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Telecommunications, Internet, Innovation and Growth in Europe and the US

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Summary: We analyze the role of information & communication technology (ICT) with respect to productivity growth and output growth in OECD countries where liberalization of telecommunications has contributed to accelerating internet expansion in the late 1990s. Based on the literature there is clear evidence for the US that both the ICT-producing sector and the ICT-using sector have significantly contributed to an acceleration of productivity and growth in the 1990s. The EU – in particular Germany, France, Italy and Spain – are lagging behind the US which has established a firm global lead in hardware and software. The internet will accelerate economic globalization and raises the demand for skilled labor thereby creating pressure for relative wage adjustments in OECD countries on the one hand; on the other hand investment in human capital and retraining will have a higher social rate of return in the future while it is unclear that the European model of the market economy is up to the new challenges. We also look into some theoretical aspects of innovation, internet/telecommunications and growth. Empirical evidence for Germany is presented that the use of telecommunications and the internet positively contribute to output growth and employment growth. Moreover, we report recent results from our gravity modeling of OECD trade showing that international telecommunications contributes positively to higher trade volumes. Economic policymakers in the EU face problems in optimally exploiting the growth opportunities of ICT; in the whole OECD the well-known imperfections of information markets generally compound progress towards a dynamic knowledge society.

Zusammenfassung: Dieser Beitrag untersucht die Rolle der Informations- und Kommunikationstechnologie (IuK) für das Produktivitätswachstum in OECD-Ländern, wo die Liberalisierung der Telekommunikation zu einer zunehmenden Internet-Expansion in den späten neunziger Jahren geführt hat. Anhand der Literatur lässt sich eindeutig erkennen, dass sowohl die IuK-produzierenden als auch -nutzenden Sektoren in den USA erheblich zum Produktivitäts- und Wirtschaftswachstum der neunziger Jahre beigetragen haben. Die EU - und hier insbesondere Deutschland, Frankreich, Italien und Spanien - hinken dieser Entwicklung hinterher. Das Internet wird die wirtschaftliche Globalisierung beschleunigen und mithin den Bedarf an qualifizierter Arbeit erhöhen. Dies hat zur Folge, dass in OECD-Ländern der Lohnanpassungsdruck sowie der zukünftige soziale Ertrag von Investitionen in Humankapital und Umschulungsmaßnahmen steigt. Zum jetzigen Zeitpunkt ist es unklar, ob das europäische Marktwirtschaftsmodell diesen Anforderungen gewachsen ist. Des weiteren werden einige theoretische Aspekte zum Zusammenhang zwischen Innovationen, Internet und Telekommunikation und Wachstum betrachtet. Für Deutschland werden empirische Belege angeführt, die auf die positiven Auswirkungen des Einsatzes von Internet- und Telekommunikation auf Wachstum und Beschäftigung hindeuten. Ferner werden aktuelle Ergebnisse unseres Gravitationsmodells für den OECD-Außenhandel angeführt, die den positiven Einfluss von internationaler Telekommunikation auf die Höhe des Handelsvolumens zeigen. Wirtschaftspolitiker in der EU sehen sich mit dem Problem konfrontiert, das Wachstumspotenzial der IuK optimal auszunutzen. OECD-weit erschweren die bekannten Mängel von Informationsmärkten die Entwicklung hin zur dynamischen Wissensgesellschaft.

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Telecommunications, Internet, Innovation and Growth in Europe and the US*

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1. Telecommunications, the Internet and Transatlantic Growth Differentials

1.1 Telecommunications and the Internet

Technological progress and deregulation plus privatization have stimulated the growth of the internet which can be used in many ways, including for international and national telephony based on the internet protocol (IP); voice-over-IP is most interesting for cable TV firms which thereby could become powerful telecommunications firms, too. About $ 1 billion was spent in 2000 on voice-over-IP services with some $ 6 billion expected for 2005 worldwide; an upgraded cable TV network is the basis for AT&T's roughly 0.7 million local telephony users which still is less than 1/200 of circuit-switched lines in the US. However, in the long term IP calls running over a private data network – instead of low quality public internet networks – could become a fast growing business in the United States (US) and elsewhere.

The internet in both the US and Europe is rather unregulated at the beginning of the 21st century, but telecommunications is regulated on both sides of the Atlantic – an indirect incentive for internet services to expand. To the extent that Internet Service Providers (ISPs) and end users need access to the fixed-line network, telecommunications regulations will affect the internet business (WELFENS, 2001a).

Technically, the internet differs from telecommunications; the latter establishes a dedicated line between two partners, whereas internet traffic consists of data packages which are split over several lines and recombined at the end so that the recipient will get the data from the sender. Internet business is largely based on computer networks. From this perspective the growth of the internet is crucial for the hardware and software industry. Given the dominance of the US in the hardware and software market, the developments in the huge US markets are of particular relevance.

Deregulation in the US and Europe

Following the divesture of AT&T in 1984 the US has had competition in long distance telephony, while the local loop remained in the hand of the newly created "Baby Bells" which were hived-off the old AT&T (SCHWARTZ, 1997; SPINDLER, 1999). Until the Telecommunications Act of 1996 cable TV firms and telecommunication operators were not allowed to compete, but with the digitization of telecommunications and TV this restriction became obsolete in technical terms. The Telecommunications Act therefore removed the legal market demarcations; moreover, it allowed long distance companies to enter the local loop, while regional Bell companies were allowed to enter the long distance market provided that they had opened the market for local telephony.

AT&T has entered the local market via its newly acquired cable TV subsidiary. Cable TV companies offer local telephony, broadband internet services and TV programs.

In the UK competition in long distance and international telephony was introduced in the form of a duopoly in 1984, followed by broader competition after 1990 in this field (local telephony is becoming open for competition only as of 2001). US cable operators – facing restrictions at home – entered the British market in the early 1990s and offered new service packages including internet services. In order to create competition the dominant telecommunications operator BT was not allowed to enter the cable TV market; in the Netherlands the government forced the ex-monopoly operator KPN in 1998 to reduce its share to one of over 300 regional cable franchises; and to a minority position.

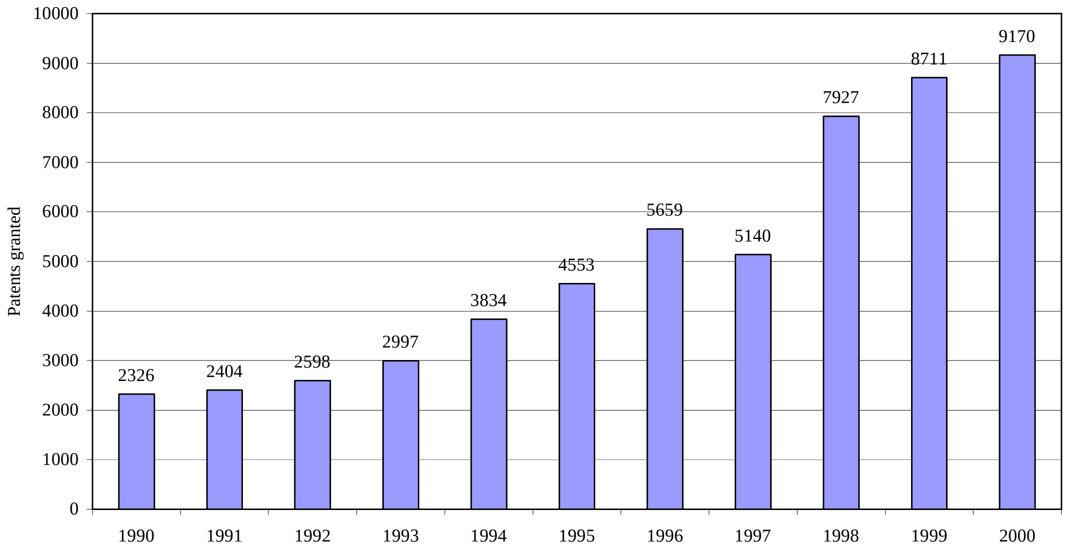
1998 was the starting date for EU liberalization in telecommunications network operation and telecommunication services. Several smaller EU countries obtained an extended grace period. The number of ISPs in Europe has strongly increased in the 1990s, but at the turn of the century the ISP business has internationalized and consolidated. While many leading ISPs in Europe are subsidiaries of the formerly dominant telecommunications operator, the leading players in the US were newcomers to the telecommunications sector, namely AOL, YAHOO and MSN (Microsoft); Excite@home is the only major ISP in the US which is a subsidiary of a major telecommunications operator, namely AT&T. US telecommunications companies were slow to understand the economic significance of the internet. However, US computer and chip producers have strongly pushed for the growth of the internet and the information society, respectively (BRESNAHAN, 1999; MACHER / MOWERY / HODGES, 1999).

1.2 Telecommunications and Technological Dynamics

The 1990s have witnessed an enormous increase in patent applications and patents granted in telecommunications, both in the US and Europe. There has been a clear acceleration of patent dynamics at the U.S. Patent and Trademark Office, largely in the context of mobile telecommunications and internet-related technologies (Figure 1).

The growth rate of telecommunication patents was the highest among the top ten fields of patent applications at the European Patent Office (see Table 1). Advanced electronics, which has links to telecommunication and computer networks, is also among the top ten in Europe. The figures on technological specialization show that the US and a few European countries (Sweden, the Netherlands and Finland) have a positive patent specialization in telecommunications; Germany is negatively specialized in this field.

Fig. 1: Telecommunications-Relevant Patents Granted at the U.S. Patent and Trademark Office



Source: U.S. Patent and Trademark Office, Patent Counts by Class and Year; own calculations.
Note: Telecommunications relevant patent classes: 370, 375, 379 and 455; all patent documents including utility, plant, and reissue patents as well as statutory invention registrations and defensive publications.

Tab 1: Specialization (Relative Patent Share in Interval -100, +100) in 1995-97 in Technology-Intensive Fields with High Growth Rates in Patents*

	Growth	USA	Japan	Germany	France	UK	Switzerland	Canada	Sweden	Italy	Netherlands
Telecommunication	13.6	10	-3	-34	-7	17	-75	50	70	-67	18
Turbines	10.6	-8	-74	-40	87	8	83	-84	-7	-96	-52
Railway Systems	8.5	-74	-41	67	9	-67	58	-22	-19	0	-26
Paper-Making Equipment	7.6	-4	-88	28	-71	-43	-54	30	85	-41	-62
Automobiles	6.7	-47	-14	57	35	-31	-84	-71	-12	10	-56
Medi. Sector, Instruments	6.6	46	-80	-38	-36	-7	38	-64	32	-20	-29
Advanced Electronics	6.4	-18	46	1	-21	-18	-52	42	-52	-44	48
Power Distribution	6.4	-20	8	16	34	-23	-27	-53	13	-7	-36
Agrochemicals	6.1	35	-59	0	-3	5	22	52	-53	-13	-69
Medi. Sector, Electronics	5.8	42	-31	-47	-64	-9	-48	-19	10	-65	35

** Average Annual Growth of Patent Applications at the European Patent Agency in 1989-1997*
Source: FhG-ISI, Karlsruhe

While telecommunications has been a traditional part of the Old Economy, it became a major part of the New Economy in the 1990s. The main reason is that the dismemberment of AT&T in 1984 and pro-competitive laws (in the US in 1996 and in the EU related to the deregulation date 1998) have stimulated competition and technological dynamics in this field; moreover, privatization of incumbent operators has further contributed to innovation dynamics since telecom operators which face declining telecommunication prices in a more competitive environment naturally try to raise revenue by product innovations and new services. Part of the high-technology dynamics in telecommunications is, however, not covered by patents. Advanced software plays a key role in both fixed and mobile telecommunications.

The innovation race has been stimulated in European fixed line telephony and in mobile telecommunications by many US operators investing in joint ventures. By contrast, only a few European network operators have invested in the US. The British Vodafone has been a successful investor. Deutsche Telekom's acquisition of Voicestream - one of the three US cellular companies using GSM - is an important case since it shows that GSM technology, which has been the hallmark of EU mobile telecommunications can be rolled out successfully in the US. However, Voicestream is only No. 6 in the large US mobile telephony market; if Congress should block moves of Deutsche Telekom to acquire other mobile operators Germany`s leading network operator might have to pull out of North America which would be to the disadvantage both of Deutsche Telekom and to customers in the US and Canada. While US operators can easily acquire EU telecommunications operators EU firms face broad restrictions in the US and Canada; since part of the digital information market is a global marketplace such asymmetries do not reflect a level playing field and impair global market integration and industry consolidation. With share prices in Worldcom falling strongly in 2002 – after announcing of improper accounting which had overstated profits – the US telecommunication sector might face strong pressure for further consolidation. In Europe former monopoly operators also are facing problems as a consequence of falling profit rates and declining ratings which have forced many privatized operators to scale back earlier investment plans.

The growth of the internet could create a virtuous circle between the telecommunications sector and the technologically highly dynamic computer industry, governed by Moore's law that the power of chips can be doubled every two years without significant cost increase. The internet plays a crucial role here not only as a novel service, but the internet protocol also has an important role in that it is now increasingly used by fixed network operators to build new digital networks.

1.3 Taking Stock: Transatlantic Growth Differential

In the period 1991-2000 the United States (US) recorded a formidable growth rate of about 3% p.a. where a considerable impulse for high and sustained growth stems from high investment in information and communication technology (ICT). Between 1993 and 2000 the US even recorded 4% growth where the acceleration in labor productivity growth in the second half of the decade was quite remarkable. Roughly one-half of investment growth in the second half of the 1990s can be attributed to ICT which mainly is comprised of telecommunications and computers/PCs plus software. Euroland by contrast has grown only by about 2% in the period 1991-2000 where the large core countries of Germany, Italy and France have not even achieved 2%; Germany`s growth rate in 1992-2001 was 1.5% while that in partner countries in the euro zone was 2.3% - hence reunited Germany recorded relatively low growth (with no improvement in the late 1990s compared to the first half of the decade).

Given the long and strong economic upswing in the US in the 1990s, it was rather surprising that the inflation rate has remained very low in the US. Obviously, the nonaccelerating inflation rate of unemployment has reduced in the US, but it is rather unclear why this should be the case.

The economic upswing in the euro zone in 1999/2000 was rather modest, and already in 2001 the growth rate of Euroland fell below 2%. The EU has had lower investment growth than the US and also has failed to position itself adequately in the changing global innovation race (WELFENS ET AL., 1998; WELFENS ET AL., 1999). However, one should not overlook remarkable intra-EU differences in economic growth; the UK, Ireland, Spain, Portugal, the Netherlands, Finland and Sweden recorded higher growth than the three EU core countries Germany, Italy and France.

With the US – after the end of the Cold War – no longer devoting roughly 55% of its R&D budget to the military, the international innovation race has accelerated and increasing specialization should have been realized in EU countries. Empirical studies point, however, to technological despecialization in OECD countries in the 1990s (JUNGMITTAG ET AL., 1998). Given intensified technological competition Schumpeterian rents in medium-technology-intensive sectors can be expected to have reduced so that rates of return for the respective German firms might have fallen. At the same time the R&D conversion process in the US, France and the UK after 1990 has stimulated technological upgrading in the civilian tradables sector which lets one expect that profitability and stock market performance in those countries should improve relative to Germany – and to Japan which is the other G-5 country which had a tradition of devoting more than 90% of R&D funds to civilian markets. Focusing on Euroland’s performance relative to the US the negative German developments together with the positive French civilian R&D dynamics might cancel out; at the bottom line the structural R&D effect of the end of the Cold War seems to have worked in favor of the US.

There is no doubt that the Maastricht convergence process has reduced economic growth since prior to the start of the euro and the ECB in 1999 many countries, including Italy, Germany, France and Spain had to reduce government-GDP ratios in order to reduce deficit-GDP ratios and subsequently excessive debt-GDP ratios. Germany, Spain and France were close to the 60% maximum for the debt-GDP requirement in 2000; among the large EU countries only Italy still had an excessive debt with 110.7% of GDP – but well below the peak ratio of 123.9% in 1994. While the Maastricht convergence process required fiscal retrenchment in some countries it also is true that downward interest rate convergence brought a reduction of the interest payments relative to GDP.

The euro has continuously lost value vis-à-vis the dollar since the start of the new currency in January 1999; the overall loss was close to one-fourth in the period 1999-2000. This is not so critical in the staggered introductory phase of the euro which is being completed with the introduction of coins and notes in early 2002. While the euro zone has witnessed a modest acceleration of growth in the late 1990s, the US recorded a sustained upward shift in the expansion path of the production potential, whereas Japan recorded a downward kink in the growth rate of the production potential (COUNCIL OF ECONOMIC ADVISORS, 2001). Thus the question arises why there are such strong differences in the triad. Subsequently we will only focus on transatlantic differences where a major aspect concerns employment growth. Average annual employment growth reached 1.5 % in the US in 1991-2000 but only 0.5% p.a. in the euro zone (the same growth rate for EU-15 as well). Employment dynamics and labor markets, respectively, thus have played a major role for transatlantic growth differences. Another aspect concerns the investment-output ratio which fell in Euroland from a peak of 21.7% in 1991 to about 20% in all years from 1995-98 (20.8% and 21.4% in 1999 and 2000, respectively) while the US investment-GDP ratio increased from 16.3% in 1991 to 21.1% in 2000 – with a year on year increase in each year of the period from 1991-2000 (EUROPEAN COMMISSION, 2000).

The considerable depreciation of the euro raises the question whether this is a transitory development or a more long-term phenomenon. We will argue that it is likely to be a sustained problem unless policymakers in Euroland take adequate measures and revise their current policy stance.

The main effects of a strong real devaluation of the euro are the following:

- Stimulating Euroland's exports towards the dollar area automatically makes Euroland more dependent on the US business cycle.
- The inflow of foreign direct investment from the US and other non-EU countries could increase since, following FROOT / STEIN (1991), foreign investors can – in a world of imperfect capital markets – acquire firms more cheaply than before.

- A risk premium emerges as reflected in the interest rate; as of 2001 there was not yet a euro risk premium visible, but with a sustained devaluation of the euro such a premium might gradually emerge. A risk premium would raise the real interest rate and reduce the investment-GDP ratio.
- The inflation pressure in Euroland is increasing since the import of more expensive imported intermediate products and final products will translate into a rise of tradables prices.

The critical question indeed concerns the medium and long-term development of the euro. Based on transatlantic interest rate differentials and relative stock market prices WELFENS (2000) presented a robust out-of-sample forecast. In the following sections we want to shed further light on the devaluation issue.

Taking a closer look at the transatlantic growth differential we find several remarkable points in the 1990s (RÖGER, 2001; WELFENS, 2001a):

- The USA has grown continuously faster than Euroland in the 1990s.
- The growth rate of labor productivity in high technology clearly outpaced that of the EU after 1993. Germany – representing one-third of Euroland's GDP – faces not only a considerable gap vis-à-vis the US; worse yet is that the labor productivity in technology-intensive fields was lower than the average for the overall economy in the mid-1990s.
- The US has exploited the economic potential of the internet revolution much faster than the EU; both the user density (demand side) and the host density (supply side) have increased much faster in the US than in France, Italy and Germany. The US has a firm lead in computer density, being one-fifth ahead of Germany and one-fourth ahead of France; Italy has just half the US computer density and was matched in 2000 by the Republic of Korea.
- The fall in prices of ICT goods – relative to the GNP deflator – reached about 8% in 1981-94, but after 1995 it increased to 15% p.a which has considerably stimulated innovations, both process innovations and product innovations, including novel digital services. Falling relative prices clearly stimulate diffusion. This should benefit the US even more as the world's leading computer producers and software firms are located in the US. With the US facing tightening labor markets in the mid-1990s the incentives for firms to invest in labor-saving ICT increased – leading to a sustainable ICT investment growth in the late 1990s.
- A study by the OECD (2000) shows clearly that countries with a high R&D intensity in the ICT field also have a high R&D intensity for the overall economy. While Sweden, Finland, Korea, the US and Japan are leading economies from this perspective, Germany is only in a medium position. This OECD

study, based on ICT dynamics with respect to employment, value-added, trade and R&D, suggests that Germany is among the lower third of the 29 countries.

- High investment in ICT has considerably contributed to high US growth. While the share of ICT investment in national output has remained constant in the EU (see the following table), the figure for the US has roughly doubled. It reached 4.5% of GDP in 1999 which was almost twice as high as the figure for the EU. The UK, Sweden and the Netherlands recorded figures in the range of 3-4%. Denmark, Belgium, Finland and Ireland were in the range of 2.3 to 3%. Germany and France were close to 2%, with Italy even at 1.8%. In the US almost 2/3 of the increase in the overall investment-GDP ratio is due to the rise in the IT investment-GDP ratio.

Tab 2: Investment in Information Technologies and Total Investment in the 1990s

	(1)	(2)	(3)	(4)	(5)	(6)
	IT investment/GDP			Total fixed investment/GDP		
	1992	1999	(2)-(1)	1992	1999	(5)-(4)
Austria	1.61	1.89	0.28	23.50	23.65	+0.15
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
Finland	1.61	2.48	0.87	19.61	19.28	-0.32
France	1.70	2.05	0.35	20.93	18.86	-2.07
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
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
Netherlands	2.23	3.09	0.86	21.32	21.47	+0.15
Portugal	0.96	1.81	0.85	25.01	27.48	+2.46
Spain	1.52	1.58	0.06	23.09	23.69	+0.60
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	2.42	0.61	20.72	21.26	+0.54
USA	2.60	4.54	1.94	17.01	20.33	+3.32

*Notes: Nominal shares of GDPin percentage points. 'Belgium' also includes Luxembourg data; * unweighted.*

Source: DAVERI, F. (2001): Information Technology and Growth in Europe, p. 5.

With the investment-GDP ratio strongly increasing in the US in the late 1990s there was a considerable increase in labor productivity. Labor productivity growth and overall output growth accelerated in the US in the second half of the 1990s as is shown in the following table. Germany's labor productivity growth reduced in the period 1995-2000 in comparison to 1977-95. The same is true for Japan. Only France and the UK achieved an improvement over time, and both countries did so on the basis of accelerated output growth (by contrast, in Germany output growth reduced). In the 1990s Japan – having launched a successful economic and technological catching-up process in the 1970s and 1980s – faced the problem of having reached the technological frontier and for various reasons found it very difficult to switch from a strategy emphasizing catching-up to one of global Schumpeterian leadership.

Tab 3: Labor Productivity Growth in Selected OECD Countries

	1995-2000*	**1977-95**
US	2.2	1.4
Japan	2.0	2.6
Germany	1.8	1.9
France	1.8	1.6
UK	1.5	1.9

** Estimate*

Source: OECD (2000)

Tab 4: GDP Growth in Selected OECD Countries

	1995-2000*	**1977-95**
US	4.00	3.00
Japan	1.25	3.50
Germany	1.75	2.25
France	2.50	2.25
UK	2.75	2.25

** Estimate*

Source: OECD (2000)

A modest trend output growth rate of Germany – much lower than that of the USA, France or the UK in the second half of the 1990s – points to a specific weakness of the German economy. Part of the slow growth puzzle might be related to German unification and low economic growth in eastern Germany, respectively (WELFENS, 1999). Since 1997 the growth rate of eastern Germany has been lower than in West Germany. East Germany's labor productivity rate achieved about 1/3 of the West German figure in the late 1990s, but economic catching-up with western Germany, so strongly visible in the 1990s, seems to have achieved a critical threshold. However, the West German economy also has achieved only rather modest growth – except for the regions Baden-Wuerttemberg, Bavaria and Hessia.

2. Theoretical Analysis

2.1 ICT Dynamics and Growth

It was not fully clear until 2001 whether high US growth in the 1990s was significantly related to high productivity growth in information and communication technologies. GORDON (1999) claimed that the acceleration of US productivity growth in the 1990s was mainly due to cyclical factors on the one hand, and to high productivity growth in the production of information technology goods (which would account for the remainder of accelerated productivity growth) on the other. A skeptical view also comes from KILEY (2000) who points to high adjustment costs associated with information technology (IT) investment implying a reduction of productivity growth in a period of high IT investment. The contrasting view that both production of IT goods and use of IT contributed considerably to aggregate productivity growth in the 1990s has been particularly emphasized by JORGENSEN / STIROH (2000), OLINER / SICHEL (2000), WHELAN (2000a,b), and the COUNCIL OF ECONOMIC ADVISORS (2000, 2001), all of which provide some empirical evidence for their view.

With different researchers holding opposite views on an important empirical phenomenon, here the acceleration of productivity growth, the most straightforward way to clarify the issue is theoretical research on the one hand and more detailed empirical research on the other hand. As regards theoretical aspects we will subsequently present some reflections where we will argue that differences in productivity growth in the US and Euroland / Germany in the 1990s can partly be explained by differentials in ICT dynamics and the associated direct and indirect growth effects. As regards the empirical side it seems that three papers have brought clear evidence that both the production of IT goods and the use of IT were important for the acceleration of productivity growth in the 1990s. STIROH (2001) has presented an empirical study with industry-level data for the US. He shows that most IT-intensive sectors recorded significantly larger productivity gains than other industries. Using a battery of econometric tests he shows a strong correlation between IT capital accumulation and labor productivity where a novel decomposition of aggregate labor productivity is presented. The crucial conclusion is that virtually all of the aggregate productivity acceleration can be traced to the industries that either produce IT or use IT rather intensively with hardly any contribution coming from sectors that are less involved in the IT revolution. STIROH writes (2001, p.2-3):

"Industry-level data show that the recent U.S. acceleration in productivity is a broad-based phenomenon that reflects gains in a majority of industries through the late 1990s… For example, the mean productivity acceleration for 61 industries from 1987-

95 to 1995-99 is 1.09 percentage points and the median is 0.67 percentage points. Nearly two-thirds of these industries show a productivity acceleration. Even when the particularly strong productivity industries that produce IT (or even durable goods manufacturing as a whole) are excluded, the data show a significant acceleration in productivity for the remaining industries. This suggests that U.S. productivity revival is not narrowly based in only a few IT-producing industries… The productivity acceleration in the late 1990s for IT-intensive industries, for example, is about 1 percentage point larger than for other industries. Moreover, rapid IT capital deepening in the early 1990s is associated with faster productivity growth in the late 1990s, even after controlling for other input accumulation and productivity growth in the early 1990s. Production function estimates also show a significant and relatively large output elasticity of IT capital.... If cyclical forces were driving the productivity gains, one might expect these gains to be equal across industries or at least to be independent of IT-intensity… The data show a contribution to aggregate productivity in the 1990s from all three groups, although the vast majority comes from IT-related industries. For example, the 26 IT-using industries contributed 0.66 percentage points to the aggregate productivity acceleration and the two IT-producing industries 0.16. The 33 remaining industries contributed only 0.08. Once one accounts for reallocation of intermediate materials, the industries that either produce or use IT account for all of the aggregate productivity acceleration, with the other industries making a *negative* contribution to the acceleration of aggregate productivity growth in the late 1990s."

This finding is quite important since it points to a shift in Schumpeterian dynamics in the US and possibly in other OECD countries as well. In Europe only Sweden, Finland, Ireland, the UK, and the Netherlands show a high share of ICT dynamics, and it is unclear whether major EU countries such as Germany, France, and Italy can catch up. DAVERI (2001) shows in his empirical analysis for Europe that the UK, the Netherlands, Sweden, and Ireland are not much behind the US, but other EU countries have a considerable lag. Cross-country differences in IT investment and accumulation rates are closely linked to growth effects from information technologies except for Ireland. CREPON / HECKEL (2001) also find for France that productivity growth is strongly associated with a small number of industries that make an intensive use of computers; all in all they estimate the contribution of computerization in France to have reached 0.7 percentage points in annual growth in the period 1987-1998.

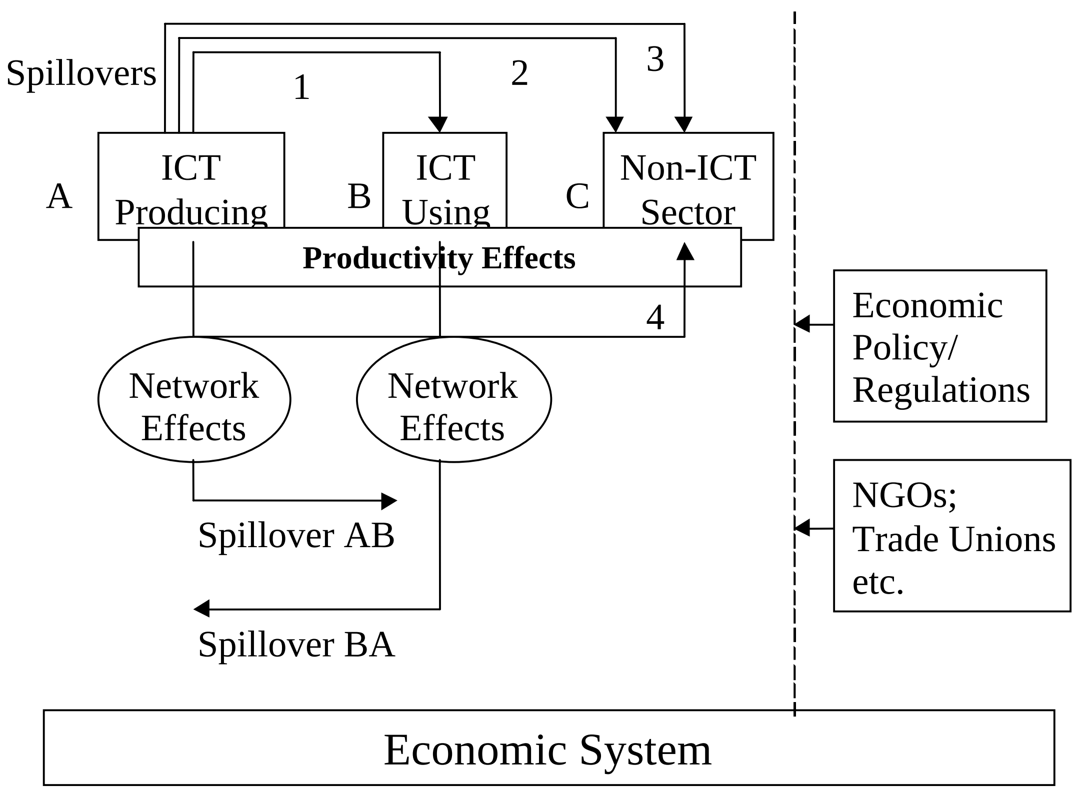
Aggregation Problems and Sectoral Aspects: ICT-Producing Versus ICT-Using Sectors

When labor productivity growth is measured at the aggregate there is considerable scope for misleading conclusions; e.g. if in a three sector economy with three input factors labor, capital (non-ICT) and ICT-capital there is high labor productivity growth in sector I (say ICT-producing sector), average labor productivity growth in sector II

(ICT-using sector) and negative labor productivity growth in the third sector. Simple aggregate growth accounting might find that the economy under consideration has not experienced any productivity acceleration in the context of ICT growth. An aggregate view without accompanying disaggregated analysis is totally inadequate to the analytical challenge of the ICT problem.

In a three-sector perspective one has to take into account three sectors where both the ICT-producing sector and the ICT-using sector can have spillover effects – both within the broadly defined ICT sector (A+B) and with respect to the overall ICT sector vis-à-vis the non-ICT sector. Some of the ICT-internal spillover effects could be magnified via network effects (see Figure 2). While technological dynamics will influence the ICT sector economic policy and the NGOs – including employer organizations and trade unions – also can have an impact on the productivity growth in each sector and the overall economy, respectively.

Fig. 2: ICT and Productivity Growth



The usefulness of disaggregate analysis is fully discussed in the STIROH (2001) paper in which it is shown that virtually all of the aggregate productivity acceleration in the US during the 1990s can be traced to the industries either producing ICT or using ICT intensively – with no or negative contribution from the remaining industries that are less involved in the IT revolution. It is worth noting that the gross output growth rate for agriculture, forestry and fishing in the US fell from 0.58% p.a. in the period 1987-95 to -0.67% in 1995-99 and in construction remained negative (at around –0.8%) in both periods whereas durable goods manufacturing had a growth rate which increased from 3.97% to 6.47% and retail trade increased from 0.97% to 3.03% p.a.

Another important contribution to growth accounting is by VAN ARK (2001) who makes a distinction between ICT-producing manufacturing and service industries, intensive ICT-using manufacturing and service industries and the non-ICT sector (the rest of the economy). VAN ARK presents measures of the contribution of each sector to growth and acceleration of growth in output, employment and labor productivity for ten OECD countries during the 1990s: Productivity growth differentials between the US and most EU countries are partly explained by a larger and more productive ICT-producing sector in the US, but also by bigger productivity contributions from ICT-using industries and services in the US. The annual percentage point contribution of the ICT-using sector in the US increased from 0.3 in the period 1990-95 to 1.37 in 1995-99 while the overall increase in labor productivity was 1.15% in the first period and 2.54 in the second period; the ICT-producing sector contributed 0.31 points in the first period and 0.65 points in the second period. By contrast, labor productivity growth in Japan was only about 0.8 percent p.a. in both periods, and the role of the ICT-using sector contributed only about 0.35 points with a slight decline over time. In Germany, the annual labor productivity growth fell from 2.10 percent in the first period to 1.66 percent in the second period. The ICT-producing sector accounted for 0.1 points in the first period and for 0.4 points in the second period; a similar result is found for the Netherlands. However, while the contribution to labor productivity growth in Germany's ICT-using sector fell from 0.53 percentage points in the first period of 0.52 points in the second period, the contribution of the Dutch ICT-using sector increased from 0.32 percentage points to 0.61 points in the 1990s. In Denmark, Finland and the Netherlands (and the US) the contribution of the ICT-using sector slightly exceeded that of Germany's respective sector in the second half of the 1990s; it is also worthy mentioning that France and Italy had a rather low contribution of the ICT-using sector in both subperiods of the 1990s. Finally, it was remarkable that the non-ICT sector in the US accounted for a stable contribution to overall labor productivity growth while it fell in Canada, Denmark, Finland, France, Germany, Italy and the Netherlands in the 1990s.

Against such a background the analysis of the ECB (2001) – not taking into account relevant theoretical and empirical analysis – is partly doubtful. The ECB is suggesting that there is no New Economy effect in the euro area in the 1990s, but the ECB does not look into any disaggregated analysis nor does it try to decompose cyclical and trend effects. Furthermore, it limits the analysis (due to data problems) to Germany, France, Italy and Finland; in the case of aggregate growth accounting the Netherlands is also included which means that three-fourths of Euroland is covered. Comparing Euroland with the US on the basis of this limited sample is also inadequate since the comparable basis would be roughly California plus Washington, New York, Michigan, Illinois, Massachusetts and Florida.

The ECB's first statement, namely that in the period 1990-2000 GDP per hour worked in the euro area and the US was roughly equal, namely 1.8% and 1.7%, is misleading since the US unemployment rate has reduced whereas it has increased in the euro area; a methodologically correct analysis would calculate a hypothetical "comparable employment labor productivity growth" (CELPG) – that is with a lower unemployment rate / a higher employment rate in the euro zone whose development would match that of the US; the CELPG rate would on theoretical grounds certainly be lower than 1.8% for Euroland. The ECB's second main statement is based on the comparison of the US with Germany plus France, Italy, and Finland which is doubtful per se and even more so when the main conclusion is derived: "This suggests that also in the United States there is little evidence of positive spillover effects from ICT-producing sectors to the rest of the economy in the period from 1991 to 1998" (ECB, 2001, p.43); however, the empirical analysis of STIROH (2001) and VAN ARK (2001) suggests the opposite. The third statement of the ECB also is rather doubtful and is based on an aggregate growth accounting exercise with France, Germany, Italy and the Netherlands representing Euroland. The ECB shows with respect to explaining labor productivity growth – which declined from 2.4% in 1991-95 to 1.3% in 1996-99 – that ICT capital deepening has gained in relevance for labor productivity over time: 0.39 percentage points in 1996-99 compared to 0.26 in 1991-95. The role of other capital deepening has declined from 0.73 percentage points to 0.28; that of total factor productivity growth has fallen from 1.41 points to 0.61 percentage points – the latter might however simply reflect a complex overlap of procyclical effects with unclear labor market effects on the one hand and ICT spillover effects on the other hand. The conclusion drawn by the ECB is not well founded as it states (ECB, 2001, p. 48): "The analysis of output and productivity developments in the euro area undertaken in this article suggests that in the period up to 2000 there were only very limited, if any, positive spillover effects from the use of ICT." It is unclear why the ECB is not also taking a look at non-euro member countries such as the UK and Sweden. For the ECB in its certainly difficult challenge to conduct monetary policy in a way which is both noninflationary and supporting growth and employment – the latter to the extent that this causes minor inflation risks.

ICT Analysis Versus ICT Potential Dynamics

It is not only important to understand the actual ICT dynamics in the EU which may or may not be characterized by spillover effects in ICT use; it also is important to analyze the potential of ICT dynamics by taking a closer look at advanced US states and advanced EU countries (e.g. Sweden, Finland, the UK, Ireland, Germany, France, and the Netherlands). A serious problem in the context of such benchmarking analysis could be that Euroland's ICT dynamics are rather weak for reasons related to problems in telecommunications competition (with international intra-Euroland calls being several times more expensive than in the US – taking a look at long distance rates) or in labor markets where a declining wage drift in several EU countries reduces the ability of expanding firms to attract skilled labor away from declining sectors – and this in a period in which the full exploitation of the New Economy growth effects would require accelerated intersectoral relocation of labor. In Germany effective wage rates increased in the period 1991-2000 by 28% while the negotiated wage rate increased by 40.9%. These figures – based on Deutsche Bundesbank – indicate that labor market rigidity and lack of wage drift (and wage dispersion) could be part of the relatively low ICT dynamics in Germany and possibly in some other countries in the euro zone as well.

Recent Analysis

According to DAVERI (2001) the growth contribution differs considerably across OECD countries (see subsequent table). Daveri also finds that in terms of the share of IT capital (augmented by the software component), the EU faced considerable differences. In 1999 IT capital accounted for roughly 6% of overall value-added in Sweden and the UK, 5% in Ireland and the Netherlands, but only about 3% in Germany, Italy, France, and Spain, with Portugal and Greece being only 2.5%. In the US the share of IT capital in overall value-added was 8% (0.029 for hardware, 0.034 for software, and 0.016 for communications equipment) which is 1/5 of the value-added share for total capital. In Greece, Italy, Spain, and Ireland communications equipment absorbed about 2/5 of the IT capital share of value-added. In most other EU countries the distribution of value-added to the various IT categories was more similar to that found in the US.

The growth contribution of IT capital reached almost 1% in the US in 1991-99 – actually increasing over time in the 1990s. Ireland, Denmark, the Netherlands and the UK also were rather strong performers. IT capital contributed between one-half and roughly one percentage point to overall growth in Ireland, Sweden, Finland and Ireland in 1996-99; in the US and the UK IT capital contributed as much as 1.45 and 1.17, respectively. As regards the US and the UK the software component seems to have been almost as important as the hardware component. One may state the hypothesis that the financial services sector – being relatively large in the US and the UK – plays a crucial role for the Anglo-American lead. The US economy has shown a very high growth rate of nominal software expenditure which rose by about 15% p.a. in the period 1992-99; the figure for Germany was only a meager 7% p.a.; the ratio of software expenditures to hardware expenditures was 1.44 for the US in 1995 while Germany had a ratio of

1.08; however, by 1999 the ratio in the US had reached 220:100 while expenditures on hardware and software in Germany were roughly 100 dollars of software expenditures for every 100 dollars spent on hardware (DEUTSCHE BUNDESBANK, 2001). As regards the statistical bias emerging from different methods of price measurement and real output measurement the DEUTSCHE BUNDESBANK (2001, p.43) argues that the German growth gap vis-à-vis the US was reduced by about 0.4 percentage points in the second half of the 1990s; however, the transatlantic growth differential of roughly 2 percentage points in the period 1996-99 remains high. For both the European Central Bank and national policymakers in EU countries it would be important to fully understand the phenomenon of the New Economy.

Tab 5: The Growth Contributions of IT Capital and Its Components

	(1)	(2)	(3)	(4)	(5)	(6)
	1991-99	1991-95	1996-99	1991-99	1991-99	1991-99
	IT	IT	IT	HW	SW	TLC
USA	0.94	0.53	1.45	0.50	0.36	0.08
Ireland	0.64	0.38	0.96	0.30	0.12	0.22
Denmark	0.52	0.42	0.65	0.29	0.14	0.09
Netherlands	0.68	0.65	0.72	0.33	0.22	0.13
UK	0.76	0.43	1.17	0.39	0.26	0.11
Portugal	0.43	0.39	0.49	0.18	0.05	0.19
Austria	0.45	0.47	0.43	0.23	0.12	0.11
Spain	0.36	0.38	0.34	0.17	0.06	0.14
Greece	0.34	0.25	0.46	0.12	0.04	0.18
Finland	0.45	0.21	0.74	0.27	0.10	0.08
Belgium	0.48	0.48	0.49	0.23	0.14	0.11
Sweden	0.59	0.38	0.85	0.38	0.13	0.08
Germany*	0.49	0.54	0.45	0.24	0.12	0.13
France	0.41	0.40	0.44	0.20	0.11	0.11
Italy	0.31	0.28	0.35	0.15	0.05	0.11

Notes: *IT = HW+SW+TLC = Hardware+Software+Communications equipment. Data in percentage points.*

** Germany = 1992-1999*

Source: DAVERI, F. (2001): Information Technology and Growth in Europe, p. 6.

Tab 6: The Growth Contributions of IT and Non-IT Capital, Labor and Total Factor Productivity, 1991-99

	(1)	(2)	(3)	(4)	(5)
	GDP	IT CAPITAL	NON-IT CAPITAL	Labor	TFP
USA	3.34	0.94	0.42	0.90	1.08
Ireland	6.91	0.64	0.63	1.93	3.72
Denmark	2.87	0.52	0.60	0.34	1.40
Netherlands	2.83	0.68	0.31	1.09	0.75
UK	2.68	0.76	0.37	0.51	1.04
Portugal	2.47	0.43	1.05	-0.35	1.34
Austria	2.33	0.45	1.29	-0.46	1.04
Spain	2.32	0.36	1.10	0.36	0.51
Greece	2.25	0.34	0.65	0.46	0.78
Finland	2.13	0.45	-0.13	-1.05	2.86
Belgium	1.88	0.48	0.68	0.00	0.72
Sweden	1.86	0.59	0.32	-0.28	1.23
Germany*	1.65	0.49	0.56	-0.23	0.83
France	1.64	0.41	0.49	-0.19	0.92
Italy	1.41	0.31	0.82	-0.30	0.58

Notes: *Data in percentage points. Column (1) presents GDP (business sector, measured at factor costs) growth rates from 1991-99. Column (2)-(5) present the contributions of employment (hours worked), IT and non-IT capital and total factor productivity to GDP growth.*

** Germany = 1992-1999*

Source: DAVERI, F. (2001): Information Technology and Growth in Europe, p. 7.

While the US recorded an acceleration in growth contribution from IT capital, namely from 0.53 in 1991-95 to 1.45 in 1996-99, Germany had a rather flat contribution from IT capital, namely 0.5. Insufficient structural change, the monopoly of telecommunications until 1998, and lack of cheap internet rates (including the refusal of Deutsche Telekom AG (except for the second half of 2000) to offer a flat rate for standard telecommunications users could be main elements in explaining the modest IT contribution in Germany (WELFENS, 2001b, 2001c; WELFENS / JUNGMITTAG, 2001). Comparing the US and the EU it is quite obvious that computer density in the Community is much lower than in the US. Germany reached three-fourths of the US computer density; France was slightly weaker, and Italy, with about one-half of US computer density, was just at the level of Korea in 1999. In the EU only the Scandinavian countries had a computer density comparable to the US. It is noteworthy that Sweden's tax policy contributed actively to raising computer density by giving firms tax incentives to sell used PCs at discount prices to employees.

In the digital economy the inventory-output ratio is lower than in the traditional economy since computerization allows improved production planning and logistics. At the same time the digital economy consists to a considerable extent of digital services where the supply elasticity is obviously very high. In the case of services provided via the internet [e.g. software (application sharing services) or music] the supply elasticity is extremely high. This could contribute not only to higher growth in fields where demand follows a logistical expansion path over time but also could reduce the inflationary pressure for any given money supply growth; that is, in economic upswings the inflation rate will increase less than in the traditional economy. This seems to indeed have been the case in the 1990s. CREPON / HECKEL (2001) find that computer use and total factor productivity gains in the ICT sector have reduced the inflation rate by 0.3 and 0.4 percentage points in the period 1987-1998, a considerable impact with respect to the average inflation rate of 1.4% in this period in France.

JORGENSEN/STIROH (2000) have argued that US growth resurgence is partly related to an increasing use and production of ICT. OLINER / SICHEL (2000) have also concluded that the revival in US productivity growth is strongly related to information technology dynamics. About two-thirds of the rise in US labor productivity in 1996-99 can be explained by an increasing use and production of information technology. This two-thirds can in turn be partly assigned to capital deepening and partly to higher total factor productivity growth. DAVERI (2001) argues that growth in EU countries is also partly an information technology story. The following table shows that IT capital accumulation can explain a considerable part of cross-country growth gaps. The shares of the growth gaps explained by IT capital is roughly 25-30% of the total for six EU countries (Germany, France, Italy, UK, Sweden, and Belgium), but this fraction is larger for Denmark (90%), and Greece, Spain, Portugal, the Netherlands, Austria and Finland (50-60%). As regards capital input, differences in the overall contributions of capital cannot explain much of the EU growth gap vis-à-vis the US. It is noteworthy that the growth gap observed in Italy, Germany, France, and Sweden vis-à-vis the US is largely explained by gaps in the contribution of labor. Following similar experiences in the 1960s, 1970s, and 1980s (DOUGHERTY / JORGENSEN, 1996), the growth contribution of labor was negative in many EU countries in the 1990s. As regards total factor productivity growth, several EU countries show higher TFP growth rates than the US. DAVERI (2001) emphasizes that while it is difficult to draw clear conclusions with respect to TFP given the residual character of this variable, the time variations of the TFP growth rates are interesting. The five largest countries in the EU had smaller TFP growth in 1996-99 than in the 1980s and the first part of the 1990s. However, TFP growth has increased in Portugal, Greece, Finland, and Ireland over time. This intra-EU difference is not fully understood, although BASSANINI / SCARPETTA / VISCO (2000) argues that the increase in TFP was relatively high in countries with flexible labor markets and less regulated product markets. However, Spain, the UK, and the

Netherlands were indeed countries with considerable labor market deregulation in the 1980s and 1990s. One cannot simply rule out that labor market deregulation is important, as a combination of high ICT investment with accelerated structural changes develops towards a dynamic service society. In the services sector we have, however, well-known problems in measuring productivity (ARK / MONNIKHOF / MULDER, 1999; BOSWORTH / TRIPLETT, 2000). With respect to the impact of labor one cannot rule out that rising unemployment rates in the 1980s and early 1990s contributed to growth positively via a positive effort effect of those having a job, but the combined effect of labor quantity and labor effort obviously was negative in many EU countries.

Tab 7: ICT Investment Effects - Contribution to Potential Growth in the 1990s (% Points)

	ICT Price Decline in the EU identical to that in the US		**ICT Price Decline in the EU = 50% of that of the US**	
	1992-1994	1995-1999	1992-1994	1995-1999
Belgium	0.35	0.60	0.35	0.51
Denmark	0.22	0.38	0.22	0.32
Germany	0.25	0.41	0.25	0.35
Greece	0.12	0.21	0.12	0.18
Spain	0.19	0.39	0.19	0.33
France	0.24	0.42	0.24	0.35
Ireland	0.84	1.91	0.84	1.64
Italy	0.25	0.42	0.25	0.36
Netherlands	0.41	0.67	0.41	0.56
Austria	0.24	0.41	0.24	0.34
Portugal	0.25	0.55	0.25	0.47
Finland	0.31	0.63	0.31	0.53
Sweden	0.30	0.68	0.30	0.57
UK	0.35	0.64	0.35	0.54
EU15	0.27	0.49	0.27	0.41
US	0.40	0.87	0.40	0.87

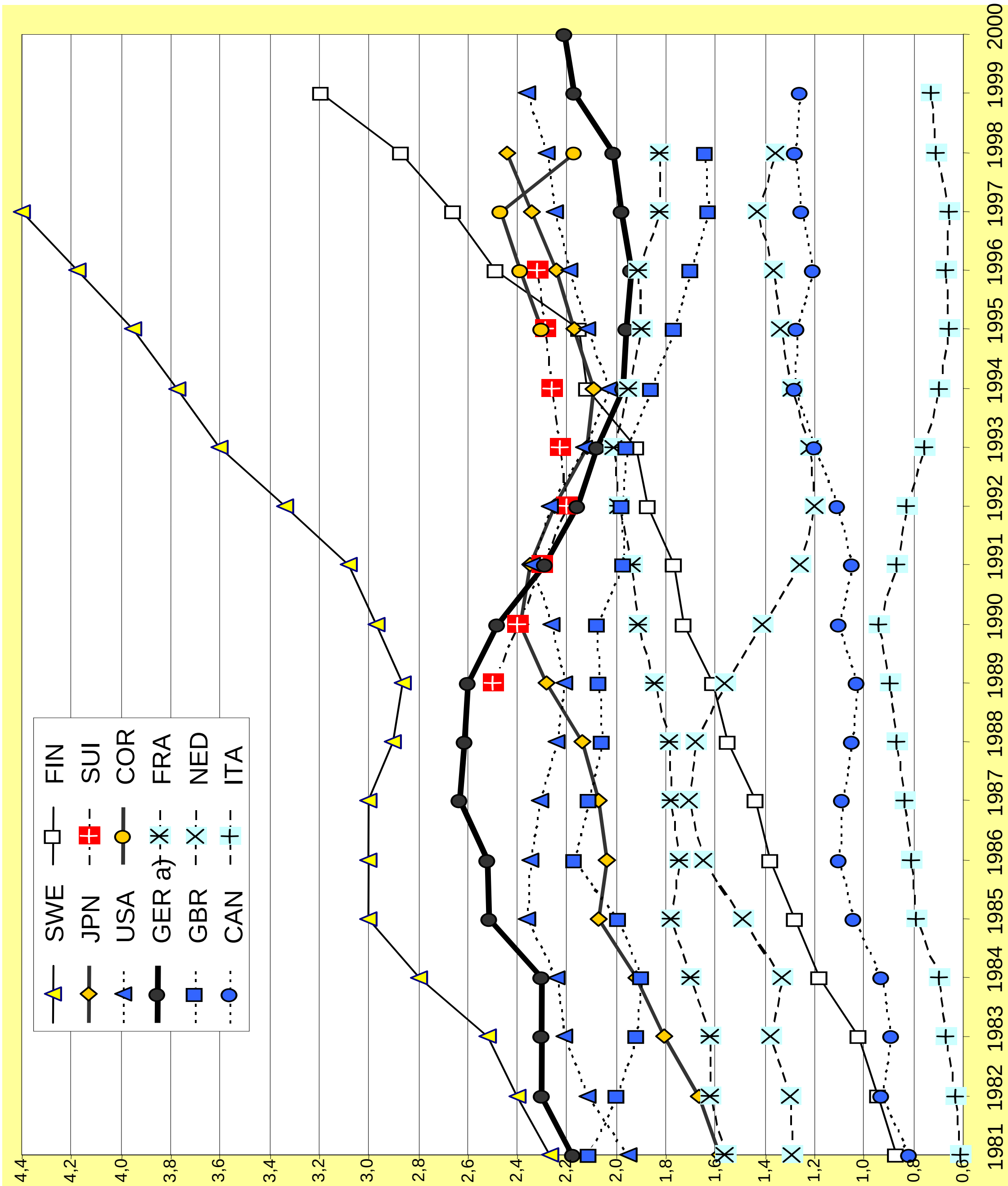
Source: McMorrow, K. / Roeger, W. (2001): Potential Output: Measurement Methods, "New" Economy Influences, and Scenarios for 2001-2010 – A Comparison of the EU15 and the US; Economic Papers No. 150, April 2001, p. 71.

According to McMORROW / RÖGER (2000) there has been some acceleration in the growth contribution of ICT in EU countries where the authors distinguish between two cases, namely EU computer price reductions equal to the US and (ii) the case of only a 50% price reduction, which might reflect various impediments to low prices in Europe, including government regulations in Germany forbidding high rebates on products (this law is being abolished in late 2001). At the bottom line the contribution of ICT to potential output growth in the US has been about twice as high as in the EU-15. Among EU countries only Ireland, itself strongly shaped by US multinational investment in ICT, showed a growth contribution of ICT exceeding that in the US in the 1990s. Disregarding Ireland only Sweden, Finland, the UK, the Netherlands, and Belgium came within a range of about two-thirds of US figures in 1995-99. With a direct ICT investment effect of almost 1 percentage point in the late 1990s, the US clearly benefited from high nominal investment growth in ICT when prices were falling in relative terms.

ICT dynamics are certainly not the full story behind the different growth performance of various OECD countries. However, ICT is one crucial element. Moreover, rapid accumulation of ICT capital might facilitate the exploitation of new knowledge and stimulate innovation as well as diffusion. This is particularly interesting when we take a closer look at the development of R&D-GDP ratios in general and at the development of high technology labor productivity. As regards the latter RÖGER (2001) shows that the US has established a clear lead vis-à-vis the EU since 1993; with a lag of about two years the US world market share of high technology exports has increased strongly while that of Germany and Japan has fallen since 1993. Both Germany and Japan no longer benefit from the exceptional position they had in the Cold War era, namely that they were special among the largest five OECD countries in devoting almost their entire R&D resources to civilian projects.

As the following graph shows, there is a general tendency of R&D-GDP ratios to rise in the late 1990s. Sweden is the leader in the OECD with an increase of slightly more than 1 percentage point in the 1990s, bringing the country to a top figure of roughly 4%. Finland also shows a strong increase and reached 3.2% in 1999. Germany's R&D ratio decreased for more than a decade after 1987, and it has increased only modestly from a bottom figure of about 2% in 1996. The US had a slight reduction of the R&D ratio in the early 1990s but increased in the second half of the decade and was close to 2.3% in 2000. The temporary reduction of the US R&D ratio is, however, mainly due to the falling expenditures on military R&D. This also holds for France and the UK which, however, stabilized R&D ratios in the late 1990s. While Canada and Italy were close together in 1989 with slightly less than 1%, Canada has increased its R&D-GDP ratio, while that of Italy has fallen to a very low level of roughly 0.6% in the mid-1990s. Interestingly, both Japan and Korea reached R&D-GDP ratios slightly above that of Germany in the 1990s.

Fig. 3: R&D-GDP Ratios in Selected OECD Countries, 1981-2000



Given the fact that most EU countries are high wage economies, it is obvious that these countries must achieve high labor productivity if full employment is to be reestablished or maintained. High capital intensity (referring here to non-ICT-capital), high ICT intensity, and high knowledge intensity are the three pillars upon which a high wage economy can be built. Facing EU eastern enlargement, one may anticipate that many plants in capital-intensive sectors, e.g. automotive or steel, will be relocated to Eastern Europe. Hence it will be all the more important that high wage EU countries generate sufficient increases in R&D capital, human capital, and ICT capital.

If the expenditures on R&D and software were to systematically increase in OECD countries in the early 21st century this would mean that the share of sunk costs in most products would increase. From a theoretical point of view this reduces price flexibility in the sense that innovative products are typically less exposed to price competition than standardized goods. However, high sunk costs imply that incumbent firms have considerable room to maneuver with respect to temporary price cutting when a newcomer wants to enter the market. They could disregard all sunk costs to fend off the intrusion of newcomers. If newcomers were to try to enter new markets particularly in phases of an economic upswing, this could imply that price increases in the economic upswing will be less pronounced in the future.

2.2 Perspectives on Inflation and Growth

US inflation rates were low throughout the 1990s. This is surprising given the considerable boom in the second half of the 1990s. High economic growth could in itself be an explanation of low inflation to the extent that high growth rates were anticipated in stock markets – we will show a formal model below. Moreover, the strong appreciation of the dollar – in the late 1990s especially vis-à-vis Asian countries – has helped to maintain low inflation rates; this holds at least until 1999/2000 when international oil and gas prices increased strongly. While the previous period of a strong dollar in the mid-1980s was accompanied by a high current account deficit and a high budget deficit, the strong dollar of the late 1990s developed only in combination with a high current account deficit. This current account deficit is not necessarily pointing to competitiveness problems of US industry; rather it seems to be the mirror of high capital inflows in a system of fixed exchange rates. A relatively high marginal product of capital in the US generates high capital inflows; at the same time the low growth rate of Euroland’s three core countries, namely Germany, France and Italy, points to a rather low marginal product of capital in Euroland which is part a broader analysis explaining the weak euro in 1999/2000 (WELFENS, 2000).

When US stock market indices started to fall in 2000/2001 the euro could not improve its position. Anticipation of changing US long-term interest rates might explain the coincidence of falling stock market prices in the US and a stable dollar; portfolio investors would not switch from the US stock market towards the stock markets in Euroland; rather US investors would move from the US stock market to the US bond market. In both the US and EU-15 a shift in the Phillips curve was observed; that is, unemployment rates could fall without causing inflation rates to rise as steeply as in previous decades; the NAIRU has reduced (RICHARDSON ET AL., 2000). It is unclear whether the shift in the Phillips curve is mainly reflecting changes in goods markets or in labor markets. Part of the explanation might be that the elasticity of the supply side in goods markets has increased in the context of an expanding New Economy; with more and more digital services being developed and sold within the business community and directly to consumers the fact that digital services hardly face any capacity constraint suggests that at least in the services sector the supply elasticity has increased. To the extent that international outsourcing of labor-intensive services is facilitated by the internet, there is another argument why tightening labor markets would not lead to wage increases as fast as in the past.

The strong depreciation of the euro in 1999/2000 raises the issue of links between the exchange rate and the price level. A strong depreciation will raise the price of tradables with a certain time lag unless there is a high rate of process innovations which would bring about reductions in unit labor costs (or in capital costs). Even with a depreciation of the currency it remains to be seen how monetary policy will behave on the one hand and how stock markets will develop on the other hand. For the inflation analysis we will focus on a modified quantity equation (WELFENS, 2000):

(I) $MV'(i,Y) = PY + \phi(i,...)P'Q,$

where M is the nominal stock of money, V' velocity of money, Y real output, P the price level (with $P=(P^T)^{ß}(P^N)^{1-ß}$; where ß is the share of tradables in overall demand), ϕ the velocity of the representative portfolio – indicating how often the stock of bonds and equities invested have been sold – P' the price of stocks, and Q the number of stocks. With the assumption $V= v(i)Y^{\chi}$ – with the absolute value of $0<\chi<1$ – dividing by PY results in the following equation where ϕ is assumed to negatively depend on i and other variables:

(II) $[M/P]\ v(i)Y^{\chi-1} = 1+ \phi(i,...)\ [h]$

The symbol h denotes the value of stocks relative to GDP. Assuming that $\phi[h]$ is relatively small so that we can use the approximation $\ln(1+x)\approx x$ then – assuming ϕ is constant and denoting growth rates by g – we obtain after taking logarithms:

(III) $g_P=g_M - (1-\chi)g_Y - \phi dh/dt.$

If purchasing power parity holds for tradables (T) in the form of e $P^{T*} = P^T$ and if we define $P=(P^T)^{ß}(P^N)^{1-ß}$, then $g_e + g_{PT*} = g_{PT}$ and therefore $g_P = g_{PN} + ß(g_e + g_{PT*} - g_{PN})$ so that we obtain the growth rate of tradables prices as the difference between the inflation rate and the change of the relative price ratio ($g_e + g_{PT*} - g_{PN}$) weighted by ß.

According to (III) for a constant nominal interest rate and a given growth rate of the money supply it holds that the inflation rate is the smaller the higher the growth rate of real output and the stronger the increase in the ratio of stock market capitalization relative to output. The coincidence of high growth and exceptionally growing stock market capitalization – relative to output – could indeed explain the inflation puzzle in the US in the 1990s.

Growth Analysis in a Two-Sector Model

Why was growth so high in the US in the 1990s? We consider a two-sector economy so that overall output Y is composed of the ICT sector (sector 1) which accounted for about 10% in the US in 2000 while the US recorded only about 6%. Denoting the relative price P_1/P_2 as q" we have

(IV) $Y = q"Y_1 + Y_2$,

Assuming that sector 2 is the consumption sector, then output in terms of consumption units is given by

(IV.I) $g_Y = (Y_1/Y)\,[g_{q"} + g_{Y1}] + (1-(Y_1/Y))\,g_{Y2}$

From this equation it is clear that the relative fall of computer prices reduces overall growth as measured in units of the consumption good. For statistical purposes the real output growth rate is measured in a different way, namely on the basis of constant historical prices:

(IV.I'): $g_Y = (Y_1/Y)\,[g_{Y1}] + (1-(Y_1/Y))\,g_{Y2}$

Here we can directly see that the high growth rate of the US is partly related to the higher share of the ICT sector in overall output and partly due to the high output growth rate of the ICT sector. The US statistical system has made two changes in the 1990s which go beyond the above formula but which almost have no net effect. Introducing a chain-weighted index – reducing the well-known problem of substitution in the presence of relative price changes – for real GDP measurement showed that real GDP growth had to be slightly revised downwards. At the same time the introduction of hedonic pricing which takes into account quality improvement – highly significant in the ICT sector (especially in the case of computers) – brought an upwards revision of real GDP. One can only wonder why Eurostat is not making similar adjustments in its SNA procedures.

We now turn to the analysis of output growth on the basis of factor inputs and total factor productivity (TFP) growth. The US recorded in some years two-digit growth rates of total factor productivity growth in the 1990s. Overall TFP is the weighted sum of sectoral TFPs, that in our case is of two sectors; here α_i (i=1,2) is the share of nominal sector 1 output relative to overall nominal output.

(V) $$TFP = \alpha_1 TFP_1 + \alpha_2 TFP_2$$

In a simple growth model based on a production function VF(K,L,Z,Q) with inputs capital K (without computers), labor L and computers Z we can decompose output growth as follows where we use $E_{Y,X}$ to denote partial output elasticities:

(V.I) $$g_Y = E_{Y,K} g_K + E_{Y,L} g_L + E_{Y,Z} g_Z + g_V; \text{ here } g_V = TFP$$

(V.II) $$g_Y = E_{Y,K} g_K + E_{Y,L} g_L + E_{Y,Z} g_Z + \alpha_1 TFP_1 + \alpha_2 TFP_2$$

The input factor computer is a proxy for ICT goods used as inputs in firms. Total factor productivity growth in the ICT sector has been enormous in the 1990s in the US and is expected to remain high; while the EU also has had an increase in productivity growth in ICT it is unlikely that West European countries will be on par with the US. It is true that Sweden, Finland, Ireland and some regions in Germany and France have a dynamic ICT industry, but global industry leaders clearly are firms from the US which also spend more than twice as much as the Europeans on software (OECD, 1998). While it is unlikely that the US lead in ICT will continue forever, it might well maintain a considerable lead over several decades.

Next we turn to the issue of heterogeneous labor; that is, we will distinguish between unskilled labor L and skilled labor H. The substitution elasticity of L and H with respect to computers is crucial, and here again we might find differences in the US and Europe. However, even if the substitution elasticity in the US would be higher than in the EU high investment in ICT would not necessarily mean a rise of unskilled unemployed in the US. The crucial question is whether the labor market is flexible enough to transitorily allow wage rates of unskilled labor to fall – with employment growth and output growth continuing, finally the demand for unskilled labor will grow strongly; this holds in part because well-paid skilled labor will increasingly demand all kinds of services which are often not very skill-intensive.

Next we will slightly modify the production function and assume that infrastructure capital Q enters the production function, too. Assuming a linear-homogeneous function F(...) and a production function Y= QVF(K,L,H,Z), we can write output per unit of skilled labor as follows – with $Y/H:= y^h$, k':=K/H, l':=L/H, Z/H:=z' and w, w' as real wage rate for unskilled and skilled labor and r and p' denoting the real interest rate and the price of computers, respectively:

$$\text{(VI)} \quad y^h = f(k'(r/w,w'/w,p'/w), l'(r/w, w'/w, p'/w), z'(r/w,w'/w,p'/w), Q, V)$$

$$\text{(VII)} \quad d\ln y^h/dt = E_{K/H,r/w}\, g_{r/w} + E_{K/H,w'/w}\, g_{w'/w} + E_{K/H,p'/w}\, g_{p'/w} + E_{L/H,r/w}\, g_{r/w} + E_{L/H,w'/w}\, g_{w'/w} + E_{L/H,p'/w} g_{p'/w} + E_{Z/H,r/w}\, g_{r/w} + E_{Z/H,w'/w}\, g_{w'/w} + E_{Z/H,p'/w}\, g_{p'/w} + Ey,q' g_Q + Ey',V(\alpha_1\, TFP_1 + \alpha_2\, TFP_2)$$

Assuming for simplicity that r/w is constant, then the growth rate of output per unit of skilled labor is given by

$$\text{(VII')} \quad d\ln y^h/dt = (E_{K/H,w'/w} + E_{L/H,w'/w} + E_{Z/H,\, w'/w})\, g_{w'/w} + \{[E_{K/H,p'/w} + E_{L/H,p'/w} + E_{Z/H,\, p'/w}] g_{p'/w}\} + E_{y',V}(\alpha_1\, TFP_1 + \alpha_2\, TFP_2)$$

Note that the elasticities Ey',q', Ey',v stand for the elasticity of output per unit of skilled labor with respect to infrastructure capital Q and the level of technology V, respectively. In the US the growth rate of $g_{w'/w}$ was positive in the early and mid-1990s; in Euroland it was close to zero. As the three partial elasticities in the first bracket are positive, it is obvious that the skill premium in the US has contributed to growth while for Germany and Euroland, respectively, there was no such growth impact as trade unions managed to maintain or even transitorily reduce vertical wage dispersion. This indeed would have reduced the growth impact of ICT to the extent that expansion of ICT would have required a rising vertical wage dispersion. The direct growth contribution of computers is indicated by the last bracket term{...}. The first two elasticities are positive, and the last one $E_{Z/H,p'/w}$ is negative since the ratio of using computers per unit of skilled labor will fall if computer prices should increase. If the absolute value for this elasticity exceeds $E_{K/H,p'/w} + E_{L/H,p'/w}$ – and this is a realistic case – then the fall of computer prices will go along with a positive value of the term {...}. While government expenditures relative to GDP were 3% p.a. in the US in the 1990s, they were close to 2 % in Germany and only slightly higher in Euroland. If the supply elasticity of infrastructure capital were of equal size in the US and Euroland, the slower growth rate of g_Q in the latter – mainly caused by low infrastructure expenditures in Germany, Belgium and Austria – would explain part of the transatlantic growth differential. Germany together with Belgium indeed recorded the lowest ratio of public investment to GDP in 2000; this might be understandable in Belgium where government is facing the challenge to reduce a debt-GDP ratio of more than 100% in 2000, but for reunited Germany that is a real puzzle since its debt-GDP ratio stood at an uncritical 60%; additionally since economic catching-up of eastern Germany requires relatively high public investment one would expect Germany to have one of the highest public investment-GDP ratios among the members of Euroland.

If we assume for the medium term that the number of skilled labor is exogenous – not a realistic presumption for the long run taking into account long-term opportunities for training and education – then the growth rate Y/H in the above equation is identical with the overall growth rate of output.

3. Innovation, ICT Dynamics and Growth: Theoretical and Empirical Aspects

3.1 Basic Theoretical Issues

The positive impact of technological change and innovation on fostering economic growth is generally acknowledged. Although the growth enhancing effects of new products and processes had been known for some time, it took some decades to attract the interest of researchers to study technical change. This lack of interest may be explained in part by complex procedures ruling science and technology (S&T) and the unknown mechanisms translating innovations into broad-based economic effects. However, it is a matter of fact that technological change is a driving force behind economic growth.

Thus, it is not surprising that recent approaches in growth theory pay much attention to technological change or its “mate”: human capital or knowledge. The basic models of the new growth theory which are in the meantime standard in modern textbooks are presented in ROMER (1986), LUCAS (1988) and ROMER (1990). A large part of new growth theory assumes a beneficial know-how “transfer” from a knowledge-generating sector which performs R&D to the sector of the economy in which companies simply adopt it. Part of this knowledge as a result of R&D efforts is paid for by the receiving firms while some part diffuses without appropriate compensation. Thus, external effects of knowledge creation (so called spillover effects) are followed by increasing returns in production of the remaining sectors and cause all-over economic growth. One essential difference between neo-classical and new growth theory may be found in these growth-creating effects. This recent line of research regards national growth to be independent of stocks of knowledge and human capital elsewhere. Thus, economies with their own knowledge-creating or human capital-creating sectors are growing faster in the long run than those without.

New growth theory is no exception to other economic modeling, as it does not pay much attention to the details either of what generates external effects in innovation or of the channels which link knowledge generation and adaptation (see e.g. JAFFE / TRAJTENBERG / HENDERSON (1992)). Moreover, to switch from the inward perspective of new growth theory to a more outward "global" perspective seems to be useful because it would be highly unrealistic (particularly for developed countries) – for the economies of the European Union, it would be simply wrong – to assume that knowledge flows will not leak out of the area delimited by national borders. In view of the increasing share of trade in worldwide production and the recent surge in the exchange and mobility of production factors, technological as well as economic developments are influenced to a non-negligible degree by other economies via world markets. In this respect think, for example, of those channels where scientific and technological knowledge accompanies exports of goods and services, the mobility of human capital within global firms or the policy of the European Commission to support preferentially trans-border R&D in the community. An extensive discussion of the trend, motives and consequences of the globalization of R&D and technology markets can be found in JUNGMITTAG / MEYER-KRAHMER / REGER (1999). Here, taking into account new trade theory and some strands of evolutionary economics following the Schumpeterian tradition, which have in common a certain overlap with traditional theory but stress the importance of technology and innovation as complementary determinants, can provide additional insights (see JUNGMITTAG / GRUPP / HULLMANN (1998) and GRUPP / JUNGMITTAG (1999)).

As far as new trade theory is concerned, a model that has been developed as part of a comprehensive analysis by GROSSMAN / HELPMAN (1991, chapter 9) is particularly instructive. It deals with the situation most common in high technology trade among OECD countries. The focus is on the long-term growth prospects of countries opening up – step by step – to different degrees of market integration. Basically, the model is built according to the following principles: countries are "endowed" with labor, human capital and technological knowledge. To keep the analysis of the model's main properties simple, Grossman and Helpman restricted complexity in that the economy consists of one sector only. The focus is set on the working of integration – not on structural change within any one country. Technological knowledge generates external effects and increasing returns for the production of traded goods. In the long run, adding some further – more technical – assumptions, growth rates depend on innovation rates – that is, on the speed with which new technological knowledge is built up.

Integrating two economies similar (or even identical) in terms of traditional endowments would lead to either unchanged trade patterns and growth rates or to increased specialization and higher growth rates in both countries. The dynamic properties of this model heavily depend on the characteristics of the stock of accumulated knowledge before integration. Because of similar endowments with traditional factors the only difference before globalization lies in the degree of knowledge specialization in different areas. Given that both economies are completely specialized on complementary fields of knowledge, integration will have no effects, neither on technological, production and trade patterns nor on long-run growth. Instead, if the stocks of knowledge have a certain overlap in both economies (e.g. knowledge accumulated in the same fields of science and technology) integration will weed out these "inefficiencies". Each country specializes on one part of this knowledge available to both economies via full integration of markets. In this situation growth is higher in both countries compared with those in closed economies. To the extent that the Internet facilitates accumulation of knowledge and reduces international integration costs one may expect a growth bonus due to faster technological progress within a larger radius of integration. At the same time the rising adjustment speed in digital financial markets might contribute to more market volatility and hence transitorily or permanently reduced growth rates.

Apart from new growth and new trade theory, evolutionary economics in a Schumpeterian tradition is concerned with the relationship between technology, trade and growth. Although it lacks a consistent body of formal modeling tools, evolutionary economics has provided a lot of interesting insights into the details of the working of economic systems. Evolutionary thinking is fundamentally based on the variation-selection principle which allows one to look at the dynamic properties of systems and, thus, it is based on economic development. Basically, evolution is thought of as being generated by creating a variety of different products and processes. Selection processes (e.g. markets) then work on reducing this variety to a certain number of viable products. The diversity of evolutionary theorizing cannot be dealt with here (on this see DOSI / PAVITT / SOETE (1990), WITT (1993) or HODGSON (1993)). One of the main forces that generate new products or processes (and, thereby, increase variety) is innovation and technological change.

Concentrating first on variation, empirical studies have found that higher rates of innovation lead to higher rates of economic growth (e.g. FAGERBERG (1988)). The larger the number of different products and the higher the rate of new product generation the higher the rate of long-run growth. Saviotti has worked out a conceptual and semi-formal tool to show that we are observing a constantly increasing number of different products. Higher degrees of product variety cause higher consumer utility. This is a main reason for economic growth (SAVIOTTI (1991)). This mechanism mainly works through better adaptation to specific consumer needs (higher utility) as well as through higher efficiency of production processes. The Internet allows a very broad variety of digital products and services to be sold in enlarged markets.

When we turn to the selection environment, most studies have found tighter selection mechanisms to favor higher growth. Here the transparency enhancing effects of the Internet could be important.

From a theoretical point of view, tighter selection does not necessarily prove more efficient because in this case a large number of product variants, which have incurred development costs, are selected out. However, this waste of resources may be compensated by long-run efficiency of fewer but superior products (see e.g. COHENDET / LLERENA / SORGE (1992) for a discussion of this fundamental problem in evolutionary economics). Market competition as one of several possible selection environments in an ideal sense weeds out all inefficient types of products in order to ensure the survival of the best-fitting alternatives. Then, in face of selection, generation of new products adapts to the characteristics of the successful variants. Therefore, it is essential for economic agents to learn quickly from the fate of successful as well as unsuccessful products on the markets and, then, to develop better variants which sell at higher prices or larger quantities. Thus, the particular strength of companies comes from learning adaptation. However, learning and adaptation are fundamentally path-dependent processes. That means, the probability to learn something useful will be much higher in areas where knowledge has already been accumulated in former times. This path-dependency of technological change and learning may be observed at the level of single companies, industries, regions and countries. It does not only explain a great deal of innovation but also the dynamics of division of labor and economic development. DOSI (1982) used this basic principle for a "theory" of technological change. Scientific and technological change is following "trajectories" until a "breakpoint" (radical change) disrupts the smooth and gradual development.

The stock of accumulated knowledge does not only consist of scientific or otherwise codified and easily accessible findings but also of acquired "tacit" practical skills. Knowledge therefore has a "public" and a "private" part. Apart from a few really globalized and highly science-based technologies the main part of worldwide knowledge has a local character in that its geographical diffusion is limited in scope because of mobility barriers to human capital or skilled labor. Accordingly, empirical studies have found a lot of evidence that the ability to learn and to innovate greatly differs between sectors, regions and countries. See e.g. PAVITT (1984), PAVITT ET AL. (1987), DOSI / PAVITT / SOETE (1990) and GEHRKE / GRUPP (1994). Thus, stocks of technological knowledge differ in scope and character between economic entities over long periods of time. The Internet seems to be ambiguous since a high rate of ICT change implies relevance of private tacit knowledge; at the same time the global Internet facilitates development of public international knowledge within the triad.

3.2. Empirical Links Between Innovations and Output

The empirical investigation of the effects of technological change or more generally innovation on economic growth has produced a voluminous and diverse literature. Roughly, there are three types of studies: historical case studies, analyses of invention counts and patent statistics, and econometric studies relating output or productivity to R&D or similar variables (GRILICHES, 1995). Here, we will confine ourselves to econometric studies, which use some indicator variables to approximate the impact of technological change and innovations.

First, one important input factor for technological change and innovation can serve as a proxy variable: R&D. Most research in this vein uses an augmented Cobb-Douglas production function which includes some kind of a R&D stock besides the usual production factors. The coefficient belonging to this R&D stock can then be interpreted as production or output elasticity of R&D. Alternatively, this kind of production function is transformed into growth rates, and the R&D intensity (R&D/Y) is included. The parameter belonging to this R&D intensity yields the rate of return to knowledge. Similar to these approaches is another procedure where total factor productivity is calculated first. Then again, either the logs of levels of total factor productivity are linked to some kind of log R&D stock or the first differences of log total factor productivity are regressed on the R&D intensity. The interpretation of the estimated coefficients is the same as before: the regression of the levels of log total factor productivity on a log R&D stock yields a measure of the elasticity of output to knowledge, while the regression of total factor productivity growth yields a measure of the social gross (excess) rate of return to knowledge (GRILICHES / LICHTENBERG, 1984 and GRILICHES, 1995).

A general problem for the measurement of the effects of R&D on output is that a number of externalities arise in the innovation process. Summarizing the relevant literature on this topic, CAMERON (1998) distinguishes between four kinds of externalities. First, a *standing on shoulders effect* which reduces the costs of rival firms because of knowledge leaks, imperfect patenting, and movement of skilled labor to other firms. In a wider sense international technological spillovers due to foreign trade can also be considered as within the standing on shoulders effect. Secondly, there exists a *surplus appropriability problem* because even if there are no technological spillovers, the innovator does not appropriate all the social gains from his innovation unless he can price discriminate perfectly to rival firms and/or to downstream users. Thirdly, new ideas make old production processes and products obsolescent: the so-called *creative destruction effect*. Fourthly, congestion or network externalities occur when the payoffs to the adoption of innovations are substitutes or complements. This is sometimes called the *stepping on toes effect*. The adequate consideration of these effects in empirical investigations offers a wide field for further research. Up to now, these effects are only taken rather roughly and partially into account in most empirical studies.

Generally, studies which are based on time series data on levels of output and R&D stocks for individual US, French and Japanese companies found output elasticities lying between 0.06 and 0.1 (GRILICHES, 1995). Considering results of this kind of studies for Germany and France at different levels of aggregation, the estimated output elasticities turned out to be somewhat higher. For the total economy of West Germany PATEL / SOETE (1988) estimated 0.21 as the output elasticity of R&D. However, in a recent study BÖNTE (1998) estimated only output elasticities between 0.03 and 0.04 for the R&D stock of selected sectors of West German manufacturing. At the firm level CUNEO / MAIRESSE (1984) estimated for the R&D stock output elasticities between 0.22 and 0.33 for France; MAIRESSE / CUNEO (1985) estimated values between 0.09 and 0.26, and MAIRESSE / HALL (1996) values between 0.00 and 0.17. At the level of the total economy PATEL / SOETE (1988) estimated a value of 0.13 for the output elasticity of R&D for France. COE / MOGHADAM (1993) estimated with their preferred specification an output elasticity of 0.17 for the R&D stock of France.

When growth rates are used as dependent variables and R&D intensities as independent variables, the estimated rate of return lies – summarizing the bulk of empirical results for different countries and different levels of aggregation – mainly between 0.2 and 0.5, with most of the recent estimates falling in the lower part of this range (GRILICHES, 1995). However, the results for West Germany are a little bit puzzling. At a firm level, BARDY (1974) estimated direct rates of return to R&D between 0.92 and 0.97. However, at an industry level MÖHNEN / NADIRI / PRUCHA (1986) estimated a direct rate of return to R&D of 0.13, and O’MAHONY / WAGNER (1996) found at the same level a direct rate of return of 0.00. With a different approach BÖNTE (1998) calculated net rates of return for selected sectors of West German manufacturing between 0.23 and 0.3. This is quite in accordance with the general results and with the results for France at the firm level where GRILICHES / MAIRESSE (1983) estimated a rate of return to R&D of 0.31, and HALL / MAIRESSE (1995) found values between 0.22 and 0.34.

However, most of the studies considered here simply treat R&D as another form of investment and do not allow for the effects of the externalities mentioned above. Therefore, it is unclear whether such studies underestimate or overestimate the effects of R&D. JONES / WILLIAMS (1997) derived an endogenous growth model, which takes these externalities into account, and calibrated it to a range of plausible parameter values. They find that in most cases the excess returns to R&D (calculated as the social return minus the private return) are positive, but less than 20 per cent. We may add that due to the globalization power of the Internet the divergence between private and social returns to R&D might increase – not least if the Internet reinforces international knowledge spillovers. This raises problems for R&D cooperation.

If the large degree of risk and uncertainty in the innovation process as well as information asymmetries between capital markets and R&D spenders are taken into account, it is not surprising that large social returns to R&D can coincide with relatively low rates of R&D investment. JONES / WILLIAMS (1997) conclude for the USA that the optimal amount of R&D investment is about four times the amount actually invested. However, other studies found less overwhelming empirical evidence. BARTELSMAN ET AL.(1996) applied the Jones / Williams model to Dutch manufacturing firm-level data and found that the private rate of return probably underestimates social returns by only a few percentage points. Examining the effects of R&D on productivity in a panel of French and US manufacturing firms, MAIRESSE / HALL (1996) found that R&D earned a normal private rate of return in the USA during the 1980s. For selected sectors of German manufacturing, BÖNTE (1998) concluded that his results provide no evidence for "above-normal" rates of returns due to intra-industrial spillovers.

Another important source for externalities is international R&D spillovers, i.e. the impact of foreign R&D on domestic productivity and output. COE / HELPMAN (1995) captured these effects by augmenting the above mentioned total factor productivity equation with import-weighted foreign R&D stocks. For West Germany they calculated elasticities of total factor productivity with respect to foreign R&D of 0.056 (1971), 0.072 (1980) and 0.077 (1990). The elasiticities for France were a little bit lower: 0.045 (1971), 0.061 (1980) and 0.067 (1990), whereas the elasticities for Sweden were higher: 0.067 (1971), 0.087 (1980) and 0.093 (1990). BAYOUMI / COE / HELPMAN (1999) applied the same approach to a larger sample of countries and found important differences between the values of the coefficients for domestic and import-weighted foreign R&D for different groups of countries. Comparing the G-7 countries and small industrial countries, the coefficient of import-weighted R&D stocks has the same value, but the coefficient for domestic R&D turned out to be much smaller for small industrial countries. For developing countries they assume that R&D capital is constant, and the coefficient of import-weighted foreign R&D turned out to be clearly higher. To the extent that the Internet stimulates business-related services trade in particular and trade in general, the Internet might have trade-related growth effects.

Next one has to consider different possibilities of financing R&D. R&D can either be financed by companies or by government, and there is a lively controversy about the effects of government-financed R&D on output and productivity. In his summarizing overview GRILICHES (1995) concluded that most elasticity estimates are not sensitive to whether one uses total or only company-financed R&D stocks, but that there are other indications in the data that government-financed R&D produces less benefit than privately-financed R&D. Concretely, he presents estimations where the privately versus government-financed R&D mix variable has a significant positive coefficient, indicating that the premium on government-financed R&D is smaller, but still quite large. GRILICHES / LICHTENBERG (1984) found that spillovers between academic research and some types of government R&D and the private sector exist, but they are smaller than those between firms themselves. ACS / AUDRETSCH / FELDMAN (1994) concluded that small firms (particularly high-tech start-ups) might benefit more from such spillovers. Furthermore, ADAMS (1990) found the output of the academic science base is a major contributor to productivity growth, but the time lag is approximately twenty years. The Internet creates new options for finding venture capital, and it creates enormous opportunities in international R&D cooperation.

Connected to the controversy about privately or government-financed R&D are other empirical findings concerning basic research. GRILICHES (1995) presents estimation results where the basic research coefficient is highly significant and shows a rather large size. He concluded that firms which spend a larger fraction of their R&D on basic research are more productive and have a higher level of output relative to the other measured inputs, including R&D capital, and that this effect is relatively constant over time. Based on other estimation results and additional computations he concluded that the premium for basic research over the rest of R&D is 3 to 1 as far as its impact on productivity growth is concerned.

Secondly, one output of the innovation process can be used as a proxy variable for technological change and innovation: patent applications or the stock of patents. Such a proceeding has several advantages. On the one hand, this indicator variable avoids a lot of technical data problems; e.g. unlike R&D stock measures, no artificial depreciation rate must be assumed; on the other hand, it also includes the results of other knowledge sources apart from explicit R&D activities. BUDD / HOBBIS (1989a) estimated for UK manufacturing long-term output elasticities with respect to a constructed stock of patents between 0.21 and 0.23. In a second paper, they estimated with a slightly different approach long-term elasticities of patenting of 0.114 for France, Germany and the United Kingdom, whereas the elasticity for Japan was 0.135 (BUDD / HOBBIS 1989b). For the West German business sector in the period from 1960 to 1990, JUNGMITTAG / WELFENS (1998) estimated an output elasticity of the real patent stock of 0.23. For a longer time period from 1960 to 1996 and with a slightly different approach, JUNGMITTAG / BLIND / GRUPP (1999) found output elasticities of the patent stock lying between 0.16 and 0.19. Altogether, these results suggest that the estimates of the output elasticities of the R&D stock and the patent stock are in most cases very similar and that they contribute substantially to economic growth. The Internet will stimulate growth in OECD countries to the extent it facilitates storage and dissemination of knowledge on the one hand; on the other hand Internet technology facilitates R&D specialization at the international level.

3.3 ICT as a General Purpose Technology?

For assessing the impact of ICT on economic growth, we have to differentiate between two kinds of innovations. Many innovations concern the generation of new products or changes of production processes within specific sectors. Some innovations, however, result in the development of new, general purpose technologies, i.e. broad technologies with wide applications (BRESNAHAN / TRAJTENBERG, 1995; HELPMAN, 1998). These general purpose technologies give rise to changes in a wide range of industries and probably affect production processes, interindustry relations, work organization and skill requirements (OECD, 2000). Two often cited historical examples for such epoch-making technologies are the steam engine and electricity (the electric motor), which caused the first and second industrial revolution. On the other hand, there were very important innovations in the past which affected only one sector but which had a great impact on overall economic growth. For example, mechanical spinning-machines developed in the second half of the eighteenth century in the UK (the spinning jenny by Hargraves (1767) and the water frame by Arkwright (1769) as well as the following incremental innovations) affected only textile production, but due to the fact that at that time a large share of economic activity in the UK was textile production, the productivity gains associated with this new technology had a significant impact on the UK's total economic performance.

Various scholars argue that ICT is such a general purpose technology with broad impact on many sectors of the economy. Furthermore, the advocates of the "New Economy" assert that ICT products create spillovers which are not appropriated by the investor or the consumer. Hence, ICT products might increase total output and income beyond what is indicated by the actual prices paid for it (ARK, 2000). Against this optimism some other scholars assign ICT the role of the modern "mechanical spinning-machine" because in their view the growth acceleration at the end of 20th century was mainly due to improved productivity growth in the ICT-producing sector (JORGENSEN / STIROH, 2000). Ultimately, it is a question of empirical research to assess the role of ICT in growth and structural change. However, it is a common feature of new general purpose technologies that it takes a long time before they are implemented (including organizational changes) and used in such a way that they could develop their abilities to the fullest (DAVID, 1991). In this case, the productivity gains of ICT will only be reflected in increased overall productivity with a rather large delay (ARK, 2000).

4. The Role of Telecommunications and the Internet for Trade and Growth

Jungmittag and Welfens presented three studies to assess the impact of telecommunications and the Internet on economic growth (JUNGMITTAG / WELFENS, 1998; WELFENS / JUNG-MITTAG, 2000; WELFENS / JUNGMITTAG, 2001b). In the following section we will summarize some of the major findings and highlight additional issues.

4.1 Telecommunications, Innovation and Economic Growth in Germany 1960-1990

In the first study alternative sources of technical progress were identified and approximated by means of indicator variables, which were then considered when estimating long-term production functions for the business sector of the Federal Republic of Germany, without agriculture, forestry, and fishing and without housing sector from 1960 until 1990 (JUNGMITTAG / WELFENS, 1998). They distinguished between technical progress which is the result of one's own research and development activities, and the import of technological know-how through licensing agreements. The first source of technical progress was approximated through the time lagged stock of patents at the German Patent Office (Deutsches Patentamt); the second was approximated by the real fees for licenses captured in the balance of payments of the Federal Republic of Germany. In addition, the use of telecommunications was integrated in the long-term production function in that it is approximated by the indicator variables – the number of annual telephone calls.

With the technological innovations and the role of information and communication explicitly taken into consideration, the extended Cobb-Douglas production function now is in logarithmic form:

(1) $$y_t = a + \alpha \cdot k_t + \beta \cdot l_t + \gamma \cdot pat_{t-2} + \delta \cdot lex_t + \varepsilon \cdot tc_t + u_t,$$

where *y* represents the output, *k* the capital employed and *l* the amount of labor (lower cases denote logarithms). The parameters α and β represent the partial production elasticities of the factors capital and labor. Furthermore, *pat* represents the stock of patents, *lex* the actual expenditure on licenses and *tc* the number of telephone calls.

For estimating the long-term production functions, the concept of the cointegration of time series introduced by Engle and Granger (cf. ENGLE / GRANGER, 1987) was used. This concept allows the differentiation between actual long-term relations and merely spurious regressions if time series are trending. Since in this study only the long-term relations and not the short-term dynamics between the output, the usual production factors and the indicator variables for technical progress, as well as for the role of information and communication were considered, first of all the first step of Engle and Granger's two-step procedure was applied, in which existing long-term relations were identified and estimated without specifying the short-term dynamics. However, the distribution of the estimators of the cointegrating vector provided by such a static regression is generally non-normal, and so inference cannot be drawn about the significance of the individual parameters by using the standard 't' tests. For this reason the three-step procedure, proposed by Engle and Yoo (cf. ENGLE / YOO, 1991) was subsequently used to remedy this shortcoming. Their third step, added to the Engle-Granger two-step procedure, provided a correction to the parameter estimates of the first stage static regression which made them asymptotically equivalent to FIML and provided a set of standard errors which allows the valid calculation of standard 't' tests. The superior long-term production function was then used to at least roughly assess the effects of the technical progress approximated by the indicator variables and of the need for information and communication, approximated by the number of telephone calls, as well as the impact of the usual production factors on economic growth from 1961 until 1990.

Tab 8: Estimation Results for the Augmented Production Function

Variable	First step of Engle/Granger		Third step of Engle/Yoo	
	unrestricted	$\hat{\alpha} + \hat{\beta} = 1$	unrestricted	$\hat{\alpha} + \hat{\beta} = 1$
Constant	-3.1574	-2.7882	-3.4344	-3.1174
	(-4.8813)[a)]	(-5.5155)	(-12.8774)	(-8.4231)
k_t	0.4073	0.3634	0.4372	0.3448
	(4.9118)	(5.3738)	(11.2103)	(5.9142)
l_t	0.7460	0.6366	0.7893	0.6552
	(5.4446)	--	(15.9455)	--
pat_{t-2}	0.1611	0.1833	0.1738	0.2315
	(1.6913)	(1.9955)	(6.2744)	(3.4501)
lex_t	0.0494	0.0631	0.0498	0.0833
	(1.5696)	(2.2805)	(4.4865)	(3.5447)
tc_t	0.1580	0.1803	0.1390	0.1795
	(2.7992)	(3.5497)	(5.7917)	(4.2943)
D80	-0.0168	-0.0165	-0.0169	-0.0161
	(-2.1905)	(-2.1551)	(-7.6818)	(-2.9815)
D81	-0.0202	-0.0223	-0.0202	-0.0239
	(-2.6738)	(-3.0828)	(-8.7826)	(-4.3455)
R^2	0.9977	0.9974	0.9976	0.9973

$R^2_{adj.}$	0.9970	0.9967	0.9969	0.9966
DW-test	2.0108	2.1136	--	--
EG-test	(28.6)[b)]	(28.5)	--	--
	-5.3968	-5.6735	--	--
	(0.0859)[c)]	(0.0261)	--	--
F-test of the restriction				1.4396 (0.2345)[c)]

[a)] *Empirical t-values are in brackets, but statistical conclusions on the basis of usual t-tests are only permitted if the third step of the Engle/Yoo procedure has been applied.*

[b)] *Number of observations available after forming lags and first differences and number of I(0) variables in brackets.*

[c)] *Significance levels in brackets.*

The estimation results for the unrestricted and restricted version of this long-term production function are reported in Table 8. A view of the *t*-values calculated for the estimates of the third step of the Engle / Yoo procedure shows that all coefficients of the unrestricted as well as the restricted estimation are unequal to zero at a significance level of 1 %. Therefore, all three indicator variables have a highly significant power of explanation. Furthermore, the magnitudes of their coefficients verify that the factors approximated by the indicator variables make contributions to real gross value-added that cannot be neglected. The estimates of the coefficients of the factors capital and labor also seem to be very reliable. They are rather similar to the estimates in SCHRÖER / STAHLECKER (1996) where a long-term Cobb-Douglas production function is estimated using quarterly data from 1970 until 1989. SCHRÖER / STAHLECKER (1996) introduced after a data mining process a dummy variable which changes the slope of the time trend to approximate a change of technical progress. The R^2s of 0.9977 and 0.9974 for the first step of the Engle / Granger procedure and 0.9976 and 0.9966 for the third step of the Engle / Yoo procedure indicate a very good fitting of the models to the observed data. The DW test statistics suggest that the presence of first order autocorrelation can be excluded. Turning to the EG test statistics it can be seen that the unrestricted as well as the restricted production function forms a cointegration relation at significance levels of 8.59 % and 2.61 %. Therefore the sum of the partial production elasticities is now permitted beyond all usual significance levels as the F-test shows. Based on these estimation and testing results, the restricted product function containing all three indicator variables is superior to other augmented production functions with only one or two indicator variables which had been considered during the empirical investigation, but are not reported here due to the limitation of space.

Tab 9: Sources of Growth in the Business Sector, Germany 1961 - 1990

Source	Average annual percentage changes						
	61 - 90	61 - 65	66 - 70	71 - 75	76 - 80	81 - 85	86 - 90
k_t	1.5	2.5	1.9	1.8	1.1	0.8	1.0
l_t	0.2	0.7	0.1	-0.6	0.5	-0.6	1.1
pat_{t-2}	0.1	0.3	0.2	-0.3	0.2	0.1	0.3
lex_t	0.3	0.4	0.3	0.3	0.0	0.0	0.8
tc_t	1.1	1.2	1.7	1.2	1.3	0.7	0.7
Total:							
fitted	3.3	5.2	4.3	2.3	3.2	0.9	4.0
realized	3.3	5.2	4.4	1.7	3.6	1.1	3.8

Note: Differences between the sums of the individual components of the growth rates and the fitted total growth rates are caused by rounding up and down and by joint effects.

Due to the approximation of different sources or causes of technical progress and of information and communication by means of appropriate indicator variables, it was then possible to assess, at least roughly, the effects of these variables as well as of the usual production factors on the growth of real gross value-added. The results of the ex-post forecasts of average annual growth rates for the whole observation period as well as for different subperiods are reported in Table 9. The comparison of the realized total and the forecasted total growth rates of real gross value-added in the business sector without agriculture, forestry, and fishing and without housing rental shows a good fitting of the model to the observed data. Only in the first half of the seventies when the first oil price crisis takes place does the model overestimate the growth rate by 0.6 percentage points. Partly to even things out, the model underestimates growth by 0.4 percentage points in the second half of the seventies.

Turning to the individual factors, it can be seen that the development of the capital stock has the greatest impact on the growth rates of gross value-added in most cases, accounting for 0.8 to 2.5 percentage points. This result is in accord with the results for other countries (cf. BUDD / HOBBIS, 1989a, BUDD / HOBBIS, 1989b and COE / MOGHADAM, 1993). The influence of telephone calls (as an indicator for information and communication) is in second position, accounting for 0.7 to 1.7 percentage points of the average annual growth rates. Here, it must be stressed, that even in phases of low growth rates this influence was a substantial engine of the remaining economic growth. The impact of the factor labor on economic growth is strongly influenced by fluctuations of the number of employees due to business cycles. Especially the reductions of the number of employees after the first and second oil price crises had negative impacts on economic growth. On the other hand, the strong increase of the number of employees in the second half of the eighties fostered economic growth. The lagged stock of patents and the real license expenditures had in most cases a moderate influence on growth. Nevertheless, these two sources of technical progress account for slightly more than 12 % of the total increase of gross value-added. Their share increases even to 27.5 % in the second half of the eighties, mainly due to the strong increase of real license expenditures.

Altogether, the results suggest that the considered sources of technical progress as well as the increasing requirement for information and communication contribute substantially to economic growth in West Germany.

4.2 Growth and Employment Effects of an Internet Flat Rate in Germany

The second study was concerned with the impact of an Internet flat rate on growth and employment in Germany (WELFENS / JUNGMITTAG, 2000). The starting point of this study was the fact that the dissemination of knowledge and the efficient information sharing that results from it are of central importance to economic growth. Assuming that (given a liberal regulatory environment) Internet use will become a means of knowledge dissemination in the middle and long term – at low rates determined by common sense or by competition – and will contribute to growth on a similar scale as telecommunications, then – going back to the elasticities assessment in JUNGMITTAG / WELFENS (1998) – a one percent increase in knowledge dissemination via the Internet would drive economic growth in the corporate sector (excluding the atypical sectors of agriculture and forestry, fishing and residential rentals) up by a good 0.18 percent. The accelerated information sharing associated with increasingly intensive telecommunications network use in the latter half of the 20th century has had positive diffusion effects on product and process innovation. At times, there has been accelerated demand for telecommunications based on network effects. For existing telecom users in the corporate sector, the user value of telecommunications rose as other companies increasingly availed themselves of modern telecommunications services such as fax and ISDN. In the case of Internet use, which is still at an early expansion stage in Germany, there are most likely considerable positive network effects to be realized. Moreover, the Internet is a novel way to link creative potential in the household, corporate and science sectors, thus promoting innovation.

Tab 10: Persons Employed in the Information Industry 1997-1999

Sector	Persons Employed			Change (%)	
	1997	1998	1999*	97/98	98/99
Hardware, Software & Service	**973,500**	**1,001,500**	**1,037,420**	**3**	**4**
Information Technology	379,000	396,000	433,160	4	9
Manufacture of Office Machines and DV Devices	*147,000*	*128,000*	*135,680*	*-13*	*6*
Software and IT services	*232,000*	*268,000*	*297,480*	*16*	*11*
Telecommunications	322,000	338,000	338,000	5	0
Manufacture of Optical Telecom-munications Devices	*101,000*	*101,000*	*101,000*	*0*	*0*
Telephone/telecommunication services	*221,000*	*237,000*	*237,000*	*7*	*0*
Electronic Components	83,500	83,500	81,500	0	-2
Entertainment Electronics	41,000	36,000	35,280	-12	-2
Specialized Dealers and Distribution*	148,000	148,000	149,480	0	1
Media	**692,000**	**691,020**	**698,690**	**0**	**1**
Publishing Industry	222,000	217,000	219,170	-2	1
Print Industry	285,000	284,000	284,000	0	0
Film & Video Production, Rental, & Distribution; Movie theaters	24,000	32,000	32,640	33	2
Radio & TV, Program Production	72,000	62,000	65,100	-14	6
Correspondence & News Offices, Free-lance Journalists	38,000	44,000	45,760	16	4
Book, Magazine & Music Trade*	51,000	52,020,	52,020	2	0
Total	**1,665,500**	**1,692,520**	**1,736,110**	**2**	**3**

** Estimated*

Source: Professional Association for Information Technology in the VDMA and ZVEI; Federal Statistics Office: (1) FV Communications Technology; (2) FV Construction Elements.

If flat rate pricing brought about a 20 % price reduction, the share of the population having Internet access at home – at a conservative estimate – would rise from 16 % to 17 % (greater reductions in usage costs are conceivable in the long term). Assuming a proportionality between Internet access and knowledge dissemination, the latter would be increased by roughly 6.5 %, which would in turn generate a percentage point of added economic growth in the corporate sector. A similar scenario results if one uses the broad definition of Internet use. Here, a 20 % price reduction would cause Germany's 33 % share to rise to approximately 38 %, implying corporate sector growth effects of just over 2 %. Meanwhile, the broader indicator naturally is fraught with more uncertainty. If this assessment is applied to the economy as a whole (including the housing industry, agriculture and forestry, fishery), a realistic growth surplus of a good one-half percentage point emerges for Germany as a consequence of flat rate pricing – with an implied price reduction of 20%.

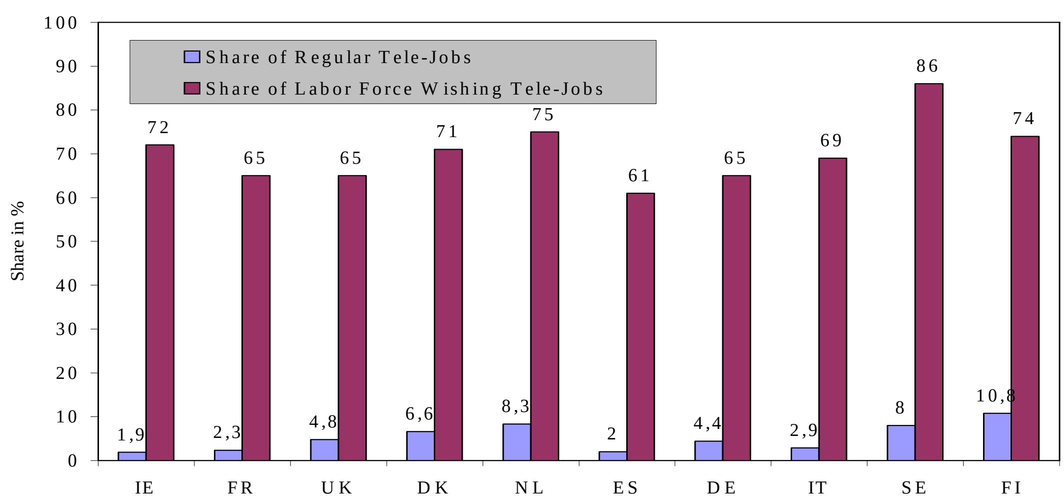
Even today, the employment growth in the information industry contributes greatly to overall employment growth. In all, the number of employed persons rose by 128,000 between 1997 and 1998. This is equivalent to an increase of approximately 0.4 %. Alone in the Hardware, Software and Services subsector, the number of employed persons grew by 27,900, an increase of approximately 2.9 % (see Table 10). This sector, with a 2.7 % share of the total labor force in 1997 and a 2.8 % share in 1998, supplied 21.8 % of Germany's total employment growth. Its contribution to employment becomes even more pronounced when we take a look at its Software and IT Services subsector. Here, the number of employed persons rose by 36,000 from 1997 to 1998. At shares of 0.65 % and 0.75 % of the total labor force for the years 1997 and 1998, respectively, this subsector was responsible for 28.1 % of the total growth in employment. It also contributed significantly to the rise in employed persons from 1998 to 1999. While Hardware, Software and Services together register a growth of employed persons of "only" approximately 4 %, the figure is approximately 11 % for just the Software and IT Services subsector.

Again assuming a proportionality – between Internet use and employment – a 20% reduction in Internet use costs (using the "At-Home Internet Access" indicator) would mean an increase in employed persons in the Software and IT Services subsector of roughly 18,500 beyond the expected growth. If one uses the broader indicator for Internet access, which is probably the more relevant one in this case, the number of employed persons added in this subsector would be roughly 45,000. Assuming this proportionality for the information industry as a whole, there would be 108,000 newly employed persons using the "At-Home Internet Access" indicator, and 263,000 additional employed persons using the broader Internet access indicator – all in addition to the expected trend-driven growth. In a more drastic scenario assuming a 50 % reduction in Internet use costs – which is, however, subject to a considerably higher uncertainty, as it entails shifting to the edge of the available sample of observations – then the consequences of the narrow and wide indicator definitions switch. While the broader indicator for Internet access now shows additional employment of 360,000 persons, the "At-Home Internet Access" indicator would lead to roughly 430,000 additional employed persons in the information industry. This result also implies that a drastic price reduction would decrease the validity of the broader indicator for private Internet use and increase the importance of "At-Home Internet Access". Thus, the present conclusion is absolutely in agreement with intuitive expectations. In the face of unemployment figures near four million at the turn of the year 1999/2000, the possibility of creating 100,000 to 400,000 additional jobs through more liberal price-setting policies in the Internet sector should be seen as momentous for Germany in any case.

A number of more indirect effects could not be quantified in greater detail within the scope of this middle-term analysis. For example, the Internet has other demand-side growth effects due to its increasing utilization of realizable transaction cost reductions. The commodities in question can thus afford a rise in demand, which translates to a positive real income effect. Meanwhile, it cannot be ruled out that the Internet-based growth of some sectors will be connected with shrinking effects in other sectors. Based on US experiences, a positive net effect can be assumed with a high degree of certainty. Moreover, higher Internet use rates and more favorable conditions for Internet use in households and businesses are crucial for Germany in its international competition for location. Germany could attract more direct investments, especially in the sector of communications-intensive industries, and thus reduce its international weakness in per capita direct investment influx in the OECD sector, which has been in evidence for years (naturally, this would also involve developments in the corporate tax reform and other measures).

Finally, a powerful and ubiquitous Internet facilitates the start-up of new businesses and the creation of virtual businesses and considerably increases their chances for growth. Thus, the American City Business Journal writes that small businesses that use the Internet grow 46 % faster than those that don't use it (INTERNET ECONOMY INDICATORS, 1999). In Germany's Business-to-Business sector – especially in small and medium-sized businesses – there is considerable room for expansion. The same applies to teleworking, where Germany has only remained in the European center field to date (ECaTT, 1999 and INSTITUT DER DEUTSCHEN WIRTSCHAFT, 1999) – even though employed persons in all European countries have shown a marked interest in this mode of working (see Figure 4).

Fig. 4: Actual and Desired Levels of Teleworking in Europe



Source: ECaTT (1999)

So flat rate pricing will lead to a steep rise in demand for private and corporate Internet use. This will likely result in increased investment in transmission capacities, due to time-related bottlenecks. The resulting employment effects will likely represent a rising share of the predicted increase in total employed persons (using the broader Internet use indicator) in the total information industry. Flat rate pricing at the retail level demands the introduction of similar models in the wholesale sector or rather in relations between dominant network operators and service providers (CAVE/ CROWTHER, 1999).

Meanwhile, there are indeed ways for Internet providers to influence the times at which users access the system. One conceivable option is that of bonus points for users who go on the Internet at off-peak times, where the bonus points could be used as “admission fees” for buying information stored in user clubs or for free access to certain services. Other user incentives are also conceivable in the interest of optimizing Internet use.

According to a number of current studies, the cost of data traffic based on Internet protocol are significantly lower than in conventional telephone traffic; orders of magnitude of 1:10 and more are quoted. This creates interesting growth perspectives for Internet telephony services and other Internet-based services. Still, the Internet expansion potential hinted at here can only be realized if new types– albeit cost-oriented by all means – of flat rate models are applied at the wholesale and retail level.

4.3 Telecommunications and Foreign Trade

International trade among OECD countries and worldwide has strongly increased after World War II. Explaining trade traditionally rests upon differences in factors supplies and relative prices on the one hand (survey CAVES / FRANKEL / JONES, 1990); on the other hand Schumpeterian influences associated with product cycle trade or trade with differentiated products plays a major role; the latter has stimulated models with monopolistic competition (e.g. DIXIT / NORMAN, 1980; KRUGMAN, 1979; LANCASTER, 1980; HELPMAN / KRUGMAN, 1990). Technological aspects also are important for goods characterized by static and dynamic scale effects. A very important link exists between per capita income and trade: on the one hand rising per capita income will raise the demand for differentiated products; on the other hand an increase in national output will raise the demand for intermediate and final products. Thus the impact of a rising aggregate output can – with population given – reflect two different links between trade and income.

From a theoretical point of view, transaction costs and information costs play an important role for international trade, but little empirical research has been made about this. Transaction and information costs basically are like tariffs so that exports and imports are affected negatively. At the same time such costs add to overall costs which reduces overall profitable output.

Establishing and expanding international business always involves the use, storage and processing of relevant information – information about suppliers, markets, prices, technology trends and export or import markets. Precise and adequate information is required for choosing optimum market penetration strategies. With reduced international communication costs expanding into international markets becomes more easy, and therefore modern and more efficient telephone systems can be expected to have a positive impact on trade. From a theoretical perspective – taking into account that foreign direct investment can be an alternative for serving foreign markets which depends on the size of firm-internal transaction costs relative to the costs of market transactions – technological progress in telecommunications might create a bias in favor of more firm-internal transactions. Indeed, in a dynamic perspective there might be both more foreign direct investment and more trade, the latter reflecting creation of a larger market radius as a consequence of falling international information and transaction costs while a rise of FDI could reflect the interplay of the enlargement of market radius and of reduced firm-internal transaction costs.

Given the gradual EU liberalization of telecommunications services – beginning in 1984 already and culminating in the 1998 deadline for the liberalization of network operation and telecommunications services – one may anticipate that international information and communication costs will fall; it would indeed be interesting to assess the potential impact of telecommunication systems on trade in Europe and elsewhere. In this paper we focused on the link between the telecommunication system and trade within the gravity approach (WELFENS / JUNGMITTAG, 2001b).

EU integration created a customs union by 1968 and thereafter the single market by end-1992 so that trade barriers have been reduced over time. Among the important elements of the single market program the opening-up of public procurement is rather important; moreover, the elimination of customs controls has reduced international transaction costs. This could mean that the role of information costs for trade has increased over time.

International trade relations can be modeled in various ways. Particularly prominent is the gravity equation which is based on market size in the importing and the exporting country on the one hand; on the other hand distance plays a crucial role. Certainly, there are also other important variables, including the role of telecommunications which will be analyzed here.

The natural point of departure is that international telephone calls are an important element for finding out about and arranging sales abroad or profitable imports. The number of telecommunication minutes is one potential proxy variable for measuring international telecommunications. From an economic perspective increasing international telecommunication links amount to a reduction of information and trading costs. While it is true that the internet has increasingly become an important source of information at the beginning of the 21st century it is realistic to assume that traditional telephony has been the dominant source of international information in the 1990s – and international telephony indeed will continue to play an important role in the future. From a data perspective it is important in principle that data on international telecommunications are available in a distinct way: we know how many international telephone calls went from country i to j (there is, however, depending on national competition conditions and prices, respectively, a potential bias with respect to originating calls coming relatively more often from i or j). With internet data traffic the direction of information diffusion is more difficult to assess. This holds particularly since preferred routings often use the US; even intra-Asian internet traffic is partly routed via the US which offers a cheap hub function due to low prices in leased lines and IP services (FCC, 2000).

By taking into account the role of telecommunications in a gravity model – as a new element in research – we can offer a better explanation of international trade than in previous approaches. Moreover, we also have the opportunity to come up with, based on refined empirical analysis, more adequate forecast analysis which could be particularly relevant for Eastern Europe and other areas in the world economy. Assuming that telecom density and the use of telecommunications are proportionate we can furthermore provide an estimate of the trade potential for the case that telecom densities should increase in the future in Eastern Europe and Asian (and other) NICs. With respect to Eastern Europe EU accession can be expected to stimulate the growth of telecommunication penetration rates.

The main result of our analysis – summarized in Table 11 – is that we can for the first time provide empirical evidence of the positive impact of telecommunications on trade. Moreover, we find that the elasticities of GDP in both the exporting and the importing country are smaller in the augmented model than traditionally. This implies that trade generation effects of output growth in Eastern Europe and NICs will be smaller than assumed traditionally. At the same time this points to the enormous relevance of adequate telecommunication liberalization and investment-enhancing regulation in the telecommunications sector; in particular this could be relevant for the Stability Pact and the economic reconstruction of the western Balkans, respectively (WELFENS, 2001d).

Tab 11: Results for the Restricted Estimations of the Augmented Gravity Model

	(1) 1995	(2) 1996	(3) 1997	(4) 1995	(5) 1996	(6) 1997
Const.	3.676	3.830	3.892	3.407	3.562	3.665
	(8.113)	(8.404)	(8.213)	(7.463)	(7.720)	(7.644)
$\log(GDP_i)$	0.619	0.603	0.595	0.638	0.624	0.609
	(8.127)	(7.926)	(7.412)	(8.356)	(8.102)	(7.540)
$\log(GDP_j)$	0.481	0.447	0.439	0.500	0.467	0.452
	(7.031)	(6.433)	(6.024)	(7.215)	(6.569)	(6.150)
$\log(DIST_{ij})$	-0.600	-0.602	-0.600	-0.622	-0.628	-0.625
	(-7.089)	(-7.098)	(-6.810)	(-7.347)	(-7.307)	(-7.110)
Language	-0.040	-0.104	-0.110	0.000	-0.061	-0.073
	(-0.260)	(-0.679)	(-0.728)	(0.003)	(-0.385)	(-0.472)
EU	0.293	0.241	0.264	0.307	0.257	0.277
	(2.716)	(2.285)	(2.259)	(2.843)	(2.426)	(2.378)
$\log(TM_{ij} * TM_{ji})$	0.218	0.237	0.241			
	(5.413)	(5.866)	(5.758)			
$\log(TM_{ij} + TM_{ji})$				0.408	0.442	0.456
				(5.042)	(5.377)	(5.456)
Adj. R^2	0.908	0.905	0.893	0.906	0.902	0.891

1) t-statistics in brackets. White's heteroskedasticity-consistent estimators of the variance matrix of the regression coefficients are used to calculate t-statistics.

5. Some Long-Term Aspects

In the US productivity growth in the 1980s and 1990s has benefited from growing trade – indeed mainly from rising import penetration as is shown in the empirical analysis of MANN (1998); she also shows that Germany had no significant productivity-enhancing effect from trade. This might reflect lack of flexibility of firms in Germany's tradable sector, but it also could indicate the different regional trade orientation of the US and Germany over time. While the US has strongly increased imports from Asian NICs which increasingly have realized high R&D-GDP ratios and thus can be expected to export more technology-intensive products over time, Germany's imports from Asia have been rather modest.

A strange finding for Germany also concerns the fact that labor productivity in the high technology sector was lower than average in the 1990s (WELFENS 2002; GRIES/ JUNGMITTAG/WELFENS, 2001a). This might point both to weaknesses of Germany's high technology firms and to inefficient R&D subsidization. From this perspective Germany seems to be rather poorly positioned to exploit growing high technology dynamics in the OECD. One may also point out that the R&D expenditure-GDP ratio reached a historical peak of 2.9% in 1989 but then fell – when Theo Waigel was Minister of Finance – to 2.3% in 1998; this ratio has not improved in 1999/2000; and the new Minister of Finance, Hans Eichel (a teacher!), seems to be determined to pursue the benign neglect attitude for R&D promotion. By contrast, the OECD's leading country in terms of R&D-GDP ratio, Sweden, recorded a ratio of 4% in 2000. Germany's expenditure on education also is meager: 4.7% in 1998 is slightly more than half the top figures of roughly 8% in Scandinavian countries and also much worse than the US with about 6%. Add to this the fact that Germany ranks – according to OECD analysis focusing on employment, output, exports and R&D in ICT – among the lower third in ICT among the 29 OECD countries. Finally, Germany' labor markets are rather inflexible and tax reform has been biased in favor of large multinational companies which undermines the growth perspectives of new firms in the digital sector.

Germany also is facing problems in the telecommunications sector where the former monopoly operator – under the supervision of the Ministry of Finance – has not been fully privatized. This is much in contrast to the UK, Spain, Italy and several other OECD countries. In addition the internet subsidiary of Deutsche Telekom has dropped its offer of a flat rate for normal telephone users (narrow band and ISDN) as of January 2001. This is much to the disadvantage of a full exploitation of digital growth opportunities; to make matters worse, Deutsche Telekom has offered as a "substitute" DSL which not only is not available at short notice but cannot be used in most parts of eastern Germany where modern glass fiber networks imply the impossibility of benefiting from DSL. The DSL technology is a kind of turbo for fixed networks based on standard twisted copper lines. Thereby Deutsche Telekom is directly undermining the growth potential of eastern Germany which is facing problems in keeping up with west German growth figures.

At the bottom line we find that the ICT sector is a crucial element for productivity growth and long term structural change in the US, Japan and Europe. We support the basic conclusion of VAN ARK (2001, p.20):" …part of the U.S. advantage during the late 1990s can also be ascribed to greater productivity gains from the ICT-using sector. Indeed European countries have not succeeded to extend their increase in employment sufficiently to ICT-using industries. Various reasons may explain these differences, but lack of structural reforms in product and labor markets may be one reason for Europe's lack of employment and productivity growth in the ICT-using sector." Since the role of the ICT-using sectors is so important for labor productivity growth in OECD countries the renewal of the old economy partly is associated with digital dynamics. Comparing the US and the EU the European lead in mobile telecommunications could become a crucial EU advantage if UMTS networks are combined with innovative digital products and broad regional market integration. While the European

Commission has proposed expansion of broadband networks in the Community there are not enough incentives for digital innovations. Both national and supranational economic policies – including innovation policies - have not paid much attention to the imperfections of information markets; since digital information stands for experience goods or confidence goods so that the quality of the respective product is difficult to assess and thus the marginal willingness to pay is rather low it is quite important to promote approaches which combine digital products with reputation building and market segmentation. Only with strong market segmentation will average revenues in digital markets be rather high (WELFENS, 2002) so that investors in the digital information market will be able to generated sustained high revenues necessary to finance high costs of investment and innovation.

In highly competitive international telecommunications markets only a few dynamic competitors will achieve high profit rates; revenue from mobile date traffic may well offset the falling per customer revenue from mobile voice telephony – here both Japan and the EU offer encouraging developments at the beginning of the 21st century. Moreover, provision of quality information and customer-taylored knowledge could be quite important for a profitable new economy. The tendencies observed in Germany and other EU countries are worrying: In most EU countries leading internet providers are forming alliances with tabloid papers and not with top publishers from the scientific community, but fishing for digital mass markets with almost zero willingness to pay could be a favorite dead end of internet portals. There might be no sustainable knowledge economy if segmented profitable information markets cannot be established. Since information markets are known to be rather imperfect markets government support for selected innovative projects and for quality certification agencies should be considered. More structural reforms in Europe and revised budget priorities also are needed in the Old World.

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Appendix: Methodological Issues in Growth Statistics

Comparing Germany / Euroland and the US there are considerable differences in statistical procedures concerning the measurement of inflation and growth, respectively. Since 1995 the US BEA has been using a chained Fisher quantity index for determining real GDP. While the US approach uses current price structures – taking into account substitution effects which tends to generate rates of growth in the year following the base period which are smaller than those generated with traditional approaches – Germany and most other EU countries use a Laspeyres price index. US hedonic pricing approaches for measuring inflation reduces the US inflation rate and a fortiori raises the real growth rate. Since Germany and most other EU countries were not using hedonic pricing there is a bias in transatlantic growth comparisons. The overall bias from the US use of the Fisher chain index and from hedonic pricing is in the range of 0.3-0.4 percentage points (DEUTSCHE BUNDESBANK, 2001).

Tab A1: The Tax Burden on Low and Middle Wages (Income tax plus social security contributions in 1999 as % of labor costs)

	(1)	(2)	(3)	(4)
B	34.9	41.3	51.2	52.4
DK	14.6	31.0	40.9	40.9
D	31.1	34.5	47.0	47.0
EL	34.3	36.8	35.2	36.5
E	28.4	30.3	332.6	36.2
F	31.5	38.8	40.4	43.5
IRL	-5.2	19.9	21.5	24.7
I	28.2	37.4	44.2	44.7
L	4.7	11.4	30.0	27.9
NL	21.8	34.2	40.3	41.1
A	19.0	31.8	41.7	43.7
P	22.0	26.0	30.3	32.1
FIN	27.6	40.3	43.3	45.4
S	40.9	44.5	48.8	49.7
UK	14.2	23.8	26.2	25.5
US	12.6	24.5	29.3	29.8
JP	14.7	14.7	18.3	18.4

(1) single individual with two children, earning 67 % of the APW (Average wage of production workers).

(2) married couple with two children and a single earner at the APW.

(3) single individual with no child, earning 67% of the APW.

(4) married couple with two children and two earners, with earnings split between the two partners at 100% and 67% of the APW.

Source: European Commission (2001), European Economy, Supplement A, No. 1

Tab A2: Public Expenditure on Education (% of GDP)

	1995	1996	1997				
	Total	Total	Pre-primary + Not Allocated	Primary	Secon-dary	Tertiary	Total
B (1)	n.a.	n.a.	0.7	1.2	2.7	1.2	5.7
DK	8.0	8.8	1.2	1.8	3.2	1.8	8.0
D(2)	4.8	4.7	0.6	:	3.0	1.1	4.7
EL(3)	2.9	3.1	:	1.1	1.3	0.8	3.2
E	4.9	4.8	0.3	1.2	2.2	0.9	4.6
F	6.0	6.0	0.7	1.2	3.0	1.1	6.0
IRL	5.2	5.0	0.1	1.6	2.0	1.3	4.9
I	4.7	4.9	0.5	1.1	2.2	0.7	4.5
L	4.4	4.3	0.0	1.9	2.1	0.2	4.1
NL	5.2	5.3	0.4	1.2	1.9	1.4	4.8
A	5.6	6.5	0.6	1.3	2.9	1.7	6.4
P	5.8	5.7	0.6	1.7	2.4	1.0	5.7
FIN	7.3	7.4	0.8	1.6	2.3	2.0	6.7
S	7.8	8.0	0.5	2.1	3.2	2.1	7.9
UK	5.2	5.1	0.4	1.1	2.1	1.1	4.7
EU-15	5.2	5.3	0.5	0.9	2.5	1.1	5.0

Notes: Includes public institutions and government-dependent private institutions

(1) The data for B are for 1994.

(2) The data for D include primary and secondary combined.

(3) The data for EL include pre-primary and primary combined.

Source: European Commission (2001), European Economy, Supplement A, No. 1

Tab A3: ICT Sectors in Europe and the US, Value-Added (% of GDP)

	1992	1995	1996	1997	1998	1999	95/99 annual change
B		3.3	3.5	3.5	3.8	4.1	8.6
D	3.5	3.4	3.3	3.6	3.7	3.9	5.1
E		2.8	3.0	3.2	3.4	3.6	12.6
F	3.9	3.8	3.9	4.0	4.1	4.3	6.2
IRL		6.5	6.7	7.5	7.3	7.6	17.8
I	3.4	3.3	3.3	3.3	3.5	3.7	10.3
NL		4.3	4.4	4.5	4.7	5.0	7.9
A		4.7	4.4	4.2	4.4	4.8	1.0
P		3.4	3.5	3.7	4.0	4.3	12.5
FIN		4.3	4.6	5.5	5.5	5.8	21.4
S		4.3	4.8	5.4	5.9	6.5	16.3
UK	5.0	5.2	5.2	5.2	5.4	5.6	7.3
EU11	3.8	3.6	3.7	3.8	4.0	4.2	7.7
US	5.0	5.3	5.5	6.1	6.4	6.8	12.9

Source: CSFB

Tab A4: Spending on Information and Communication Technology (% of GDP)

	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
B	5.4	5.5	5.4	5.4	5.7	6.2	6.1	6.7	7.1
Dk	6.1	6.4	6.1	6.2	6.4	6.7	6.6	7	7.3
D	5.3	5.5	5.2	5.1	5.2	5.6	6.2	6.6	7
EL	2.4	2.3	3.7	3.8	3.9	4.1	4.8	5.5	5.9
E	3.8	3.8	3.7	3.7	3.9	4.1	4.5	5	5.3
F	5.7	6	5.7	5.8	6	6.5	7	7.6	8
IRL	5.4	5.2	5.8	5.7	5.8	5.5	5.3	5.3	5.2
I	3.6	3.8	4.1	4.1	4.1	4.3	4.9	5.5	5.9
NL	6.4	6.4	6.3	6.3	6.6	7	7.3	7.8	8.1
A	4.9	5.1	4.5	4.6	4.7	5.2	5.7	6.2	6.5
P	2.7	2.9	4.4	4.8	4.9	5.1	5.8	6.1	8.3
FIN	4.6	5.1	5.5	5.5	5.9	6	6.3	6.8	7
S	7.4	8.3	7.6	7.5	7.4	8.1	9	9.6	10.1
UK	7.1	7.4	7.2	7.8	7.8	7.8	7.5	8	8.4

EUR-12	4.9	5.1	5	5.1	5.2	5.5	6	6.5	6.9
EU-15	5.3	5.5	5.4	5.5	5.6	6	6.4	6.9	7.2
US	7.1	7.3	7.4	7.5	7.7	7.7	8	8.1	8.3

Source: EITO OBSERVATORY (2000); D = Germany

Tab A5: ICT Production Effects - Contribution to TFP Growth over the 1990's (% Points)

	TFP Growth Increase in the EU's ICT Sector identical to that in the US		**Two Scenarios for 1995-1998**	
			No TFP Growth Increase in the EU's ICT Sector	**TFP Growth Increase in EU ICT Sector = 50% of that in the US**
	1990-1995	**1995-1998**		
Belgium	0.16	0.22	0.14	0.18
Denmark	0.04	0.06	0.04	0.05
Germany	0.13	0.19	0.12	0.16
Greece	0.02	0.04	0.03	0.03
Spain	0.09	0.14	0.09	0.12
France	0.14	0.25	0.15	0.20
Ireland	1.09	2.17	1.41	1.79
Italy	0.13	0.19	0.12	0.15
Netherlands	0.18	0.27	0.18	0.22
Austria	0.10	0.18	0.11	0.14
Portugal	0.11	0.22	0.13	0.17
Finland	0.16	0.38	0.25	0.31
Sweden	0.15	0.27	0.17	0.22
UK	0.17	0.33	0.21	0.27
EU15	0.14	0.24	0.15	0.19
US	0.23	0.50		

Source: McMORROW, K. / RÖGER, W.(2000): Potential Output: Measurement Methods, "New" Economy Influences and Scenarios for 2001-2010 – A Comparison of the EU15 and the US; Economic Papers No. 150, April 2001, p. 69.

Tab A6: Sectoral Developments in the Euro Area[1] and the USA

		Share in nominal value-added		Growth in real value-added		Growth in employment		Growth in labor productivity	
		1991	1998	1991-98	1995-98	1991-98	1995-98	1991-98	1995-98
		%	%	%	%	%	%	%	%
ICT-producing sectors, manufacturing	EU	0.9	0.7	6.5	11.5	-5.6	-2.3	12.9	14.2
	USA	1.5	1.8	20.9	25.6	1.4	3.5	19.2	21.3
ICT-producing sectors, services	EU	3.6	4.2	5.5	8.1	-0.5	0.1	6.1	7.9
	USA	4	4.8	6.3	7.8	3.9	5.3	2.3	2.4
ICT-using sectors, manufacturing	EU	4.5	3.9	0.8	1.6	-3	-1.1	3.9	2.7
	USA	3.4	3	2.4	2.9	-0.9	0.1	3.3	2.7
ICT-using sectors, services	EU	11.3	12	2.4	3.2	2.2	2.9	0.2	0.3
	USA	10.4	13.1	4.7	7.4	3.4	4.5	1.2	2.7
Manufacturing	EU	21	18.6	0.7	1.5	-2.5	-0.6	3.3	2.1
	USA	17.4	16.4	4.5	4.1	0.3	0.6	4.2	3.5
Business services	EU	47.9	51.8	2.2	2.7	1	1.8	1.2	0.9
	USA	48.3	52.7	4.8	6.6	2.6	2.9	2.2	3.7
Total economy	EU	100	100	1.5	1.9	-0.3	0.4	1.8	1.4
	USA	100	100	3.5	4	1.8	2	1.7	2

1) Euro area estimate based on Germany, France, Italy and Finland, which together account for around 73 % of euro area nominal gross value-added.

Note for EA: Owing to the rapid decline of measured prices in the ICT-producing manufacturing sector, its share in nominal value-added decreased despite high rates of growth in real value-added. Manufacturing and business services include the ICT sectors.

Note for USA: Owing to the rapid decline of measured prices in the ICT-producing manufacturing sector, its share in nominal value-added hardly increased despite high rates of growth in real value-added. Manufacturing and business services include the ICT sectors.

Source: ECB, Monthly Bulletin, July 2001