GROWTH AND PRODUCTIVITY

1. Is the United States Increasing its Lead?

At the end of World War II a substantial fraction of Europe's capital stock was damaged and Europe found itself in a state of economic backwardness compared to the United States. In the following years, under the impulse of reconstruction policies, US aid, and European integration, European countries started closing the gap at an extremely rapid rate.

Such a convergence process is what we should expect to observe under the assumptions of technological diffusion across countries and international capital mobility. As long as Europe is less rich than the United States, i.e. has less capital, the return on investing in Europe should be higher than in the United States, and Europe should accumulate capital more rapidly than the United States. However, this is not what happened. The period of convergence stopped in the mid-1970s when oil shocks and rising unemployment started taking their toll. Given that productivity per capita was still lower in Europe than in the United States, one should have expected the convergence process to have continued at a moderate pace. Instead, the United States exhibited a better growth performance in the 1980s and the 1990s than Europe. This phenomenon is displayed in Table 5.1.

Table 5.1

Annual average GDP growth rate, constant 1995 PPP USD

	1970–1980	1980–1990	1990–2000
Germany	2.68	2.22	1.53*
France	3.21	2.33	1.77
Italy	3.53	2.19	1.50
Netherlands	2.88	2.16	2.84
Belgium	3.31	2.01	2.05
Luxembourg	2.55	4.36	5.15
United Kingdom	1.91	2.66	2.09
Ireland	4.63	3.56	6.64
Denmark	2.21	1.92	2.16
Spain	3.47	2.96	2.45
Greece	4.60	1.59	2.23
Portugal	4.63	2.88	2.57
Finland	3.39	3.02	2.03
Sweden	1.91	2.07	1.65
Austria	3.59	2.28	2.03
European Union	2.94	2.36	1.91
United States	3.15	3.14	3.25

* Because of German unification in 1990, the annual GDP growth rate, at constant 1995 PPP USD, is calculated for the period 1991–2000.

Source: OECD Statistical Compendium.

Only Luxembourg and Ireland managed to outperform the United States. With respect to other countries the United States extended its lead. Table 5.2 shows the relative gap between per-capita GDP in European countries and the United States. These numbers eliminate population growth as a source of growing GDP differentials between Europe and the United States.

As we can see, in the 1990s Europe lost further ground and in 2000 per capita GDP was 30 per cent lower than in the United States, which was a larger gap than in 1970. Among EU countries a clear

Table 5.2

Per capita GDP relative to the United States, constant 1995 PPP USD

	1970	1975	1980	1985	1990	1991	1995	2000
Germany	0.86	0.87	0.90	0.87	0.88	0.80	0.76	0.70
France	0.75	0.80	0.79	0.75	0.76	0.78	0.73	0.69[a]
Italy	0.66	0.68	0.73	0.70	0.72	0.74	0.71	0.65[b]
Netherlands	0.80	0.83	0.80	0.75	0.75	0.77	0.75	0.75[b]
Belgium	0.73	0.79	0.81	0.76	0.78	0.81	0.77	0.74[b]
Luxembourg	0.92	0.92	0.89	0.90	1.05	1.11	1.19	1.25[b]
UK	0.67	0.68	0.65	0.64	0.66	0.66	0.66	0.63[b]
Ireland	0.45	0.49	0.50	0.49	0.56	0.58	0.64	0.81[b]
Denmark	0.85	0.85	0.83	0.85	0.80	0.82	0.81	0.76[b]
Spain	0.51	0.58	0.53	0.50	0.54	0.56	0.54	0.54[b]
Greece	0.45	0.52	0.53	0.49	0.47	0.49	0.46	0.45[c]
Portugal	0.39	0.41	0.44	0.41	0.47	0.49	0.48	0.47[b]
Austria	0.69	0.75	0.79	0.76	0.77	0.80	0.76	0.72[b]
Finland	0.67	0.73	0.73	0.73	0.76	0.71	0.67	0.71[a]
Sweden	0.84	0.86	0.80	0.78	0.76	0.76	0.71	0.69[b]
European Union	0.76	0.78	0.78	0.76	0.77	0.76	0.73	0.70

[a] Calculated with total population of 1999.
[b] Calculated with total population of 1998.
[c] Calculated with total population of 1997.

Source: OECD, Statistical Compendium.

trend of convergence is only visible for Luxembourg and Ireland, while over the last 30 years most of the other countries converged temporarily but than diverged again, in particular during the 1990s.

It may be believed that this latter trend is essentially the outcome of de-synchronisation of business cycles between the two sides of the Atlantic. This may indeed be part of the story. Nevertheless, in 2000, which was, in our view, the peak of the current cycle on both sides of the Atlantic, Europe was considerably worse off (in relative terms) than at the beginning of the 1990s.

2. The Role of the Labour Market

What explains the exceptional performance of the United States in the 1990s? In Table 5.3 the supply determinants of growth are shown for both the United States and Europe. In the United States about half of the 3.4 per cent average GDP growth in the 1990s can be explained by the increase in labour input (per hour) (1.8 percentage points) and the other half by the increase in productivity (per hour) (1.7 percentage points). In Europe growth was only 1.8 per cent, and most of this growth can be explained by productivity gains (1.6 percentage points) while the contribution from additional labour input was very small (0.3 percentage points) and in some countries, such as Germany, even negative. While the United States succeeded in employing a growing labour force and in reducing the unemployment rate, European labour markets were much less flexible, and in many countries unemployment increased and participation rates declined.

Differences in labour market institutions play various roles in explaining the differential growth experience of Europe and the United States in the 1980s and 1990s.

First of all, labour market developments affect changes in labour input. The workforce has risen more in the United States than in Europe due to strong immigration. If the labour market works properly, as is approximately the case in the United States, this implies an equiproportionate increase in labour input, and thus faster growth than in Europe. If the age and skill structure of the immigrants and their participation rates were the same as those of Americans, this growth supplement would be entirely eliminated if one looked at per capita growth. However, this is not the case as immigrants are more likely to be of working age and may have higher participation rates even controlling for their age. On the other hand, they are typically less skilled than natives, which tends to reduce their contribution to growth. Hence their net effect on measured productivity is ambiguous.

In Europe, too, active population has increased due to demographic changes, changes in female participa-

Table 5.3

Determinants of Growth 1990–1999, Comparison between the United States and Europe
Average annual percentage change, in constant prices

	GDP	Labour input	Capital stock	Labour productivity	Change in productivity caused by: Capital deepening	TFP
United States						
1990–1995	2.4	1.4	1.9	1.0	0.2	0.9
1996–1999	4.4	2.1	3.7	2.3	0.5	1.8
1990–1999	3.4	1.8	2.8	1.7	0.4	1.4
Western Europe[a)] (D)[b)]						
1990–1995[c)]	1.4 (1.6)	– 0.4 (– 0.6)	2.3 (3.0)	1.9 (2.3)	1.0 (1.2)	0.9 (1.0)
1996–1999	2.2 (1.7)	0.9 (– 0.4)	2.2 (2.3)	1.3 (2.1)	0.5 (1.1)	0.8 (1.1)
1990–1999	1.8 (1.7)	0.3 (– 0.5)	2.3 (2.7)	1.6 (2.2)	0.8 (1.2)	0.9 (1.1)
of which: high growth countries						
Finland						
1996–1999	5.5	2.3	0.9	3.1	– 0.5	3.7
Ireland						
1996–1999	9.9	5.8	4.7	4.0	– 0.4	4.5

[a)] Weighted average of following countries: Germany (1992–95, 1996–99), Finland, France, Ireland, Italy, Netherlands, Norway, Sweden, Spain, United Kingdom. – [b)]Germany. – [c)]Germany 1992–95.

Source: Oliner and Sichel (2000), calculations by the author.

Box

Growth vs. Level Effects

Many economists involved in short-run macroeconomic analysis express their forecasts in terms of growth rates. However, the growth rate can be high for several different reasons. In particular, it can be high because the economy is adjusting to a shock which has permanently increased the level of GDP by a given amount. For example, an increase in labour market participation by 10 per cent typically increases GDP by 10 per cent. Upon impact, however, the effect is virtually zero as it takes time for the labour market to absorb these new entrants and for firms to accumulate the capital needed to create new jobs. Then, as competition by these new entrants depresses wages, firms will find it worthwhile to create new positions and to invest accordingly. As they do so, GDP rises, i.e. experiences a boost in its growth rate. Over time, however, as these new entrants are absorbed, wage pressure goes up, and the additional flow of job creation and investment gradually dies out. Growth slows, and GDP eventually grows at the same rate as before the shock, being simply 10 per cent higher than if the shock had not occurred. This is what is called a *level* effect. A similar response is observed if there is a permanent increase in the savings rate, for example, which, after a while raises the level of the capital output ratio and of GDP.

In contrast, a permanent increase in the resources devoted to R&D will increase the number of discoveries being made each year, and hence the pace at which productivity grows. This generates a permanent improvement in the underlying growth rate of the economy. For example, the economy may now grow at 3 per cent a year instead of 2 per cent a year forever.

Some economists doubt whether such permanent increases in productivity growth actually do occur in reality. They point out that innovation has decreasing returns and that people eventually run out of good ideas, so that the growth supplement permitted by an increment in resources devoted to R&D would eventually disappear. However, there is no doubt that the growth effects of a permanent boost to innovation are much longer lived than those of an increase in savings or in active population.

tion, and also an inflow of immigrants. But European labour markets, plagued by wage rigidity, did not react with a matching increase in employment. Instead, unemployment has risen. This has tended to push down per capita growth in Europe. Finally, another factor which boosted labour input in the United States, especially in the 1990s, is the fall in the natural rate of unemployment, which seems to have gone down from 6 per cent to 4 per cent. It is not clear what caused this, but some argue that it may simply be a composition effect due to a lower fraction of youth in the workforce (Shimer 1998). The argument is that the young automatically have a higher rate of unemployment because of their higher labour turnover rate. However, since the same phenomenon is taking place in Europe, it should not have differential effects to a first-order approximation.

If Europe had had more flexible labour markets, it would have employed more people and grown faster in the 1990s. Or, alternatively, Europe could have grown at the same rate while investing less, as the United States did, which would have meant higher consumption and higher welfare.

The contribution of an increase in labour input is neutralised if one looks at labour productivity or, better, at hourly productivity, since in this case output is divided by the appropriate labour input. Labour productivity depends on technology – as measured by total factor productivity – and on the capital/labour ratio. Here differences in labour market institutions tend to generate a positive growth differential in favour of Europe, because higher wages induce firms to substitute capital for labour up to the point where labour productivity is compatible with the wage level. When this process takes place, faster capital accumulation is observed than if wages were not rigid. This probably helps to explain why labour productivity rose faster in Europe than in the United States in the 1980s. However, this is nothing to rejoice about, since the extra capital accumulation is in *relative* terms. Total capital is lower than at the full employment level, but proportionately by less than employment.

Changes in the composition of the workforce, or adjustment of the capital/labour ratio to changes in labour market institutions are only transitory phenomena. That is, they change the long-run *level* of output, but not its growth rate (see Box). In the long run, growth depends on the level of technology (which we measure using total factor productivity). Until 1990, TFP used to grow at a much faster rate in Europe than in the United States because Europe's technology level was catching up with the US level. Since then, a new phenomenon has occurred: the United States has grown faster than Europe in terms of TFP. At the same time it has closed its secular gap in investment rates. The next section investigates whether a new growth regime is now prevailing, and whether Europe should worry about it.

Table 5.5

Total factor productivity, cumulative growth over 5-year periods

	Euro area	United States
1975–1980	14.5	3.0
1980–1985	9.2	6.9
1985–1990	10.3	5.1
1990–1995	4.6	7.3
1995–2000	6.3	12.2

Source: OECD Economic Outlook Database.

3. The Effect of Information Technology

Investment rates in the United States accelerated considerably in the 1990s. However, they have traditionally been below those of Europe and have remained so until very recently, as shown in Table 5.4. So it is unlikely that physical capital accumulation explains why the US-European gap widened in the 1990s, as it has merely caught up in terms of investment rates. In fact as shown in Table 5.3, capital stock growth in the business sector was somewhat higher in the United States than in Europe, but as labour increased much more in the United States, the capital deepening effect (i.e. the increase in capital intensity) was only half of that in Europe (0.4 against 0.8). Despite the smaller capital deepening effect, labour productivity growth in the United States was slightly higher in the 1990s than in Europe (1.7 per cent against 1.6 per cent). The reason for the higher US labour productivity growth was that its total factor productivity, which is an estimate of the role of technical progress, increased more (1.4 per cent against 0.9 per cent). The difference is even bigger in the second half of the 1990s, although part of this difference could also be cyclical as the United States experienced an exceptional boom while the recovery in Europe remained more moderate.

Table 5.5 looks at the growth rate of total factor productivity as calculated by the OECD over a longer time horizon.

The results are striking. Whereas total factor productivity grew much faster in Europe than in the United States prior to 1990, this pattern reversed in the 1990s. During that decade, the United States accumulated almost ten extra percentage points of productivity growth relative to Europe.

An important question is therefore: what explains this development? A leading hypothesis is that the United States has benefited from new information technologies much more than Europe. This advantage comes from several factors.

First, the United States is an important producer of IT goods such as semiconductors, computers and software. Table 5.6 summarizes the GDP share of these industries in the United States and in Europe. Clearly, the US share is higher than that of the European Union, and the three major Eurozone countries produced ICT goods less proportionately than the United States. However, two

Table 5.4

Investment/GDP ratio

in %

	United States	Euro area
1960	17.2	23.2
1970	16.7	24.6
1975	15.5	22.3
1980	17.1	21.4
1985	18.3	18.7
1990	17.0	21.1
1995	17.9	19.9
2000	21.5	20.9

Total factor productivity is calculated as a residual after the contributions of labour and capital inputs have been accounted for.

Source: OECD Economic Outlook (2001).

Table 5.6

Share of value added in information and communication technologies

in %

Country	Share of ICT in value added
Sweden	9.3
United States	8.7
United Kingdom	8.4
Finland	8.3
European Union	6.4
Germany	6.1
Italy	5.8
France	5.3

Source: OECD Statistical Compendium (2000).

notable exceptions stand out: The UK, and two Nordic countries, Sweden and Finland. These three countries have a share of value added in ICT which is similar to that of the United States.

These industries, which account for a larger fraction of US GDP, grew much faster than others. Therefore, one element of an explanation for the better US performance is a composition effect: the United States grows faster because a greater fraction of its GDP is in sectors which themselves have grown fast. One underlying reason is that IT products seem to be associated with a considerable potential for learning and productivity improvements.[1]

Second, an increasing fraction of investment has been in the form of information technology (IT). According to Jorgenson (2001), this investment has been on-going from the mid-1970s and, until recently, has been accelerating. However until the 1990s economists failed to see its effect on aggregate productivity, especially since total factor productivity growth slowed down to almost zero in the mid-1970s. In the meantime, it has shown up in the growth statistics. Information technology is comparable to the steam engine or electricity in that it is a general purpose technology which may raise productivity in all sectors of the economy. Adoption of IT in turn triggers technological and organisational innovations in the user sectors. For these reasons an adoption lag can have substantial negative consequences for the productive and innovative performance of an economy.[2]

Finally, the last half of the 1990s is associated with the development of the Internet. The Internet has been disproportionately developed in the United States, and it disproportionately benefits it. This is because it is a network, and the economic contributions of the network grow more than proportionately with its number of participants, as it is determined by the number of *matches* within the network. Thus, networks benefit larger markets and larger linguistic zones more than smaller ones. Both this market size effect and the use of English as a *lingua franca* imply that the number of sites in English vastly outnumber those in other languages.

According to Jorgenson (2001), over the period 1995 to 1999, the output of the US computer industry grew by 40 per cent, and that of the software industry by 20 per cent. Similar figures are found (36 per cent and 16 per cent, respectively) for growth in the stock of computers and software capital in the US economy. While this means that in 1999 information technology capital only represents 5 per cent of annual GDP, its contribution to the average annual growth rate of 3.4 per cent is about 1 percentage point. Furthermore, this is probably an under-estimate as the externalities generated by IT may account for some of the residual total factor productivity growth of 0.75 per cent, while IT has also facilitated the quality of the workforce associated with higher education.

From a broader perspective, one may ask why it has taken such a long time for IT to have a noticeable impact on growth. This is a matter of much speculation, but recent theoretical and empirical work has claimed that technological breakthroughs diffuse quite slowly and may not even be adopted for a while. The reason is that there are high learning costs associated with implementing the new technology. Furthermore, part of this learning is social in that one draws lessons from others' experience with the new technology. Consequently, a firm has a strategic incentive to delay adoption of the new technology until others have adopted it. Finally, when the new technology is invented there is an initial stock of capital specific to older technologies, and it may be valuable to wait for this capital to depreciate before investing in the new technology. As argued by Greenwood and Yorukoglu (1997), this implies that technological diffusion is slow. According to their estimates, it takes about 15 years for a new technology to be adopted by 50 per cent of firms.

According to these authors' numerical simulations, a technological breakthrough initially leads to a *slowdown* in the rate of measured productivity growth. This is because the introduction of a new technology requires a sustained investment in learning at the beginning of this technology's life

[1] For example, in 1965 Gordon E. Moore made the observation that the number of transistors contained by a micro-chip doubled every 18–24 months. One may have believed that this was typical of an infant industry, but the semiconductor industry is no longer in its infancy and Moore's law has not been invalidated yet after 35 years! As a result, growth in capacity has been astronomical. In 1971 a chip contained 2,300 transistors. In 2000 it contained 42 million. Conversely, the price of microprocessor, has experienced a tremendous downward trend. According to Jorgenson (2001), the price of a chip declined by 40 per cent per cent a year on average between 1974 and 1996. Given the increase in capacity of these integrated circuits, this means a 70 per cent yearly decline in the unit price of capacity.

[2] The international comparison of IT investment in volume terms is, however, distorted by differences in price measurement (hedonic versus traditional approach).

cycle. As a consequence, skilled labour is transferred from the direct production activity to learning, and the medium-run effect of that is that productivity in the output sector is depressed. Only in the long run does the economy reap the full benefits of the technological breakthrough, once the transitional period of learning the new technology is over and most skilled workers are employed again in the direct production activity. This vision squares well with the observation that in the mid-1970s, when the personal computer was invented, there was a severe slowdown in the rate of measured total factor productivity growth. This phenomenon has been and remains a matter of much debate. One leading interpretation is that it was due to soaring energy prices associated with the first oil shock. While it is hard entirely to dismiss the role of energy prices, as Greenwood and Yorukoglu do, it is plausible that the oil shock played a role in speeding the adoption of new technologies by further depressing the value of existing, energy-intensive vintages of capital. Evidence from the stock market squares well with this view. The mid-1970s were associated with a sharp drop in stock prices. This was followed by a recovery which turned into an explosion in the 1980s and 1990s. Hobijn and Jovanovic (2000) distinguish between the contribution to stock prices of firms that were already around in 1972, and were supposedly locked into an old technology, intensive in energy and unfriendly to IT, and firms that entered the market later and adopted new technology. A striking finding is that the rise in the stock market in the 1980s and 1990s is *entirely* due to new firms. Incumbents never recovered from the drop in their stock values triggered by high energy prices and technological breakthroughs. Furthermore, industries where stock prices dropped by the largest margin were precisely those where IT investment was subsequently the strongest. This phenomenon would not have taken place had the surge in energy prices been the sole reason for the fall in the value of incumbent firms, but also reflected markets' expectations that incumbent firms were not going to be able to compete with new entrants using superior technologies. For example, share prices dropped by 44 per cent in manufacturing (where IT represents a relatively low fraction of total capital) and rose by more than 70 per cent in services (where IT is a high fraction of the total capital stock). Therefore, the productivity slowdown could be re-interpreted as the net of two effects: a direct reduction in productivity in old technologies, and a diversion of skilled labour input toward learning the new technologies.

Another interesting aspect of the IT revolution, which has implications for Europe, is that it has been associated with an increase in the rate of "creative destruction", namely with greater entry and exit of firms. Hence, the rate of business failures almost trebled in the 1980s as compared to the 1960s and 1970s. And at the same time there was a four-fold increase in the rate of business incorporations.

Altogether, these pieces of evidence are reasonably convincing that IT played an important role in the recent boost in US economic performance. However, this does not imply that the proceeds of growth are shared equally among the population. In particular, the last three decades have been associated with a rise in US wage inequality. Between 1974 and 1985, workers below the 60th percentile of the distribution of wages all experienced negative wage growth, on average, while workers above that level experienced positive wage growth. Hence the income share of the bottom quintile (i.e. the poorest 20 per cent) fell from 4.2 per cent to 3.4 per cent between 1974 and 1995, while the top quintile income share has increased from 41.9 per cent to 49.2 per cent (Wolfson and Murphy, 1998).

While this increase in inequality is partly due to the collapse of egalitarian wage-setting institutions such as trade unions, labour economists are convinced that technical change is the driving force behind the rise in inequality, and recent evidence suggests that computers are one of the most important factors. Therefore, the force which allowed the United States to take-off in the last twenty years, widening the productivity gap with Europe, is also the one which made it more unequal and which may generate social conflicts in the future.

For example, Autor et al. (2001) have found a high correlation between computerisation at the industry level and a shift in the composition of labour input away from routine tasks in favour of non-routine cognitive tasks. This is direct evidence that computers substitute for tasks performed by low-skilled workers and are complementary with tasks performed by highly educated workers. According to their estimates, this means that, holding factor prices constant, the total proportion of college-educated workers in the workforce should have increased by 15 percentage points between 1970 and 1990. This is a measure of the size of the demand shock triggered by computerisation. Similarly, Doms et al. (1997) find that plants that adopt new information technologies more than others have a greater proportion of highly educated workers, managers, and professionals.

Beyond the direct complementarity between new technologies and skills, these may tend to increase inequality because more educated workers are in a better position to learn them. Consequently, when a new technology is introduced, it is likely to attract only workers with a relatively high level of education, while the others remain working with the old technology. A consequence is that capital moves from the old to the new technology. This reduces the complementary input for workers who remained in the old technology, which in turn reduces their productivity and wages. Caselli (1999) has studied this phenomenon and points out that the IT revolution has indeed been associated with a greater dispersion of capital/labour ratios.

In the longer run, one may be more optimistic about the consequences of technological breakthroughs for the distribution of income. As time passes, the new technology becomes easier to operate. This is because educational levels go up, and also because there are strong market incentives eventually to design technology so as to make it easier for unskilled workers to use. This way, a large number of workers can use it, which increases the scale of production and thus the monopoly rents earned by those who designed the new technology.

This is what happened to the automobile industry when Henry Ford introduced the assembly line in 1913. This allowed a large number of low-skilled labourers to work on the new technology, which increased their productivity and wages relative to their previous activity in other sectors, and hence reduced inequality. The same phenomenon is observable in the computer industry, as more user-friendly operating systems and software are being introduced. Some formal models indeed predict that inequality tends to *overshoot* its long-run level after the introduction of a new technology, i.e. to go up and then down. Indeed the increase in inequality has levelled off in recent years.[3]

4. Documenting Europe's Technological Deficit

If we are willing to accept the hypothesis that information technologies played a key role in the US productivity surge in the 1990's, one may ask whether the inability of Europe to catch up has to do with a deficit in high technologies.

To begin with, there is evidence that the United States is more actively involved in research and development and more specialised in high-tech goods than Europe. For example, the OECD Science and Technology indicators imply that R&D expenditures are about 20 per cent higher, as a fraction of GDP, in the United States than in Europe. In 1998, the United States was paying 30 cents in royalties to the rest of the world for every dollar of royalties it received. The corresponding figures are 59 cents for the UK, $1.18 for Germany, $1.38 for France, $1.74 for Italy, and $6.64 for Spain.

Furthermore, Butler (1992) shows that high-tech manufacturing output represented 30 per cent of US manufacturing output in 1990, and 20 per cent of German manufacturing output. Between 1985 and 1990, this figure shows an upward trend in the United States, while it has stagnated in Germany. Similarly, Kravis and Lipsey (1992) have computed indices of comparative advantage in high-tech, medium-tech, and low-tech goods defined as the ratio of the export share in the corresponding technology group over total export shares. They report that in 1986, Germany's comparative advantage in high tech-goods had dropped to 0.86 from 1.08 in 1966. At the same time, the United States had enhanced its comparative advantage from 1.4 to 1.6, and Japan's had slightly deteriorated from 1.7 to 1.6.

Does this pattern also apply to information technologies? If one takes the software industry as an example, a recent OECD study (1998) shows that it accounts for 2.7 per cent of GDP in the United States versus only 0.9 per cent in France. The corresponding figures for employment are 0.9 per cent and 0.7 per cent respectively, implying greatly higher labour productivity in that sector in the United States as compared with France. On the other

[3] According to Wolfson and Murphy (1998), bottom wages started growing again between 1985 and 1995, but this was not sufficient to reverse inequality. However, the bottom income share was almost constant between 1985 and 1995.

hand, if one aggregates all IT sectors together, then Europe has comparable or even higher employment shares (OECD, 2000). But productivity in this sector is again much higher in the United States, 40 per cent higher than in Germany and almost twice as high as in France. Indeed, Business Week has reported that out of the 100 top firms in the New Economy, only six are European, and three of these are Scandinavian (in Cohen and Debonneuil, 2001).

Thus, Europe tends to specialise less in the production of high-tech goods than does the United States. This pattern of trade is mirrored by the pattern of specialisation in research and development. For example, in 1993 the US accounted for 54 per cent of world patents in biotechnology, 51 per cent in computers, and 32 per cent in communication, versus 13 per cent, 14 per cent and 13 per cent, respectively, for France plus Germany. On the other hand, these two countries accounted for 25 per cent of world patents in instruments, 25 per cent in construction, and 52 per cent in transportation, vs. 6 per cent, 5 per cent and 3 per cent for the United States (Office de la Science, 1997). Also, in the United States, the IT sector accounts for 35 per cent of total business R & D, while the corresponding figures are 26 per cent for France and 20 per cent for Germany (OECD, 2000). In other words, Europe innovates in medium-tech, mature industries, while the United States is at the cutting edge.

Why does this matter? There is no *a priori* reason why producing yoghurts should be more detrimental to the welfare of consumers than producing micro-chips. However, it is likely that specialisation in high-tech industries has side benefits which may enhance growth and benefit the economy as a whole. These industries offer more opportunities for learning and innovation than low-tech ones, and allow the economy to grow faster and obtain more rents associated with intellectual property rights. The above mentioned evidence on the fall in semiconductor prices and the explosive increase in micro-chip capacity suggests that this is indeed the case.

In principle, this may be offset by relative price effects: the terms of trade of the fast-growing, high-tech economy deteriorate relative to the slow-growing, low-tech one because low-tech goods are not perfect substitutes for high-tech goods. In other words, low-tech economies also benefit from the extra growth potential of high-tech ones, because yoghurts become more expensive relative to computers. However, the comparative growth experience of Europe and the United States over the last ten years suggests that these price effects are not strong enough to offset the growth premium associated with specialisation in high-tech goods.

While high-technology innovations and production have important implications for growth, using them is even more important. Hence, the question now is whether Europe is also lagging in the adoption of new technologies.

Table 5.7 relates to the diffusion of the Internet by reporting the number of Internet hosts per 1,000 inhabitants. Admittedly this also measures specialisation in the production of information technology. But to the extent that site content is country specific, the greater the density of hosts, the easier

Table 5.7
Number of Internet hosts per 1,000 inhabitants in July 2001

Country	Internet host per 1,000 inhabitants (Rank)
United States	275.28 (1)
Finland	183.28 (2)
Canada	183.07 (3)
Iceland	179.74 (4)
Sweden	177.02 (5)
Norway	130.27 (6)
Netherlands	118.81 (7)
New Zealand	106.17 (8)
OECD	100.60
Denmark	98.53 (9)
Australia	91.08 (10)
Austria	84.12 (11)
Switzerland	74.09 (12)
United Kingdom	69.71 (13)
Belgium	59.70 (14)
EU	53.04
Germany	50.33 (15)
Japan	48.19 (16)
Italy	40.44 (17)
Ireland	34.60 (18)
France	27.20 (19)
Spain	26.17 (20)
Hungary	19.20 (21)
Greece	17.37 (22)
Czech Republic	16.77 (23)
Poland	14.23 (24)
Portugal	13.82 (25)
Korea	11.07 (26)
Slovak Republic	7.66 (27)
Mexico	4.66 (28)
Turkey	3.63 (29)

An Internet host is a domain name (name server) that has an IP address (A) record associated with it. This would be any computer sytem connected to the Internet (via full or part-time, direct or dial-up connections).

Source: www.netsizer.com.

Table 5.8
Access lines to the telephone

Country	1980	1990	1997
Australia	0.35 (9)	0.46	0.51
Austria	0.29 (15)	0.42	0.46
Belgium	0.25 (18)	0.39	0.48
Canada	0.41 (5)	0.55	0.62 (7)
Switzerland	0.45 (2)	0.58	0.64 (4)
Czech Republic	0.11 (23)	0.16	0.32
Germany	0.26 (17)	0.40	0.55
Denmark	0.43 (4)	0.57	0.64 (4)
Spain	0.19 (21)	0.32	0.40
Finland	0.36 (7)	0.54	0.56
France	0.30 (14)	0.50	0.58 (8)
United Kingdom	0.31 (13)	0.44	0.54
Greece	0.24 (19)	0.39	0.52
Hungary	0.06 (26)	0.10	0.32
Ireland	0.14 (22)	0.28	0.42
Iceland	0.37 (6)	0.51	0.57
Italy	0.23 (20)	0.39	0.45
Japan	0.33 (12)	0.44	0.48
Korea	0.07 (25)	0.36	0.52
Luxembourg	0.36 (7)	0.48	0.67 (2)
Mexico	0.04 (28)	0.06	0.10
Netherlands	0.35 (9)	0.46	0.57
Norway	0.29 (15)	0.50	0.63 (6)
New Zealand	0.35 (9)	0.44	0.51
OECD	0.28	0.39	0.49
Poland	0.05 (27)	0.09	0.19
Portugal	0.10 (24)	0.24	0.41
Sweden	0.58 (1)	0.68	0.68 (1)
Turkey	0.03 (29)	0.12	0.28
United States	0.44 (3)	0.54	0.66 (3)

Source: OECD, Telecommunications Database (1999).

the access to information that is useful to resident households and firms.

Major European countries are far behind the United States, by a factor of more than ten in the case of France. Another notable fact is that small Nordic countries fare much better, with a density comparable to that of the United States. In spite of this exception, Europe is clearly behind the United States – the EU has an Internet density less than a fifth of that of the United States.

One could speculate that these wide differences simply reflect a late start and that Europe is catching up quickly. However, there is no sign of such a trend. Between 1997 and 1999, for example, the density of Internet hosts trebled in the United States and France, and only doubled in Germany. Thus it does not appear to be growing faster in Europe than in the United States.

As Table 5.8 shows, there is also a deficit in terms of access lines to the telephone. However, this deficit is less pronounced: the order of magnitude is 10–20 per cent of US density for major European countries, with the Nordic countries standing out again as an exception.

According to our hypothesis, therefore, Nordic countries should have kept pace with the United States in growth terms. This is in fact only true for Finland in the second half of the 1990s, which grew by 5.5 per cent, a figure comparable to the 4.4 per cent growth rate of the United States.

One technology in which Europe has the reputation of leading the United States is cellular phones. While it is true that some prominent cell phone manufacturers are European, in terms of use this is not so much true. Table 5.9 reports the number of subscriptions per 1,000 inhabitants in 1997.

At this date, Nordic countries were all using cell phones much more than the United States. But all other European countries were clearly lagging, with Italy on a par.

Further below we discuss possible causes of the European IT gap. One important element, however, is the difference in prices between the two sides of the Atlantic. In particular, according to the OECD, the average price of Internet access is about twice as high in countries such as France, Germany or the United Kingdom as compared with the United States. Interestingly, Nordic prices are much more in line with US ones. This suggests that differences in supply, rather than demand, underlie the European handicap in Internet penetration.

That Europe invests less in IT than the United States is also evident from data on the software industry and on computer services. In 1995, this market's turnover was $212 trillion in the United

Table 5.9
Number of subscriptions to (analog and digital) mobile phones per 1,000 inhabitants in 1997

Finland	456
Norway	384
Sweden	358
Denmark	275
Italy	205
United States	204
Portugal	154
Ireland	144
Austria	143
United Kingdom	143
Spain	109
Netherlands	108
Germany	99
France	98
Belgium	96

Souce: OECD Telecommunications Database (1999).

States, against only $60 trillion in France plus Germany, which together have a population of about half that of the United States.

5. Explaining Europe's Technological Deficit

If it is true that the gap between Europe and the United States widened because the former failed to adopt new information technologies, why did this happen?

A first set of explanations relies on the idea that *product and labour market regulations* deter specialisation in high-tech industries and reduce the incentives for technical change. As we have pointed out above, in the United States adoption of new technologies was associated with an increase in creative destruction – both the rate of entry and exit in the market increased. In contrast, in Europe firm creation does not seem very dynamic. For example, according to the *Global Entrepreneurship Monitor* (1999), the percentage of adults participating in entrepreneurial activity is 4 per cent in Germany, 3.5 per cent in Italy and the UK, and only 1.8 per cent in France, vs. 10 per cent in the United States.[4]

Europe's deficit in terms of enterprise creation and risk-taking may be explained by a variety of regulatory factors:

- Heavy regulation in product markets increases barriers to entry. For example, as we have seen above, Internet penetration is limited by high costs, evidently due to reduced competition in Europe's telecom industry, which has been deregulated much more recently than that of the United States. These arguments, combined with the above-mentioned evidence on the key role played by IT in the US growth surge, suggest that the dynamic gains from deregulating such sectors, i.e. the gains from increased innovation and dynamism, may be even higher than the static gains to consumers in the form of lower prices.
- Venture capital markets also appear to have played a role, and have developed later in Europe than in the United States. These markets in Europe have a long way to go before they are comparable in relative size with the United States. For example, the French *Nouveau Marché*, which is the equivalent of the NASDAQ, had a total market capitalisation of €22 billion as of 31.12.00, as opposed to the *Premier Marché*, the equivalent of the NYSE, whose capitalisation at the same date was €1463 billion. Thus the *Nouveau Marché's* capitalization is just a minute 1.5 per cent of the *Premier Marché*. In contrast, the ratio between NASDAQ's capitalisation and NYSE capitalisation in 2000 was as high as 55 per cent (WestLB Panmure, 2001). Of course, this difference reflects supply as well as demand factors. If risk-taking is penalised by taxes and regulation, lack of managerial culture, or inadequate human capital, then we expect risk markets to be smaller in Europe, even in the absence of any impediment to their functioning. But the sheer size of the difference suggests that more is at work. In some sense, venture capital markets failed to take off in Europe, perhaps reflecting a vicious circle of expectations that they would remain marginal. If a financial market is expected to be too thin, it has poor properties in terms of diversification and liquidity. This in turn makes people reluctant to invest in it, thus validating the expectation that it will not grow (Pagano, 1993). A coordinated effort must be made to get out of this financial underdevelopment trap.
- Labour market regulation is also likely to play an important role. Dismissal costs prevent downsizing in obsolete industries, thus retaining human resources in low productivity sectors. This reduces the scope for the expansion of new sectors and the ability of Europe to compete with the United States in new technologies. In the long run, Europe finds itself with an economic structure biased toward older technologies, implying lower productivity and lower living standards. If new technologies are more intensive in dynamic learning externalities, then the productivity gap may widen as time passes. Furthermore, many national regulations concerning dismissals go beyond the simple penalisation of redundancies: they often assimilate a change in tasks assigned to incumbent workers with a dismissal, so that a court may rule out such changes. Because of such practices, not only specialisation in new technologies is discouraged, but also their use as an input for firms producing other types of goods.

[4] Indeed, the Global Entrepreneurship Monitor (2000) finds a positive correlation between the level of IT infrastructure and entrepreneurship, although the causality is unclear.

More fundamentally, labour market regulation distorts the pattern of comparative advantage away from new, high-tech goods and in favour of mature, low-tech or medium-tech goods (Saint-Paul, 1997, 2001). The reason is that demand is more volatile at earlier stages of the product life cycle, as has been found by studies of turnover (Dunne et al., 1990, Davis and Haltiwanger, 1992). Given that employment protection increases the true cost of labour by an amount which is the greater, the greater the likelihood that the job will be destroyed, they penalize young firms and industries more than mature ones. Figure 5.1 below illustrates this argument by depicting the cost of producing a good as a function of its age, for a "rigid" (heavily regulated) country and a flexible one.

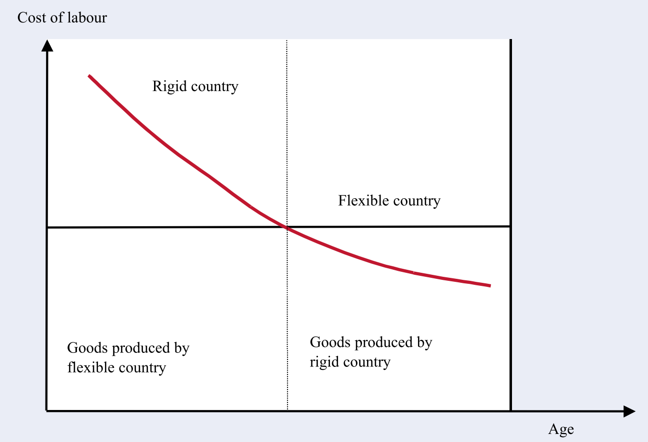
Because volatility falls with age, so does the cost of labour in the rigid country, whereas it does not depend on volatility in the flexible one. Consequently, the rigid country will specialise in goods that are at a mature stage of their life cycle, and the flexible country will specialise in young goods. The welfare consequences of this pattern need not harm the rigid country; but they will if specialising in young goods implies a bigger growth potential in the long run.

Yet if this is the right explanation, why is it that small Nordic countries have managed to keep pace to the United States in high technology, despite the fact that dismissal costs there are comparable with those prevailing in Continental Europe? One possible explanation is that they have designed alternative adjustment devices, such as active labour market policies.

Finally, another institution which may have played a role is the *Educational System*. While an even greater proportion of people go to college in the United States than in Europe, at the doctoral level the US system is far more elitist and engages in much more cutting-edge research. US universities spend considerable resources on screening applicants and attracting the best students. They develop an adequate reward structure by waiving tuition fees and offering grants to good students. During their studies, graduate students are subjected to intense training which puts them at the frontier of research. At the level of recruitment of assistant professors, the best candidates – who are identified by word-of-mouth – receive special treatment, getting substantially higher pay and research money as well as a reduction in teaching loads. In contrast, in most European countries the system makes little distinction between excellent and average students and excellent and average researchers; wages and working conditions are mediocre and identical for all of them; they typically depend little on achievements. The end result is not surprising: mediocre and average researchers stay, while many of the best emigrate to the United States. In our view, this can only be solved in the long run if the reward structure for knowledge producers is altered, bringing it more in line with the US system, or with the competitive system of professional sportsmen and artists – the best of the latter, incidentally, are typically rewarded very well by the taxpayer, and this is not seen as a problem.

Figure 5.1

SPECIALIZATION AS AN OUTCOME OF DIFFERENTIAL DEPENDENCE OF LABOUR COSTS ON PRODUCT MATURITY



Another set of explanations, however, downplays the role of institutions and ascribes most of the differences in technology between Europe and the United States to differences in factor endowment. In particular, Beaudry and Green (2000) have argued that a greater endowment of physical capital relative to human capital implies a greater specialisation in the "old" technology if, relative to it, the new technology is more intensive in human capital relative to physical capital. According to that view, the lower adoption of new information technology in Europe is simply the outcome of its relative abundance of physical capital, which itself comes from a higher savings rate over several decades as well as a lower population inflow due to migration. There is no *a priori* reason to worry about this, since greater abundance of capital harms no one. Furthermore, if this explanation is to be believed, one good side-effect of greater capital abundance is that Europe has avoided the sharp rise in inequality which was observed in the United States. For example, while in the United States real wages for men with ten to twelve years of education have fallen by 20 per cent since 1980, they have risen by 10 per cent in Germany.

On the other hand, the same phenomenon may be observed in technology adoption and inequality if instead of having more physical capital than the United States, Europe has less human capital.

In order to see whether factor endowments have followed divergent trends on the two sides of the Atlantic, we look at trends in physical and human capital. Table 5.10 compares the evolution of human capital, as measured by average years of education of the population, between the United States, France and Germany. In all countries it follows an upward trend, but Europe remains clearly behind the United States. If college graduates have an advantage at learning and using new technologies, improvements in US educational levels, which were associated with a rise in the proportion of college graduates, favoured IT adoption and specialisation much more than improvements in European levels, which were more associated with an increase in the proportion of high school graduates.

This hypothesis is all the more interesting since Nordic countries, which stand out as an exception to the European deficit in IT adoption, have educational levels more similar to the United States than to French and German levels, as is shown in Table 5.11:

Table 5.10

Average years of education

Period	France	Germany	USA
1960	5.78	8.28	8.66
1965	5.86	8.25	9.25
1970	5.86	8.27	9.79
1975	6.08	7.73	10.01
1980	6.77	8.41	11.91
1985	7.31	8.98	11.71
1990	7.56	9.06	12
1995	7.94	9.57	12.18
2000	8.37	9.75	12.25

Source: Barro-Lee Data Set.

Table 5.11

Average years of education

Period	Finland	Norway	Sweden
1960	5.37	6.11	7.65
1965	5.78	6.18	7.66
1970	6.5	7.36	7.47
1975	7.23	7.71	8.44
1980	8.33	8.28	9.47
1985	7.95	8.4	9.22
1990	9.48	10.85	9.57
1995	9.82	11.82	11.23
2000	10.14	11.86	11.36

Source: Barro-Lee Data Set.

Admittedly, differences in years of schooling do not take into account differences in educational quality. In order to have an idea of that we can look at educational achievements. Table 5.12 compares test scores between the United States, France and Germany:

This table suggests that there is no significant difference for 13 year-old students, although the 1972 science study suggests a substantially lower achievement in the United States. But a subsequent study, limited to the United States only, revealed a sharp improvement, so that there is reason to believe that the United States has improved its educational achievement since then.

To summarise: there is no *a priori* reason that differences in school quality are strong enough to overturn the conclusion that the United States has a larger stock of human capital per capita. While all three countries have accumulated human capital, the United States may well have ended up in a zone where it has reinforced its comparative advantage in high technologies.

Table 5.12

Test scores

Subject/year	France	Germany	USA
Math, 1993–98, 13 yr.	49.2	48.4	47.6
Science, 1970–72, 17 yr.	30.5	44.8	22.8
Science, 1993–98, 13 yr.	45.1	49.9	50.8
Reading, 1990–91, 13 yr.	54.9	52.2	53.5
Average score in cross-country comparable proficiency tests.			

Source: Barro-Lee Data Set.

Table 5.13

Capital intensity

	USA	France	Germany
K/L, 1975	26.1	24.2	36.9
K/L, 1990	34.7	35.6	50.1
Growth rate %	32	47	36

Source: Barro-Lee Data Set.

Turning now to physical capital intensity, Table 5.13 reports capital/labour ratios. These data are somewhat consistent with the view that physical capital abundance deters adoption of new information technologies, since production in Germany is more capital-intensive than in the United States, while the capital/labour ratio rose faster in France than in the United States, leading it to overtake the United States.

This discussion suggests that differences in factor endowments have played a significant role in explaining differences in technology levels across the Atlantic. This being said, despite the "Nordic exception", we are reluctant to dismiss the view that excess regulation is harmful for growth and innovation. The differences in entrepreneurial activity, for example, are large and appear in all sectors. It is hard to explain them as just a consequence of the fact that Europe uses the old technologies more. And regulation certainly has to do with the fact that while their high education level and small size has induced Nordic countries to specialise in IT, they have not managed to grow at the same rate as the United States in recent years.

Finally, the strong slowdown in the United States in 2001 raises the question of whether the IT boom will have any long-lasting effect at all. We believe that it will. New technologies are not introduced smoothly and can be subject to business cycles if they lead to excess investment followed by a brutal adjustment. But they can still have long-run effects, and countries that invest heavily in a technology may well end up with a permanent productivity bonus relative to others, as well as a comparative advantage in using and improving such technology.

6. Conclusion and Recommendations

The preceding analysis suggests that the following reforms would help in fighting the productivity deficit that Europe seems to have accumulated since the 1990s:

1. Proceed further with the introduction of competition in the telecom market, as we have seen that higher access prices are strongly correlated with lower IT penetration.
2. Develop incentives in terms of financial rewards and working conditions for top researchers to remain in European universities. This implies introducing a competitive labour market for such positions and an incentive structure for universities to engage in high level research.
3. While labour market reform is a wider issue that cannot be dealt with independently of the welfare state (see Chapter six), before a social consensus is reached on this issue, it is worth considering the introduction of exemptions to labour regulation (e.g. dismissal costs and working hours) for start-up firms in selected high-tech industries.
4. One should investigate the reasons for the underdevelopment of venture capital markets in Europe and remove them. If it is due to investors having wrong expectations about the future prospects for such markets, one could consider a co-ordinated move to escape from this expectational trap.

References

Autor, David, Frank Levy, and Richard Murnane (2001) "The Skill Content of Recent Technological Change: an Empirical Exploration", NBER Working Paper 8337, June.

Barro-Lee Data Set, www.worldbank.org/research/growth/ddbarle2.htm.

Beaudry, Paul and David Green (2000) "The Changing Structure of Wages in the US and Germany: What Explains the Differences?", NBER Working Paper 7697, May.

Butler, Alison (1992) "Is the United States Losing its Dominance in High Technology Industries", *Federal Reserve Bank of Saint Louis Review*, 74, 19–34.

Caselli, Francesco (1999) "Technological Revolutions", *American Economic Review*, 89, 78–102.

Cohen, Daniel and Michèle Debonneuil (2001) "L'Economie de la nouvelle e-conomie", mimeo, Conseil d'Analyse Economique, June.

Davis, Steven and John Haltiwanger (1992) "Gross Job Creation, Gross Job Destruction, and Employment Reallocation," *Quarterly Journal of Economics*, 107, 819–64.

Dunne, Timothy, M. Roberts and L. Samuelson (1989) "The Growth and Failure of US Manufacturing Plants", *Quarterly Journal of Economics*, 104, 671–98.

Doms, Mark, Timothy Dunne, and Kenneth R. Troske (1997) "Workers, Wages and Technology",' *Quarterly Journal of Economics*, 112, 253–90.

Greenwood, J. and M. Yorukoglu (1997) "1974", *Carnegie-Rochester Conference Series on Public Policy*, 46, 49–95.

Hobijn, B. and B. Jovanovic (2000) "The IT Revolution and the Stock Market: Evidence", NBER Working Paper 7684, May.

Jorgenson, Dale (2001) "Information Technology and the U.S. Economy", *American Economic Review,* 91, 1–32.

Kravis, Irving and Robert Lipsey (1992) "Sources of Competitiveness of the United States and its Multinational Firms", *Review of Economics and Statistics,* 74(2), 193–201

OECD (2001) *Economic Outlook*.

OECD (2000) *Measuring the ICT Sector.*

OECD (1998) *The Software Sector: A Statistical Profile for Selected OECD Countries.*

OECD (2000) *Statistical Compendium*.

OECD (1999) *Telecommunication Database* (CD-ROM).

Office de la Science et de la Technologie (1997) *Cartes sur table.*

Oliver, Stephen D. and Daniel E. Sichel (2000), "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story", *Journal of Economic Perspectives,* 14(4), 3–22.

Pagano, Marco (1993) "The Flotation of Companies on the Stock Market: a Coordination Failure Model", *European Economic Review,* 37, 1101–25.

Reynolds, Paul, et al. (1999,2000) *Global Entrepreneurship Monitor.*

Saint-Paul, Gilles (1997) "Is Labour Rigidity Harming Europe's Competitiveness? The Effect of Job Protection on the Pattern of Trade and Welfare", *European Economic Review,* 41, 499–506.

Saint-Paul, Gilles (2001) "Employment Protection, Innovation, and International Specialization", forthcoming, *European Economic Review.*

Shimer, R. (1998) "Why is the US unemployment rate so much lower," *NBER Macroeconomics Annual.*

WestLB Panmure (2001) www.westlbpanmure.com/publications/viewpoint4/next_economy.htm.

Wolfson, Michael C. and Brian B. Murphy (1998) "New Views on Inequality Trends in Canada and the United States", *Monthly Labour Review,* April.