to 0.3 percentage point and communications equipment about 0.1 to 0.15 percentage point. Hardware and communications equipment doubled their impact in the second half. The increase was slightly lower for software. The evidence available for Europe (*Daveri,* 2001) estimates the growth contribution of hardware at about half the US level (0.24 percentage point – weighted average based on *Daveri,* 2001), slightly lower for software (0.13) and at the same level for telecommunications equipment (0.12). Thus, lower hardware spending seems to be the major cause for lower ICT capital stocks in Europe and consequently lower contributions of ICT to overall growth.

sumed to be similar to the USA and thus cannot account for growth differences (*Daveri*, 2001, *European Commission*, 2000)[7].

Table 5: ICT growth contribution

	Country or Region	Period	Software	Hardware	Communications equipment	Total ICT
			Percentage points of MFP growth			
OECD (2001A)	USA	1990-1995	+0.14	+0.20	+0.08	+0.42
		1995-1999	+0.27	+0.49	+0.13	+0.89
Jorgenson – Stiroh (2000)	USA	1990-1995	+0.15	+0.19	+0.06	+0.40
		1995-1999	+0.21	+0.49	+0.11	+0.81
Oliner – Sichel (2000)	USA	1991-1995	+0.25	+0.25	+0.07	+0.57
		1996-1998	+0.32	+0.59	+0.15	+1.06
Daveri (2001)	EU	1991-1999	+0.12	+0.24	+0.13	+0.48
European Commission (2000)	EU	1992-1994	.	.	.	.

Table 6: ICT growth contribution in Europe

	Daveri (2001) 1991-1999	*Daveri* (2001) 1991-1995	*European Commission* (2000) 1992-1994	*Daveri* (2001) 1996-1999	*European Commission* (2000) 1995-1999
			Percentage points of MFP growth		
Belgium	+0.48	+0.48	+0.35	+0.49	+0.60
Denmark	+0.52	+0.42	+0.22	+0.65	+0.38
Germany	+0.49	+0.54	+0.25	+0.45	+0.41
Greece	+0.34	+0.25	+0.12	+0.46	+0.21
Spain	+0.36	+0.38	+0.19	+0.34	+0.39
France	+0.41	+0.40	+0.24	+0.44	+0.42
Ireland	+0.64	+0.38	+0.84	+0.96	+1.91
Italy	+0.31	+0.28	+0.25	+0.35	+0.42
The Netherlands	+0.68	+0.65	+0.41	+0.72	+0.67
Austria	+0.45	+0.47	+0.24	+0.43	+0.41
Portugal	+0.43	+0.39	+0.25	+0.49	+0.55
Finland	+0.45	+0.21	+0.31	+0.74	+0.63
Sweden	+0.59	+0.38	+0.30	+0.85	+0.68
UK	+0.76	+0.43	+0.35	+1.17	+0.64
EU	+0.48	+0.43	+0.27	+0.57	+0.49

Is it productivity in ICT production or do spill-overs exist?

Sceptics confine the impact of these developments to the ICT-producing industries. Recent research rather supports the view that the impact of ICT is felt in wider parts of the economy and thus has a positive effect on output and productivity growth. The most controversial issue in assessing the impact of ICT is its impact on labour productivity growth.

Overall, labour productivity growth in the USA is mainly due to capital deepening (0.1 to 0.33 percentage point) and multi-factor productivity growth (0.3 to 0.9 percentage point). Both categories are substantially influenced by ICT usage and production. The positive impact of ICT-related capital deepening is present in all studies cited in Table 7 and emphasises the direct, labour-productivity increasing impact of ICT investment. The controversial issue is the effect of non-ICT-producing sectors on multi-factor productivity growth. *Gordon* (2000) attributes almost all of the acceleration of multi-factor productivity growth to the ICT-producing sectors. Although *Jorgenson – Stiroh* (2000) and *Oliner – Sichel* (2000) calculate about the same effect for ICT-producing sectors, they still find a substantial contribution from non-ICT-related sectors (0.4 to 0.5 percentage point) to multi-factor productivity growth. Thus they support the view that ICT use has had positive effects in non-ICT-producing industries.

[7] The major forces determining ICT growth contribution are the size of the capital stock, its growth rate, the usage costs of capital and the development of prices for ICT goods.

Table 7: Sources and alternative explanations of the acceleration in labour productivity growth

	Bureau of Labor Statistics (2000)	*Gordon* (2000)	*Jorgenson – Stiroh* (2000)	*Oliner – Sichel* (2000)
	Percentage points of MFP growth			
Acceleration between the two periods	+0.91	+1.33	+0.95	+1.16
Average labour productivity, 1995-1999	+2.30	+2.75	+2.37	+2.57
Average labour productivity, 1973-1995	+1.39	+1.42	+1.42	+1.41
Capital deepening	+0.10	+0.33	+0.29	+0.33
IT-related	+0.38	.	+0.34	+0.50
Other	–0.31	.	–0.05	–0.17
Labour quality (skill composition)	+0.06	+0.05	+0.01	+0.04
TFP	+0.90	+0.31	+0.65	+0.80
IT-related	.	+0.29	+0.24	+0.31
Other	.	+0.02	+0.41	+0.49
Cyclical effect		+0.50		
Price measurement		+0.14		

Source: *Stiroh* (2001).

Gordon (2000) argues that recent productivity growth is not based on ICT use but that the increase in labour productivity is a normal, cyclical acceleration as the economy expands[8]. He therefore subtracts a term to account for this cyclical effect and makes some adjustments for price measurement. These adjustments eliminate the contribution of non-ICT-producing sectors to the acceleration of multi-factor productivity growth (Table 7). He repeats this exercise for sub-samples of the economy by either excluding the ICT-producing industries or the manufacturing sector and thus arrives at a reduction of multi-factor productivity in the remaining parts of the economy. His interpretation of these findings is that there is no such thing as a "new" economy, but that the massive ICT investments outside the ICT-producing sector may be focused on unproductive activities, such as market share protection, duplication of existing operations, or on-the-job consumption, and thus have a negative productivity impact[9].

This controversy cannot be resolved at the aggregate level, but needs evidence either at sectoral or firm levels. If there is a positive impact of ICT investment, it should be visible in the largest users of ICT investment goods in the service sector: communications, wholesale and retail trade, finance, insurance and business services (*OECD,* 2001A). Most of these service sectors have shown rather weak productivity growth, which is partly related to well-known problems in the measurement of output in service industries.

A number of studies found a limited acceleration of productivity growth in non-ICT-producing industries (*Brynjolfsson – Hitt,* 2000, *Brynjolfsson – Yang,* 1996, for studies at firm level). These studies support the hypothesis that productivity growth is confined to ICT-producing industries, but they did not find a negative impact of ICT usage in other industries. Recent studies are more optimistic as regards the impact of ICT investment. *OECD* (2001A) has found evidence of a positive productivity impact of ICT in the ICT-using sectors. Denmark, Finland, Germany, the Netherlands and the USA have experienced an increased contribution of ICT-using services to labour productivity growth, while industries which are less intensive users of ICT did not increase their contributions to labour productivity growth. This positive effect on labour productivity growth was confined to the second half of the 1990s. To be successful, investment has to be coupled with organisational changes and upskilling of the labour force (*Bresnahan – Brynjolfsson – Hitt,* 1999). Consequently, it is not surprising that recent studies find evidence of the positive impact of ICT usage more frequently than older ones.

[8] In a fast growing economy the labour input is quasi-fixed in the short run. The labour force adapts to rising demand by working harder and sometimes longer (variable utilisation and resource allocation effects) as inputs are not immediately increased in a business cycle upturn. Consequently labour productivity rises although the basics of the economic process are unchanged. The argument that ICT is behind productivity increases in the second half of the 1990s is diminished by this longstanding observation of a positive relationship between productivity and growth. Even without increased ICT investment, productivity would have increased in the upturn of the 1995 to 1999 period (*Gordon,* 2000).

[9] There are more critical comments which will not be discussed in detail: *Roach* (1998) argues that much of the productivity growth is due to the understatement of actual hours worked, which leads to an overstated productivity growth, as the white-collar workweek expands faster than the data measure. *Kiley* (1999) assumes large adjustment costs that create frictions which cause investment in ICT capital to be negatively associated with productivity, at least in the short run.

Based on comprehensive research on the productivity impact of ICT on the sectoral level, *Stiroh* (2001) concludes that ". . . those industries that made the largest IT investment in the early 1990s show larger productivity gains in the late 1990s and production function estimates show a relatively large elasticity of IT capital, indicating that IT capital accumulation is important for business output and productivity". This result again suggests that investment in ICT takes time to unfold its impact on output and productivity and underlines that productivity growth due to ICT is not confined to the ICT-producing sectors (*Bailey – Lawrence,* 2001, *Nordhaus,* 2001).

Stiroh (2001) produces further support by decomposing aggregate productivity growth into the contribution of individual industries and inter-industry reallocation effects and thus demonstrates that ICT-related differences are large and important for understanding the US productivity revival. ICT-producing and ICT-using industries account for almost all of the productivity revival that is attributable to direct contributions from specific industries. Industries which were not essentially impacted by the ICT revolution made no contribution to the US productivity revival. Thus, the US productivity revival seems to be fundamentally linked to ICT.

Last but not least, the cyclical effect claimed by *Gordon* (2000) as the major factor behind the pick-up in productivity should have happened at the beginning of the business cycle rather than in the middle of it. The latter indicates that something structural in the economic process has changed. This productivity increase happened exactly at the time when a significant increase in ICT spending was observable in the USA. Furthermore, if the productivity increase is a cyclical phenomenon, it should be evenly distributed over industries and not be connected to ICT usage in the industry. According to *Stiroh* (2001), the opposite holds true: the most intensive users of ICT experienced the largest productivity gains, consistent with the idea that ICT has real economic benefits.

Overall – and as is demonstrated by a number of studies (*Schreyer,* 2000, *Scarpetta et al.,* 2000, *OECD,* 2001A, *Federal Reserve Board,* 2000) – it has to be emphasised that there is no single factor which, by itself, explains the divergence in growth performance between countries. Countries that improved performance in the 1990s have generally been able to draw more people into employment, increased investment, and boosted multi-factor productivity (MFP). ICT investment is playing a crucial and – probably – growing role in laying the foundation for future growth. Policies intended to stimulate ICT investment and use have to ensure that competition (and regulation) will further lower prices for ICT equipment and services, provide adequate skill upgrading which allows to draw more people into employment, and support complementary organisational innovation at the firm level.

Conclusions

The growing consensus that the positive growth and productivity performance in the USA is related to increased investment and diffusion of ICT goods and services has raised fears that the weaker economic performance of EU countries is caused by a reluctance to adopt these new technologies.

The gap does not close quickly

Overall, the ICT spending gap between Europe and the USA widened in the 1990s, even though both regions increased their expenditures: in 1992, EU ICT expenditure per GDP (5.2 percent) was 2.3 percentage points below the US level. While the gap narrowed in the first half of the 1990s, it increased to 2.7 percentage points in the second half. Figures for ICT as a percentage of GDP somewhat hide the more dynamic development in the USA: in 1992, ICT expenditure in the EU still amounted to 90 percent of US expenditure, but by 1999 it had dropped to about 75 percent of the US level. The gap is even larger for ICT investment in the business sector: in 1999, the US economy invested about 4.5 percent of GDP in information technologies. This is almost twice the EU level of 2.4 percent.

Leading EU countries are close to or have surpassed the USA in ICT expenditure

The situation in the European Union is marked by heterogeneous spending levels in the member states: while the UK and Sweden have already surpassed, and the Netherlands, Denmark and Ireland have drawn close to the US level of overall ICT expenditure, some of the larger countries are depressing the European average.

Recent growth-accounting studies have demonstrated the increasing contribution of ICT to aggregate economic growth. In the USA, ICT investment accounted for 0.8 to 1 percentage point of output growth in the second half of the 1990s. Most studies found that the importance of ICT for economic growth more than doubled compared to the first half of the past decade. Estimates for European countries generally arrive at a lower contribution of ICT to output growth. On average, about 0.4 to 0.5 percentage point of

output growth in Europe are due to ICT. Compared to the USA, Europe seems to lose 0.3 to 0.5 percentage point of economic growth due to lacking investment in ICT.

Economic impact

The acceleration of labour productivity in the USA is mainly due to capital deepening (0.1 to 0.33 percentage point) and multi-factor productivity growth (0.3 to 0.9 percentage point). Both categories are substantially influenced by IT usage and production. Nonetheless, the contribution of ICT to multi-factor productivity growth is strongly disputed. It is argued that the increase in labour productivity is a normal, cyclical acceleration as the economy expands. If this cyclical contribution is deducted, the contribution of the non-ICT-producing sector to multi-factor productivity growth is negligible (or even negative). If productivity growth is confined to the ICT sector alone, without any ICT-induced productivity increase in other sectors, it could be argued that there is no such thing as a "new" economy. Instead, the massive ICT investments outside the ICT-producing sector may be focused on unproductive activities, such as market share protection, duplication of existing operations, or on-the-job consumption, and thus have a negative productivity impact.

Advocates of a more fundamental impact of ICT stress that productivity should have picked up at the beginning of the business cycle rather than in the middle of it. The latter indicates that something structural in the economic process has changed. This productivity increase happens exactly at the time when a significant increase in ICT spending was observed in USA. Furthermore, if the productivity increase is a cyclical phenomenon, it should be evenly distributed across industries and not be connected to ICT usage in the industry.

Recent research rather emphasises the role of ICT investment for productivity growth: evidence is mounting that ICT does have a positive productivity impact in ICT-using industries. Studies from the USA and by OECD have demonstrated that both ICT producers and ICT users experienced significant productivity gains, which is consistent with the idea that ICT has real economic benefits. In contrast, industries which were not impacted by ICT initially made no contribution to the productivity revival.

The weak productivity performance in the service sector – a heavy user of ICT – is related to the well-known problems of measuring the output of service industries and the time it takes to implement ICT. To be successful, these technologies have to be coupled with organisational changes and upskilling of the labour force. Given the complementary investments necessary, it is not surprising that most of the evidence of the positive productivity impact of ICT usage was obtained only recently. The size of the ICT capital stock was too small and the time to implement the technology too short, the consequence being that the impact was not visible until the second half of the 1990s.

In general – as is also demonstrated by a number of studies – it has to be emphasised that there is no single factor to explain the divergence in growth performance between countries. Countries that have improved performance in the 1990s have generally been able to draw more people into employment, have increased investment, and have improved multi-factor productivity (MFP). ICT investment is playing a crucial and probably growing role in laying the foundation for future growth. Policies to stimulate ICT investment and use have to ensure that competition (and regulation) will further lower prices for ICT equipment and services, and provide adequate skill upgrading which makes it possible to draw more people into employment and support complementary organisational innovation at the firm level.

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ICT Investment and Growth of Output and Productivity – Summary

The growing consensus that the positive growth and productivity performance in the USA is related to increased investment and diffusion of ICT goods and services has raised fears that the weaker economic performance of European Union member states is caused by a reluctance to adopt these new technologies.

Overall, the ICT spending gap between Europe and the USA widened in the 1990s, even though both regions increased their expenditures: in 1992, European ICT expenditure per GDP (5.2 percent) was 2.3 percentage points below the US level. Figures for ICT as a percentage of GDP somewhat hide the more dynamic development in the USA: in 1992, European ICT expenditure still amounted to 90 percent of US expenditure, but by 1999 it had dropped to about 75 percent of the US level. The gap is even larger for ICT investment in the business sector: in 1999, the US economy invested about 4.5 percent of GDP in information technologies. This is almost twice the European level of 2.4 percent.

The situation in the European Union is marked by heterogeneous spending levels in the member states: While the UK and Sweden have already surpassed, and the Netherlands, Denmark and Ireland have drawn close to the US level of overall ICT expenditure, some of the larger countries are depressing the European average.

Recent growth-accounting studies have demonstrated the increasing contribution of ICT to aggregate economic growth. In the USA, ICT investment accounted for 0.8 to 1 percentage point of output growth in the second half of the 1990s. Most studies found that the importance of ICT for economic growth more than doubled compared to the first half of the past decade. Estimates for European countries generally arrive at a lower contribution of ICT to output growth. On average, about 0.4 to 0.5 percentage point of output growth in Europe are due to ICT. Compared to the USA, Europe seems to lose 0.3 to 0.5 percentage point of economic growth due to lacking investment in ICT.

The acceleration of labour productivity is mainly due to capital deepening (0.1 to 0.33 percentage point) and multi-factor productivity growth (0.3 to 0.9 percentage point). Both categories are substantially influenced by IT usage and production. Nonetheless, the contribution of ICT to multi-factor productivity growth is strongly disputed. It is argued that the increase in labour productivity is a normal, cyclical acceleration as the economy expands. If this cyclical contribution is deducted, the contribution of the non-ICT-producing sector to multi-factor productivity growth is negligible (or even negative). If productivity growth is confined to the ICT sector alone, without any ICT-induced productivity increase in other sectors, it could be argued that there is no such thing as a "new" economy. Instead, the massive ICT investments outside the ICT-producing sector may be focused on unproductive activities, such as market share protection, duplication of existing operations, or on-the-job consumption, and thus have a negative productivity impact.

Advocates of a more fundamental impact of ICT stress that productivity should have picked up at the beginning of the business cycle rather than in the middle of it. The latter indicates that something structural in the economic process has changed. This productivity increase happens exactly at the time when a significant increase in ICT spending was observed in USA. Furthermore, if the productivity increase is a cyclical phenomenon, it should be evenly distributed across industries and not be connected to ICT usage in the industry.

Recent research rather emphasises the second interpretation: evidence is mounting that ICT does have a positive productivity impact in ICT-using industries. Studies from the USA and by OECD have demonstrated that both ICT producers and ICT users experienced significant productivity gains, which is consistent with the idea that ICT has real economic benefits. In contrast, industries which were not impacted by ICT initially made no contribution to the productivity revival. To be successful, these technologies have to be coupled with organisational changes and upskilling of the labour force. Given the complementary investments necessary, it is not surprising that most of the evidence of the positive productivity impact of ICT usage was obtained only recently. The size of the ICT capital stock was too small and the time to implement the technology too short, the consequence being that the impact was not visible until the second half of the 1990s.

In general – as is also demonstrated by a number of studies – it has to be emphasised that there is no single factor to explain the divergence in growth performance between countries. Countries that have improved performance in the 1990s have generally been able to draw more people into employment, have increased investment, and have improved multi-factor productivity (MFP). ICT investment is playing a crucial and probably growing role in laying the foundation for future growth. Policies to stimulate ICT investment and use have to ensure that competition (and regulation) will further lower prices for ICT equipment and services, and provide adequate skill upgrading which makes it possible to draw more people into employment and support complementary organisational innovation at the firm level.