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European economic growth: The impact of new technologies

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Cahiers Papers

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Cahiers Papers

European economic growth: The impact of new technologies



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Preface

The subject of this year's conference in economics and finance is the impact of new technologies on economic growth. As has been recognised by the EU Council at its meetings in Lisbon and Feira last year, this is a topic that may be of critical importance for Europe in the coming years.

Clearly, we must start by understanding the role of Information and Communication Technologies within advanced industrial economies. The evidence that there may be a strong link between investment in ICT and economic growth still largely comes from the United States, which has enjoyed one of its longest economic expansions in history at the same time as these new technologies have been adopted on an unprecedented scale. Part of the economic expansion in the US is a direct result of massive investment in ICT. But an investment boom must eventually fade and this alone is no source of permanently higher growth. The real question we need to answer is whether the ICT capital stock may also boost economic growth through positive spillover effects, through changing the ways in which we organise and conduct business. Thus, we must start by understanding the economic implications of the shift to investment in ICT that has occurred in recent years. Is it true that the "new economy" is fundamentally different from the "old economy" that has provided us with our prosperity todate?

Though the US experience provides the most insights simply because the phenomenon started there, we need to focus the discussion on Europe. In particular, why does Europe appear to have lagged behind in the transition to the "information society"? Is Europe now catching up? From the Bank's perspective, it is not enough to conclude that the faster adoption of new technologies would lead to higher economic growth, if indeed that were the case. As a European institution, we also need to know whether there is a need for public policy intervention. Why is the market not properly functioning in this transformation?

A priori, I can think of three areas of possible market failure: one is due to the inadequate financing of small and medium-size companies if these are important players in the new economic environment; a second problem could come from insufficient research and development; and a third could be a lack of the right skills in the workforce resulting from weaknesses in education and training. There are good economic reasons why the market may not function efficiently in each of these three areas.



Philippe Maystadt

President

There is a possible additional issue for the EIB. Its main mission is to support regional development in Europe. To do this we need to understand how Information and Communications Technologies affect economic growth and job creation across regions. The impacts could be considerable. For example, if the new economy were to boost growth only in a few metropolitan centres and technological clusters, then new technologies would be associated with increased income inequality. On the other hand ICT has also been associated with the "death of distance" and a more uniform distribution of certain types of economic activity and new business opportunities in remote areas. Thus, we must ask whether it is possible to implement new technologies in such a way that the growth benefits are more evenly spread across regions. Should regional development include the support for certain types of ICT related business activity? All these questions relate directly to the type of investment that should be supported by institutions such as the EIB.

Finally, the EIB is a bank. It needs to understand how the ICT revolution will affect its own operations, both on the lending and the borrowing side. New technologies have played a crucial part in the globalisation of the financial industry, and this process is far from over. We must understand how new technologies coupled with the rapid development of capital markets in Europe will affect the financial environment in which the EIB operates, and how our institution should adapt to these changes.

These are major questions, and it may be that the past gives us little insight into the longer term consequences of new technologies. When electricity was first introduced, one could have hardly imagined the series of innovations that have subsequently emerged, including the invention of the modern computer itself. Perhaps the future will see the creation of a whole series of new information related goods and services. However, we should start by focusing a little closer in the future. We should ask how European policy should evolve in the light of our new knowledge and how the Bank's own strategy should evolve in the coming years. This volume is intended to stimulate that debate.

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European economic growth: The impact of new technologies

A conference on the prospects for a new economy in Europe was held at the EIB on 18 January, 2001. The conference covered recent macroeconomic developments in the US and the EU, a review of the adoption of new technologies in Europe, the financing needs of new innovative start-up companies, and an assessment of the consequences of Information and Communications Technologies for employment and regional development.

Speakers included:



Paul David, of All Souls College, Oxford University

Andrew Gillespie, of the University of Newcastle

Hermann Hauser, of AMADEUS, Cambridge

Pierre Montagnier, of the OECD, Paris

Luc Soete, of Maastricht University

Kristian Uppenberg, of the EIB

Robert Verrue, Director General, Information Society DG, European Commission Bernard de Longevialle, of Standard & Poor's, Milan

Harald Gruber, of the EIB

Philippe Maystadt, President of the EIB

Danny Quah, of the London School of Economics

Bas ter Weel, of Maastricht Economic Research Unit on Innovation and Technology

Patrick Vanhoudt, of the EIB

EUROPEAN INVESTMENT BANK

Wonders will never cease: Prospects for a new economy in Europe

Computers can figure out all kinds of problems, except the things in the world that just don't add up. James Magary



Christopher Hurst



Kristian Uppenberg

1. Introduction

The late 1990s saw one of the most rapid diffusions of a new technology seen in history. Within the space of 5 years the number of Internet users reached 50 million. This compares with the 13 years required by TV to reach the same number of users in the 1950s and 1960s, and the 40 years that radio took in the first half of the 20th century.

Coupled with the rapid spread of Internet came a speculative bubble in high-tech companies. Throughout the last five years of the 1990s, some USD 150 billion were raised by US Internetrelated companies via venture capital injections and IPOs. It has now become the common view that much of this was a transfer of wealth from foolish investors to the staff of "dot-coms", and the customers and advisors of these companies, rather than investment properly said. However, at the time it seemed that a new industrial revolution was underway.

At the same time, the US economy set its own record, by continuing strong growth long after the "normal" business cycle. Could there be special reasons why new records were being set? It did not take a genius to put these two factors together and to conclude that a "new economy" based upon information technology, and particularly the Internet, had arrived.

Interestingly, more detailed analysis does show a remarkable turnabout in the productivity of the US economy during in the late1990s. There seems to have been something more going on than "irrational exuberance" by investors and the creation of a new pastime of Internet surfing. Section 2 explores this literature in more detail. The focus here, and in the rest of this paper is on the possible consequences of information and communications technologies (ICT) on long-term productivity growth. We largely put to one side the many other possible dimensions of a new economy that have arisen in the public debate, including a less volatile business cycle and higher future corporate profitability. Specifically, we view the core of the matter as whether investment in these technologies can boost medium-to-long-term growth prospects, even if they do nothing to prevent future economic or financial volatility. Just as the surge in stock prices or the wealth-driven consumption boom of the 1990s may have contained little tangible evidence of our definition of a "new economy," so their reversal is equally incapable of refuting it.

The macroeconomic evidence does suggest that ICT has played an important role in boosting US productivity. However, both the size of the impact and the extent to which it is spread through the economy depend upon a number of assumptions. The phenomenon is simply too short-lived for there to be adequate data to definitively identity the impact of ICT investment. Therefore, in Section 3 we turn to microeconomic reasoning on the likely impact of ICT on firms. While comparisons with the great inventions of the past goes too far, the conclusion is that ICT does appear to have the potential

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to make a significant contribution to economic growth over the medium-term, though only when a certain number of conditions are met.

The focus here is on the possible consequences of ICT on long-term growth, rather than the many other possible dimensions of a new economy. Thus, we turn our attention to Europe and ask where the continent stands in the adoption of these technologies. Section 4 addresses this issue. In general, we find a number of causes for concern. While there are certainly some market segments where European companies perform well, it seems unlikely that EU ICT production will generate the same kind of contribution to overall growth as that seen in the US. For the economy as a whole there is also a question of the optimal structure of investment. Europe is investing relatively more in telecoms than the US, but is spending substantially less on information technology (IT).

However, talking of Europe as one economic mass hides large differences between countries, some of which seem to have as "new" economies as the US. While large regional differences also exist within the US, we believe this topic merits particular reflection in the case of EU, not least because differences among EU regions are largely addressed via transfers of one form or another to support investment - including ICT (1). Section 5 addresses the question of what ICT means for the geographical distribution of economic activity. Will we see the "death of distance" or highly concentrated clusters of economic activity?

Unequal performance within Europe, and between Europe and the US is also due to a number of institutional factors that influence the rate of innovation in an economy and the extent to which it can exploit new ideas to the fullest. Section 6 briefly explores some of these issues, including computer-related skills, the functioning of labour markets, and the financing of innovative start-up companies.

Finally, section 7 concludes with a summary the main lessons we have learnt from this exercise.

2. Macroeconomic evidence of a new economy in the United States

2.1 The growth in US labour productivity in the 1990s

Let us start with a brief recap of the recent performance of the US economy. After an unspectacular recovery from recession at the beginning of the decade, the US economy gained momentum in the second half of the 1990s. Real GDP growth accelerated from 2.4% on average in 1991-95 to 3.9% in 1996-2000. While the low unemployment rate is an impressive feature of the US economy, it is nevertheless not a key element in the acceleration of US growth in recent years. Average annual employment growth did accelerate from 1.0% in 1991-95 to 1.6% in 1996-2000, but this figure remains below the averages for previous decades (2). Rather than employment growth, the key element behind higher economic growth in the second half of the 1990s is output per man-hour worked, i.e. labour productivity. In the business sector of the economy, labour productivity growth accelerated from 1.5% annually in 1991-95 to 3.3% in 1996-2000. The paper by David (this volume), gives some more detail on the evolution of GDP and labour productivity growth in the US in recent decades.

See Volume 5, Number 1, of the EIB Papers for more discussion of European regional development policy.
 Average annual civilian employment growth in fact slowed from 2.4% in the 1970s, to 1.8% in the 1980s and 1.3% in the 1990s.

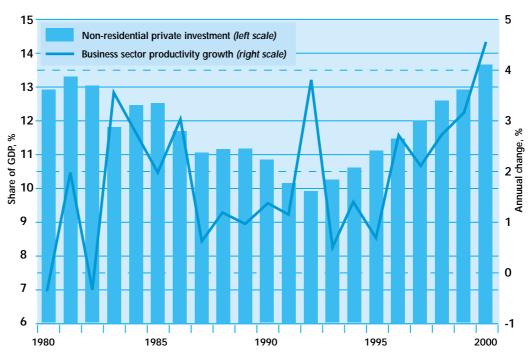


Figure 1. US labour productivity growth in the business sector and private investment as a share of GDP

As suggested by Figure 1, part of this acceleration is the result of an extraordinary rise in private non-residential investment. This increased in nominal terms from around 10% of GDP at the beginning of the decade to 14% in 2000. The link from capital formation to productivity is straightforward, as the instalment of new machinery and equipment makes it possible for any given number of workers to produce more output. If capital formation is expanded at a faster rate than employment, the ratio of capital to labour increases. This is also known as capital deepening.

Part of the acceleration in US labour productivity growth is the result of an extraordinary rise in private non-residential investment. IT has accounted for much of this. Figure 2 shows that investment in IT (as reported by the US Bureau of Economic Analysis - note that following normal US practice here we talk mainly of IT, excluding some communications) has accounted for most of the increase in non-residential investment in recent years (3). Thus, much of the capital deepening in this period must also have been due to IT equipment.

These two pieces of evidence are key to the notion that there is something "new" about the US economy in the second half of the 1990s; however, they are not enough to justify talk of a new economy, since an investment boom can also be fuelled by temporary factors. For example, the replacement of computer systems due to the Y2K bug may have stimulated IT investment. More generally, the 1990s has seen a shift from wages towards corporate profits which, combined with higher leverage, has fuelled corporate investment. Whether these factors will be sustained in the medium-term remains uncertain. A stronger sign that the US economy's growth potential has permanently improved lies rather with total factor productivity (TFP).

3) The figure shows a nominal ratio. In real terms, the rise in both total and IT investment is more dramatic as a result of the decline in the price on IT equipment. This is discussed further in a later section.

Source: Council of Economic Advisers (2001)

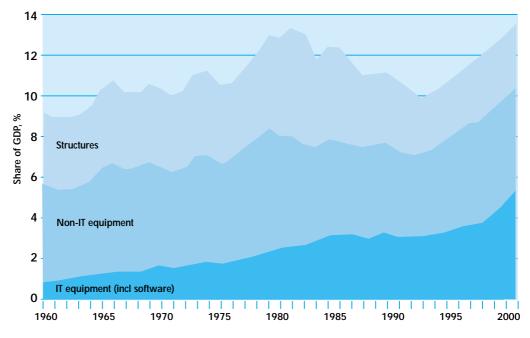


Figure 2. The structure of business investment in the US

Source: Council of Economic Advisers (2001)

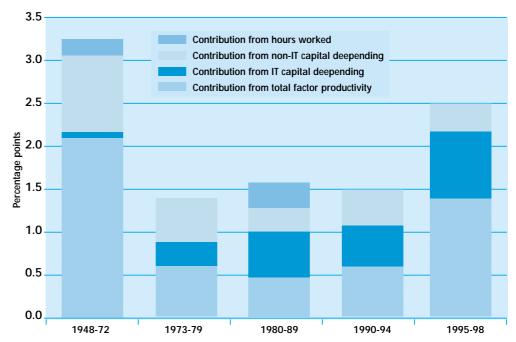
2.2 Sources of US labour productivity growth

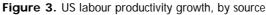
The surge in total factor productivity in the late 1990s

In the neoclassical growth model, output is a function of capital, labour and TFP. Since all these variables except TFP can be observed, the growth equation can, under some simplified assumptions, be inverted to produce TFP as a residual (see Quah, and Vanhoudt and Onorante, both in this volume). By definition, TFP is that part of output that cannot be directly inferred from increases in the quantities of capital and labour inputs, and thus refers to the quality of these inputs and how well they are being used in the economy. There are many ways in which a better utilisation of factors of production can be attained. For example, a more skilled labour force is likely to make more productive use of any given amount of hours worked. New knowledge from R&D is likely to increase TFP growth in a similar way. So long as human capital and knowledge are not included specifically as factors of production in the growth equation, they will instead boost the TFP residual.

Economists seem to have reached an uneasy consensus that the increased production and diffusion of ICT is a key element behind the rebound in TFP growth in the late 1990s. Figure 3 shows the results of one such growth accounting exercise. It documents more explicitly how US labour productivity growth has very much been an IT capital deepening story, while the contribution from capital deepening in other equipment and infrastructure peters away to nothing throughout the 1990s. Figure 3 also shows how the long period of poor TFP growth from 1973 onwards was suddenly reversed in the mid-1990s. Although the historical puzzle around the post-1973 slowdown has remained unresolved, the rebound since 1995 does appear to have an explanation. Economists who have investigated the matter seem to have reached an uneasy consensus that the increased production and diffusion of IT is a key element.

A handful of papers have taken centre stage in this debate in the past year, the main results of which we report in Table 1. While adopting somewhat similar growth-accounting approaches, there are also some important differences that make comparisons less than straightforward. For example, Oliner and Sichel (2000), use data for private non-farm business GDP, while Jorgensen and Stiroh (2000), use data for private domestic output. Still, the two papers come to similar explanations for the increase in productivity: IT capital deepening dominates that of other equipment and structures. However, TFP growth is even more important than capital deepening, and this comes from both IT producing and using sectors. A third study by the Council of Economic Advisers (2001), concludes even more strongly that IT capital deepening and TFP growth in IT using sectors are by far the main factors at play. These results are encouraging for those who believe that IT is revolutionising the way economic activity is conducted, since it suggests that IT leads to positive spillovers throughout the economy.





However, at the opposite end of this debate, a fourth paper by Gordon (2000), attributes the entire contribution of TFP to the acceleration in productivity in the IT-producing sectors of the economy. This implies that it is only the manufacture of computers that has benefited from great technical advances, with little evidence of positive spillovers from the <u>use</u> of IT in the rest of the economy.

The stark contrast between Gordon's results and those of the other papers largely stem from how the data is adjusted for cyclical fluctuations. The growth accounting framework assumes the economy is always working at full output. However, this is clearly not the case as the economy moves through the business cycle (4). This can be corrected by averaging data over long periods -

Source: US Bureau of Labor Statistics

⁴⁾ David (this volume) provides the additional insight that ICT could have boosted the pro-cyclical nature of productivity growth, both by improving inventory management during the cyclical upswing, and because the sector itself is associated with substantial economies of scale.

long enough to capture an entire business cycle. The problem is that the break in the pattern of productivity is only observable for a relatively short period after 1995. Neither Jorgenson and Stiroh nor Oliner and Sichel have taken cyclical factors into consideration in their analyses. Gordon, on the other hand, has assumed that the current business cycle displays a pattern similar to earlier expansions. Following this assumption, he concludes that as much as 0.5 percentage points of the acceleration in labour productivity growth is cyclical. The Council of Economic Advisers also accounts for cyclical fluctuations, but with a methodology that yields more upbeat conclusions than Gordon. Unfortunately, this controversy is likely to remain unresolved until the economic expansion has fully run its course, the truth probably lying somewhere in between (5).

	1	0.1		
	Jorgenson	Oliner	Council of	Gordon
	& Stiroh	& Sichel	Economic	
			Advisers	
	1990-95/	1990-95/	1973-95/	1972-95/
	1995-98	1995-99	1995-00	1995-99
Acceleration in labour productivity growth	0,9	1,0	1,6	1,3
of which:				
Capital deepening	0,3	0,5	0,4	0,3
- IT capital deepening	0,2	0,5	0,6	n.a.
- Non-IT capital deepening	0,1	0,0	-0,2	n.a.
Labour quality	-0,1	-0,1	0,0	0,1
Total factor productivity	0,7	0,7	1,2	0,3
- Production of IT goods	0,2	0,3	0,2	0,3
- Other sectors	0,5	0,4	1,0	0,0
All other factors, including cyclical adjustments	n.a.	n.a.	0,0	0,6

Table 1. Sources of the acceleration of US labour productivity growth in percentage points

Source: Council of Economic Advisers (2001); Gordon (2000); Jorgenson and Stiroh (2000); Oliner and Sichel (2000). Differences are due to rounding

Measurement problems

Apart from cyclical factors, a number of measurement issues also risk distorting the picture. Apart from cyclical factors, a number of measurement issues also risk to distort the picture. Productivity estimates are calculated using real output and input data, i.e. nominal figures deflated by a price index. This exercise is straightforward for products that do not change much over time, but becomes problematic when the rate of quality improvement is rapid. To address these problems, the United States has since 1996 applied quality-adjusted - or "hedonic" - pricing when deflating nominal IT output and investment to obtain real volumes (see Vanhoudt and Onorante, this volume). Instead of deflating nominal computer output data by an average computer price index, the hedonic price deflator is adjusted for changes in a number of performance-related characteristics, such as

5) The quarterly variation in business cycles is large enough to support all sorts of patterns; however, the smoothed business cycle in the US in the 1990s does show a different pattern from the historical average (see, for example, Schweitzer, 1998).

memory size and speed. As a result of rapid technical progress in the manufacturing of semiconductors, this hedonic price index has been falling at a rapid pace (at over 25% annually) in recent years. When this price index is used to deflate nominal IT output, real output growth is boosted accordingly. Since the amount of labour going into the manufacture of computers is growing at a much lower pace, such rapid growth in real output also generates high labour productivity growth.

Given that the usefulness of computers is determined by their computing capacity, the shift to hedonic pricing has improved the accuracy of how the real economy is measured. Nevertheless, there are unresolved questions as to how well the technical performance of computers reflects their economic value. For example, if computers are at least partially used for tasks that do not depend on their improved capacity (such as word processing and e-mail), then the shift to hedonic pricing may exaggerate investment. In other words, the future revenue stream from computer purchases may not be related to quality of the equipment bought. Vanhoudt and Onorante (this volume) show how changing from an average price index to hedonic index boosts both investment and estimates of TFP growth. On the other hand, quality improvements in in-house software are not treated in a hedonic way, so the benefits of improvements here are not captured.

In fact, this debate soon arrives at more general measurement issues. For example, both Jorgensen and Sichel (2000) and the US Commerce Department's *Digital Economy 2000* show that typically IT intensive service sectors displayed much lower productivity growth in the 1990-97 period than less IT-intensive service industries. Here again measurement issues may be at play. Triplett and Bosworth (2000), for example, argue that IT investment may have created new forms of output that are not properly identified. In banking, for instance, ATM machines have made bank transactions easier and more readily available, while debit and credit cards have reduced the need to use cheques. To the extent that measures of bank output focus on traditional transactions, such as the number of cheques processed, bank output - and hence productivity - is being underestimated (6).

David (this volume), also argues that the personal computer aided a shift towards "mass customisation" and an increase in the number of new products in the 1980s. As official government price indices tend to miss the rapid fall in prices that occur early in the life of new products, there may have been a transitory downward bias in measured productivity growth between the mid-1970s and early 1990s (when this process seems to have come to a halt).

These questions are a useful reminder of just what a synthetic and indicative number GDP actually is. But where does that leave us as regards the existence, or not, of a new economy?

2.3 A final word from the macroeconomic data

Firstly, there is little doubt that capital deepening from computer investment played an important role in boosting US labour productivity. Secondly, there is broad agreement that the US economy experienced an increase in total factor productivity in the late 1990s. However, this can be whittled away to increased productivity in the production of computers alone under one set of assumptions,

If higher TFP growth is restricted to computer production, then there must be some unease that quality-based price indexing is overstating the value of computers.

⁶⁾ The US Commerce Department has tried to circumvent these measurement issues by excluding a number of hard-to-measure sectors. They then find in the remaining sectors that ITintensive services do exhibit higher productivity growth. The problem is that many of the excluded sectors are exactly those highly IT-intensive sectors where we would like to know what has happened (such as finance).

or boosted to an even larger and broad-based improvement under another set. If the gains are restricted to computer production, then there must be some unease that hedonic, quality-based, price indexing is overstating the value of computers that are being bought.

At the same time, the Council of Economic Advisers' more detailed sectoral analysis finds a notable acceleration in labour productivity growth in wholesale and retail trade (5 and 4 percentage points, respectively). These are sectors where companies have invested heavily in IT in recent years, accompanied by a wave of reorganisation and restructuring. Can it really be that IT investment has not been a critical factor in increasing productivity here? The next section turns to microeconomics and company experience to see if more insights can be gained at this level of analysis.

3. How has IT influenced firms?

3.1 The pay-off from IT investment

Many reasons for the US slowdown in overall productivity growth after 1973 have been advanced, including the oil shocks, inadequate public investment and a declining skill level in the work force. A curious factor was that computer investment - in mainframe computers in the 1970s, followed by the PC revolution in the 1980s - did not have a measurable positive impact on productivity growth until the mid-1990s.

David (1990, 1991, and this volume), suggests that the initial inability of computers to affect productivity growth could be because long adjustment periods are needed for an economy to fully benefit from a revolutionary new technology (7).

David uses the example of the electrical dynamo to illustrate this. Before the dynamo, factories run by the steam engine were constrained by the fact that production had to be concentrated in the engine's immediate vicinity. This imposed limitations on the productivity of the manufacturing process. Production and assembly of components often could not be organised sequentially, leading to costly waiting periods, large stocks and the constant reallocation of intermediate goods within the factory. The electrical dynamo revolutionised production by allowing a larger number of smaller engines to be scattered throughout the factory. The great productivity gains from introducing the dynamo thus came not from the fact that electrical engines were necessarily faster or stronger than steam engines, but that they facilitated more efficient organisation of the work. Unsurprisingly, it took decades for factories to be reorganised and for the full gains to be realised, but there was an overall surge in productivity growth once a certain critical mass was passed (8).

David argues that there are parallels between the interconnection of electric motors through wired grids - and the associated transformation of manufacturing practices - and the interconnection of computers via communications networks. That the capacity to process information has a major

Long adjustment periods are needed for an economy to fully benefit from a revolutionary "general purpose technology". The example of the electrical dynamo illustrates this.

⁷⁾ Bresnahan and Trajtenberg (1995), have introduced the concept of "general purpose technologies" in this context. 8) Though the electrical generator was introduced by Edison in 1881, older technologies continued to dominate factories well into the early 1900s. In fact, the new electric power technology only gained momentum after the First World War, when major investment in power plants and transmission capacity produced rapid efficiency gains in electricity generation. The impact on productivity growth from around 1920 and onwards was substantial. David estimates that the acceleration in labour productivity growth in the US manufacturing industry, from 1.5% annually in 1899-1914 to 5.1% in 1919-29, was largely accounted for by higher TFP growth.

impact on business structures fits in with a long line of research on transaction costs as the determinant of optimal organisations (Williamson, 1981). For example, it has been argued that the traditional hierarchical business structure that emerged in the early 20th century was a way of minimising the number of communications links within an organisation (Malone, 1987, and Radner, 1993). Thus, the substantially lower cost of information and communications has increased the scope to outsource some activities, and has shifted the optimal organisation from one of vertical command towards laterally linked groups (see, for example, Lipsey, 1999).

A number of empirical studies do identify a positive correlation between IT investment and firm profits. For example, Brynjolfsson and Yang (1999), show (9) that the stock market values investment in IT capital by a factor of 10. This finding does not imply that there is a 10-to-1 payoff from IT investment, but rather that the firm that has a dollar of computers typically has another nine dollars of related intangibles assets. In line with this, Bresnahan, Brynjolfsson and Hitt (2000) show that skills, education, and greater use of delegated decision-making raises the value of IT investment. Thus, it is the combination of IT investment, organisational innovation and human capital investments that create the intangible assets that the stock market values so highly (10). One consequence of this is that IT may be a skill-biased technical change in the sense that the demand - and hence the wages - of skilled workers will increase relative to the unskilled. We return to this topic in Section 6 when institutional issues are briefly reviewed.

3.2 So what about the Internet?

The previous observations would suggest that it is a coincidence that the productivity gains from IT became visible at the same time (i.e. after 1995), that Internet use took off. These gains were instead the result of intra-firm organisational changes following IT investment in earlier periods.

Still, the Internet, as a major step in the diffusion of the interconnected computer network through the economy, is fully consistent with the model of the new economy set out above. The OECD (2000a) suggests that especially in business-to-business (B2B) relations, e-commerce technologies offer affordable solutions for many ubiquitous processes such as distribution, sales, after-sales service and inventory management. Importantly, such solutions are likely to become more cost-effective the more of a firm's suppliers and customers go on-line. To be effective, e-commerce technologies need to be applied all along the business value chain in an integrated fashion.

Though the figures are still very tentative, a number of estimates do show the potential for considerable reductions in costs across a wide range of sectors. For example, Goldman Sachs (1999), have estimated B2B e-commerce cost savings for the US economy, ranging from less than 15% in heavy industry, to 20-30% in services and traditional manufacturing and above 30% in electronics. Litan and Rivlan (2000), also report on a series of studies on cost savings from the use of the Internet. One of these studies uses the computer company Cisco Systems as a benchmark for manufacturing, and estimates that annual cost savings of between 1 and 2 percent per annum should be possible over the next 5 years for the manufacturing sector as a whole.

It is the combination of IT investment, organisational innovation, and human capital that creates the intangible assets that the stock market values so highly.

⁹⁾ With data for the Fortune 1000 firms over the 1987 to 1994 period.

¹⁰⁾ To return to measurement issues, Brynjolfsson and Hitt (2000), suggest that macro-level studies may have severely underestimated the benefits from investing in computers as intangible assets are poorly accounted for in the national accounts.

Even though over one-half of US households now have Internet access, the volume of business-toconsumer (B2C) e-commerce has remained relatively small, with about 1 percent of retail sales in the US taking place via the Internet. The additional profits from these B2C transactions with respect to traditional retail outlets are also likely to be relatively modest (11). Indeed, Gordon (2000), suggests that much of the higher spending on web sites by traditional retailers is simply motivated by the need to keep their customers from going to online competitors - a zero-sum game with no aggregate gains. On the other hand, there do seem to be a number of services where shifting large number of routine transactions from paper to a web based technology offers the potential for significant savings. Examples include insurance claims, tax payments, basic customer enquiries and the like. And part of the success of Dell Computers comes from the use of the web to attract customer orders, and to provide advice and technical support. From this, Dell has developed a customer-driven build-to-order business model that gives as much as 10 percent advantage over rivals in terms of production costs (Brynjolfsson and Hitt, 2000).

The Internet will considerably aid the spread of new business models for supply-chain management throughout the economy. The extent to which the Internet will generate wealth through the creation of completely new informationrelated goods and services remains to be seen. However, it seems safe to say that the Internet will considerably aid the spread of new business models for supply-chain management throughout the economy. It will act as an important catalyst for many of the changes we have mentioned before.

3.3 A few conclusions from the firm level on the benefits of IT

US firms have been investing heavily in IT in the last few years. To argue that this is nothing more than part of a high-tech bubble (12) appears to be taking new economy scepticism to the extreme. Could it really be the case that such huge IT spending is only the result of a herd instinct of managers to own the latest computer fad? While there may certainly have been inappropriate spending in some instances, firm-level studies show that large cost savings are possible from the use of IT. These benefits do not come from doing the same thing faster, but from using IT as the basis for organisational change and the introduction of new business models.

The comparison between this process and the introduction of electricity raises the hackles of IT sceptics (see, for example, Gordon, 2000), and it is perhaps too much to put IT in the same league as the great inventions of the past. As TFP growth in the US economy in the "era of electricity" (that is, from 1919 to 1929) was of the order of 2 percent per annum, it is also clear that it would be truly remarkable if the new economy were to deliver more than this on a sustained basis. Still, if the benefits from IT-motivated business restructuring are significant, and this effect diffuses steadily through the bulk of the economy, then there would be a sustained period of robust total factor productivity growth. For us, this is sufficient to be described as a new economy phenomenon, even though the impact on growth must eventually disappear when the entire economy is working with best practices (13).

¹¹⁾ To illustrate this point, Oliner and Sichel (2000), use the estimated 10% price difference on CDs between traditional and on-line retailers as a rough indication for the efficiency gains from e-commerce. Multiplying these savings with total online sales, they find that the total cost reductions amounted to only 0.2% of output in the nonfarm business economy in 1999. 12) For example, Stephen Roach, the Chief Economist of Morgan Stanley Dean Witter has put it in these terms: "Blind acceptance of every tantalising twist of the ITproduct cycle quickly became the norm in business circles. There was no rhyme or reason to ITbudgeting... America's binge on information technology outstripped any conceivable productivity pay back". (Financial Times, 15.02.2001).

¹³⁾ In other words the <u>permanent</u> increase in TFP growth required by Vanhoudt and Onorante (this volume), is perhaps too demanding a condition.

It is interesting to note that it is the US computer production industry itself that has been a leader in developing new IT related business models to manage supply and reduce inventory costs. As such, at least part of the productivity gains in US computer manufacture may be a sign of things to come elsewhere in the economy.

4. Prospects for a new economy emerging in Europe

4.1 European productivity growth in the 1990s

In stark contrast to the rebound in the United States, Europe has seen continued deceleration of productivity growth during the 1990s. How well has Europe done when compared to the American powerhouse? Unfortunately, and in stark contrast to the rebound in the United States, Europe has seen continued deceleration of productivity growth during the 1990s. Figure 4 shows how EU labour productivity slowed from around 2% in the first half of the 1990s to around 1.5% in the second half (14). This slowdown is largely due to weak investment growth in the EU. The European investment-to-GDP ratio was either falling or stagnant in each year between 1990 and 1997. As would be expected, the contribution from capital deepening (in all forms of capital) to labour productivity growth declined, from 1 percentage point in 1991-95 to 0.5 percentage points in 1995-1999.

In notable contrast to the United States, the contribution to labour productivity growth from TFP in Europe showed no major change throughout the 1990s. TFP growth during this decade, at 1.0 percent per annum, continued the decline during the previous three decades (from 1.2 percent per year in the 1980s, 1.8 percent per year in the 1970s, and 3.0 percent per year in 1960s) to arrive at the same low level as that seen in US during the 1973-1995 period (15).

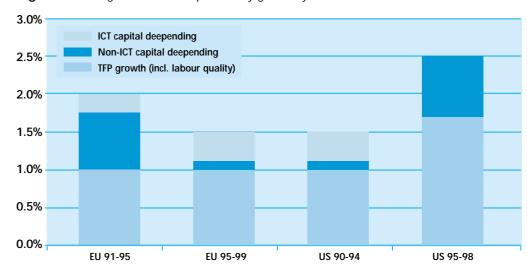


Figure 4. Average annual labour productivity growth by source

Source: European Commission (2000a), US Bureau of Labor Statistics

15) It should be noted that part of the growth in labour productivity in Europe (i.e. of those in work) in earlier decades came from an increase in unemployment - essentially by downsizing or shutting down the least productive companies.

¹⁴⁾ Figure 4 is only indicative in that it is based on a growth accounting exercise with GDP data for the EU (by the European Commission) and data on the private sector for the United States (by the Bureau of Labor Statistics). While the two calculations are not fully comparable, GDP data for the United States suggest that the differences arising from using these different measures are small.

Measurement issues complicate comparisons

If measurement issues meant that interpreting US GDP data was open to debate, international comparisons are even more problematic. The US adopted a new system of national accounts in 1999, and also revised historical data according to the new rules. One key aspect of this shift in definition was that software outlays were counted as investment rather than current expenditures, thus adding directly to GDP. A second change introduced in the United States was the shift towards the hedonic, quality related, price indices we mentioned before. These changes, both of which boosted real GDP growth, were partially offset by the introduction of chain-weighted price indices, where no single year is used as a base-year for the deflator. This has tended to reduce the growth rate of GDP, especially in economies experiencing large shifts in the composition of the economy, such as the United States. Adding these elements together, Seskin (1999) has estimated that the shift to new ways of measuring the US economy has boosted real GDP by 0.4 percentage points on average in 1992-98.

The EU has also followed the recommendations of the new international accounting standard, but has been slower than the United States in implementing the changes. For example, European software expenditures are also supposed to be counted as investment, but in practice the incomplete collection of such data has forced statistical agencies to rely on highly uncertain estimates when aggregating GDP data. In addition, only a few EU countries have begun using hedonic pricing for ICT goods (in line with normal European practice we revert to using the general expression of information and communications technologies, unless we specifically wish to make a distinction between the IT and communications sub-components).

Significantly better US productivity growth is likely to remain, even if the data could be accurately adjusted for measurement differences. The different pace with which all these changes are being introduced means that the difference in labour productivity seen in Figure 4 is likely to be exaggerated. Stripping out the contribution of software investment and hedonic pricing from the official data, Vanhoudt and Onorante (this volume), show that the difference between US and EU productivity shrinks substantially (i.e. the US estimate drops towards the EU level). However, this is an over-correction. Significantly better US productivity growth is likely to remain, even if the data could be accurately adjusted for measurement differences.

Capital deepening - estimates of the role of ICT

If - going the opposite direction from Vanhoudt and Onorante - it is assumed that US hedonic pricing is correct and that the relative decline of the (quality-adjusted) price of ICT in the US has been the same everywhere, then an estimate for real ICT investment in Europe can be generated. From this, it is possible to split capital deepening into a contribution from traditional equipment and structures, and a contribution from new ICT technologies. The results of one such exercise (by the European Commission, 2000a) was included in Figure 4 (16). It is striking how similar the EU of the late 1990s is to the US of the early 1990s. While ICT capital deepening accelerated in Europe in the late 1990s, its contribution to labour productivity remained only about half the figure seen in the United

¹⁶⁾ Additionally, it is necessary to assume a rate of return on ICT capital (set at the real interest rate in this particular calculation), and an assumed elasticity of substitution for ICTcapital goods is needed to calculate the growth of the ICTcapital stock in earlier periods when annual investment data is not available (the Commission develops two scenarios with an elasticity of 1.0 and 1.5: Figure 5 is based upon the latter number). Similar studies have been performed by Schreyer (2000), and Daveri (2000). Note that in Figure 4 the contribution of ICT capital deepening was simply subtracted from the total for capital deepening estimated with national account data.

States during the same period. Interestingly, nearly all capital deepening in Europe comes from ICT, other investment only being sufficient to balance the depreciation of the existing capital stock.

However, the EU average hides substantial diversity across countries. Figure 5 shows that the contribution to GDP growth from ICT capital deepening has been much lower in the large continental economies (and in the Mediterranean) than in the US. The gap with the US is closed substantially in some other countries (such as the Sweden, the Netherlands, the UK and Finland), while Ireland is off the scale.

These estimates are likely to be overestimates, as the assumption that price declines in Europe have matched those in the US is overly optimistic. For example, Gruber (this volume), illustrates how the price of a particular computer converges to the same level in both the US and EU, but how there may be a large difference in the first year of introduction. These initial differences are important when the composition of equipment is changing rapidly. Indeed, if market structure and the mix of ICT purchases are different, then it is unlikely that the same price changes take place everywhere. If quality-adjusted price declines in Europe were only one-half the rate seen in the US, the contribution of ICT capital deepening in the EU would drop to four-fifths of the numbers seen in Figure 5 (see European Commission, 2000a), and a significant gap opens up even with the European front-runners.

Some European countries in the northern and northwestern periphery of the EU - may also be candidates to be considered as "new economies". It is interesting that when we go down to the country level there are also substantial differences in TFP growth, with the better performers also being those countries that have spent more on ICT. For example, Figure 6 plots TFP growth against ICT investment. Despite the possibly spurious nature of any relationship between these two variables, it does illustrate that some European countries may also be candidates to be considered as "new economies". These are to be found in the northern and north-western periphery of the EU, and include Sweden, Finland, Denmark, Ireland, the Netherlands and the United Kingdom.



Figure 5. Contribution of ICT capital deepening to output growth

Source: European Commission, 2000a, Table 5, p. 126.

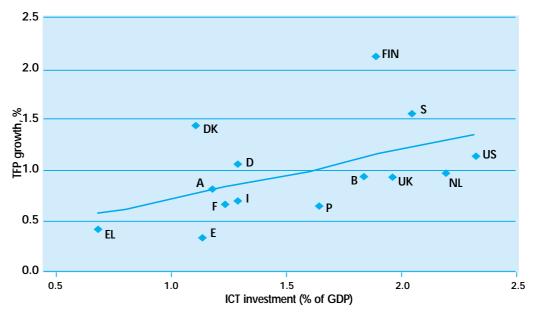


Figure 6. TFP growth and ICT investment (averages for 1992-98)

Source: European Commission (2000a) for investment and Vanhoudt and Onorante (this volume) for TFP growth. Note: Ireland is excluded from the chart for scaling reasons. Its TFP growth was 3.5 percent during the period while the ICT investment expenditure ratio was 5 percent.

As mentioned before, causality from ICT investment to TFP growth can be due to the fact that the ICT equipment and services are produced domestically, and this exhibits large productivity gains, or because the use of ICT works as a catalyst for organisational change in the economy as a whole. Let us consider each issue in a bit more detail. Are these channels for future economic prosperity likely to exist in Europe? We start with a look at the EU ICT sector.

4.2 The competitive position of European ICT production

The OECD (2000b), reports that value added in the overall ICT sector in 1997 stood at 8.7% of the business sector in the United States, compared with 6.4% for the European Union. A study by Credit Suisse First Boston (2000), also shows that value-added in ICT production in the US has been growing much more rapidly than in Europe (17). The different performance was reflected in a value added per person employed in the ICT sector (i.e. labour productivity) that was 70% higher in the United States than in Europe (1997 data from OECD, 2000a).

Its higher productivity growth suggests that the US has a comparative advantage in ICT production. Often trade data is used to check for those sectors that are competitive internationally, and there is indeed a large US <u>bilateral</u> trade surplus vis-à-vis Europe - a surplus that has widened in the 1990s. Though imports from the United States accounted for almost one-quarter of total ICT sales in the EU in 1998, Europe's share of US domestic sales stood at only 6%.

17) In the US, the value-added in ICT producing sectors went from 5.3 percent of GDP in 1995 to 6.8 percent in 1999. These two figures for the EU were 3.6 percent and 4.2 percent, respectively.

That the United States has attained a strong lead in ICT trade is also suggested by its large bilateral trade surplus vis-à-vis Europe. And these figures may not capture a substantial amount of de-facto reexports of US value-added from Ireland. Indeed, this trade data probably understates US dominance in the sector for two reasons (18). Firstly, the bilateral trade surplus with Europe existed despite divergent cyclical positions. To the extent that US ICT imports partially reflect the strong cyclical upswing in US investment demand in recent years combined with a strong dollar, the underlying structural trade balance in ICT goods and services is likely to be even more in favour of US companies.

The US IT sector has consolidated its first-mover advantages through higher R&D. It has also been able to gain economies of scale in a large and unified domestic market. Secondly, the data is very aggregate and poorly measured. For example, outsourcing along different parts of the ICT value chain might have led lower value-added production - such as the assembly of components - to locate outside the US. Thus, while there is a US trade deficit in computers, there is a US trade surplus in semiconductor components. These various activities are grouped together in the aggregate data even though they exhibit very different labour productivity. Moreover, trade data does not account for the value of copyrighted material sold in third markets (e.g. US software produced under license in Ireland for sale elsewhere in the EU would not appear as a US export). There is also scope for multinational firms to adjust transfer pricing to move profits to low tax locations, especially given the ease with which computer programmes can be sent from one location to another via e-mail. Some of the huge difference in output per worker between foreign-owned (mainly US) and locally owned companies located in Ireland is likely to be explained by these factors (see Barry and Bradley, 1997, and Murphy, 2000) (19).

The reasons for the high performance of the US IT sector include first-mover advantages in a sector where there are network externalities, and the consolidation of its competitive position through higher R&D spending. Tracking the high economic growth rate, total US business-funded R&D remained stable at around 2% of GDP between 1990 and 1998 (OECD, 2000a). In the EU this ratio fell from 1.3% of GDP to 1.1% in the same period, amidst weak economic growth.

As ICT is one of the most R&D intensive sectors, these global differences are also visible within the sector. Whereas US R&D expenditures in the Office and Computing Machinery sector stood at 15% of total sector output in 1995, the corresponding figure for the EU was only 4%. Again, one should be cautious of generalising too much, as there is enormous variation within Europe (see Figure 7). R&D spending in Scandinavia, for example, is on a par with the US. European Commission (2000a), notes that, unlike most of Europe, the Scandinavian high-tech sector was able to keep pace with the US countries in terms of productivity growth during the 1990s.

Though internationally traded goods, having a large domestic market has nonetheless helped the US industry to exploit economies of scale. Figure 8 gives an indication of how net imports account for only a tiny share of the total expenditure on ICT in each region. The importance of home markets could help explain why countries have come to specialise in different areas of ICT production when there is no obvious ex ante comparative advantage. Indeed, the adoption of GSM as a standard throughout the EU has played a critical role in establishing European market leaders in technology for mobile networks (e.g. Ericsson and Nokia). The increasing demand for chips in European communications equipment also lies behind the recent growth of the European semiconductor industry (e.g. Infineon, ST Microelectronics, and Philips).

¹⁸⁾ Thus, they may be several explanations for the surprising fact, noted by Quah (this volume), that the US is a net importer of ICT with respect to the rest of the world (with a trade deficit of USD 40 billion in 1998).

¹⁹⁾ Output per worker in foreign owned firms is almost an order of magnitude greater than that in Irish owned firms.

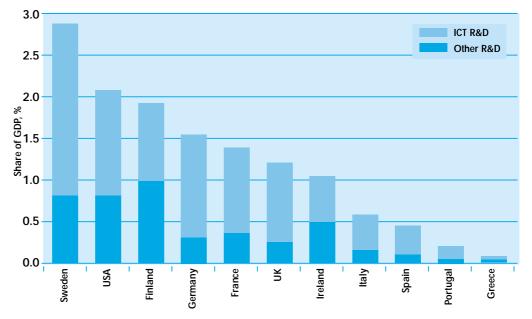
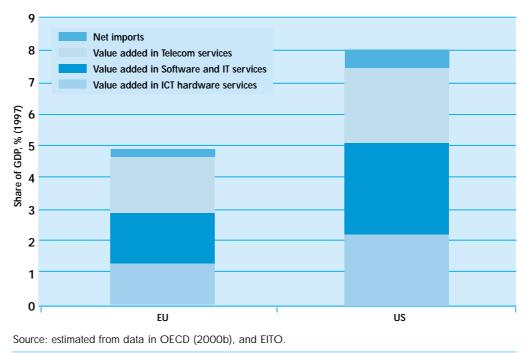


Figure 7. Business-funded R&D as a share of GDP

A similar position exists in software. The OECD (1998), has estimated that the United States supplies around 80% of the world's packaged software and is the only region with a strong position in foreign markets. Especially the market for PC software is dominated by US companies. European producers have around one-third of their home market for packaged software, but are largely absent outside Europe.





Source: Calculated from OECD data (1997 or latest).

Within Europe, Ireland is a major software producer. The OECD (2000c), even reports that the software exports of USD 3.3 billion from Ireland in 1998 were more than the USD 3.0 billion exported by the United States. However, as we have already mentioned, these exports are likely to hide a substantial amount of de facto re-exports of US value-added. Thus, the one-third position in packaged software sales held by European companies in the EU market may reflect a substantial role for US software giants based in Ireland (20).

As with equipment manufacture, US software companies have been able to gain economies of scale in a large and unified domestic market. European software developers have largely concentrated on their home markets because of language and cultural barriers within Europe (21). Nevertheless, Europe has several software producers that have attained a global reach (e.g. SAP, Software AG, Baan, and Cap Gemini Ernst & Young). European companies have also acquired an early lead in producing software for the mobile Internet, which has reached a more advanced stage in Europe than in the United States as a result of the greater adoption of mobile phones.

Thus, while there are ICT market segments where EU companies perform very well, this excellence does not seem sufficiently broad-based for the ICT production sector to make the same kind of contribution to overall economic growth that has been seen in the US. In terms of GDP, the European hardware-producing sector is only about 60 percent the size of that in the US. North American computer companies also have a commanding lead in some of the highest value-added and most rapidly developing market segments (e.g. Intel with semiconductors) and have been at the forefront of developing new manufacturing models (e.g. Dell and Cisco Systems). Putting a much smaller size together with slower productivity growth necessarily means that the ICT sector's direct contribution to growth is significantly less in Europe. With lower R&D spending, and fewer innovative start-ups, European catch-up with the US is likely to be a slow process.

This being said, substantial diversity can be observed within the EU. Some EU countries even had larger value added ratios than the US (6.8%), including Sweden (9.3%), the UK (8.4%) and Finland (8.3%). It could also be the case that demand will shift towards those sub-sectors where Europe performs particularly well (such as wireless communications) - generating faster growth in the future.

4.3 The structure of ICT investment and possible consequences for TFP growth

If Gordon (2000), were right, and the acceleration of US growth has come only from the production of computers, then the previous section would suggest that the EU "new economy" is unlikely to be quite so novel as the North American version. However, we have also seen evidence at the firm-level that there can be substantial productivity gains associated with the use of ICT. This implies that Europe could gain from the adoption of ICT even when it is not producing much of it.

If the acceleration of US growth has come only from the production of computers, then the EU "new economy" is unlikely to be quite so novel as the North American version.

²⁰⁾ Irish software sales account for around 40% of Europe's packaged software market and 60% of its market for business applications. Even though they account for a relatively small share of the total (120 out of 760 firms), in 1998 foreign owned firms in Ireland accounted for more than 80 percent of the sector's revenues, and almost 90 percent of exports (OECD, 2000c).

²¹⁾ The total European software market was estimated by EITO (2001), at around EUR 67 billion in 1999 (split evenly between systems, applications software, and implementation). Note that customised software does not benefit from large measured quality improvements (see Vanhoudt and Onorante, this volume). Thus, the contribution to reported real GDP growth will not be the same as equipment manufacture or packaged software (where hedonic price adjustments are made).

We have little idea of what combination of computer hardware, communications equipment and services provides the optimal foundations to support organisational change. Indeed, this must depend upon the activity in question. For want of a better yardstick, we can compare the structure of ICT expenditures in Europe to those in the US to see if there are notable differences.

A first observation is that the US lead over Europe is entirely in IT (see Figure 9). And while there has been convergence in telecoms spending within Europe, there are notable differences across countries when it comes to IT. Figure 10 looks more closely at spending on IT (as in Figure 9, data is shown in nominal terms to avoid issues of price deflators). To avoid going into a country-by-country discussion, we have split the EU into only two groups according to the importance of IT spending. A striking feature of this graph is the large and widening gap between the United States and the EU, and particularly with the "below average" group. Since this latter group includes the three large continental economies, it accounts for two-thirds of EU GDP.

This converts into a large difference in terms of the IT capital stock available, and particularly the adoption of newer technologies. For example, the stock of computers and Internet hosts in each country largely line up as one would expect given accumulated expenditures over the past decade (see Gruber, this volume).

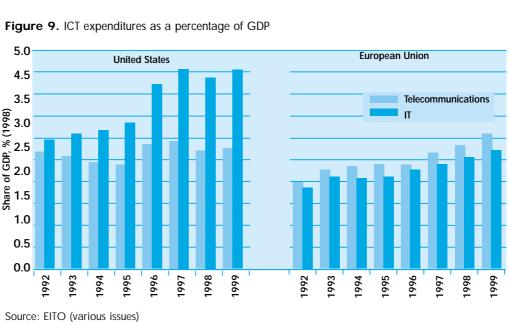
In contrast with IT expenditures, EU telecommunications spending has recently surpassed that of the US in terms of GDP. A large share of these expenditures is actually for services that cannot be

considered as investment - making telephone calls and sending data messages. Figure 11 looks

more narrowly at investment in telecommunications equipment in the two regions (22). It shows that

Europe has traditionally invested more than the United States in telecommunications equipment and

The US lead over Europe is entirely in IT spending. Telecoms spending has recently surpassed that of the US in terms of GDP.



Note: nominal ratios including services.

has retained this lead in the second half of the 1990s.

22) Since EITO does not produce comparable data for the United States at this level of disaggregation, we change the date source to the OECD for this chart.

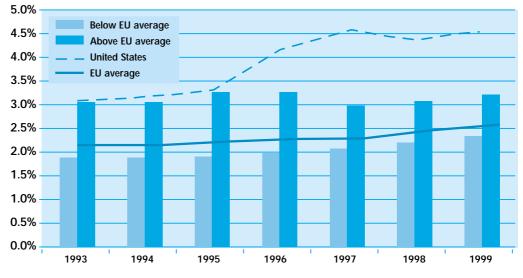


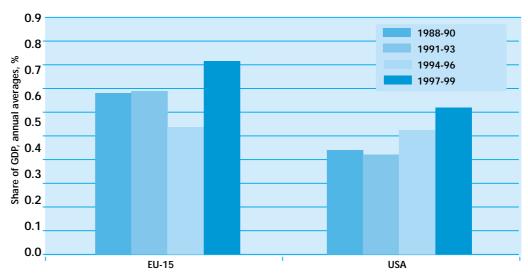
Figure 10. IT expenditures as a percentage of GDP

Source: EITO (various issues)

Note: The "above average" group consists of Portugal, Netherlands, Ireland, Denmark, Finland, UK and Sweden. The "below average" group consists of Greece, Italy, Austria, Belgium, Germany, France and Spain.

Though higher investment was needed in Europe to bring the telecoms network towards US standards (and there are still more lines per head in the US than in the EU) essentially all households and firms are now connected, and Europe is even ahead of the US in the diffusion of enhanced data access such as ISDN (see Gruber, this volume). Thus, it seems unlikely that the quality of communications infrastructure is the constraint to the development of a new economy in Europe. Any competitive disadvantage relative to the United States is more likely to relate to prices and competition in the sector more generally (we return to this issue in Section 6).

Figure 11. EU and US investment in telecommunications equipment

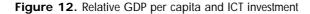


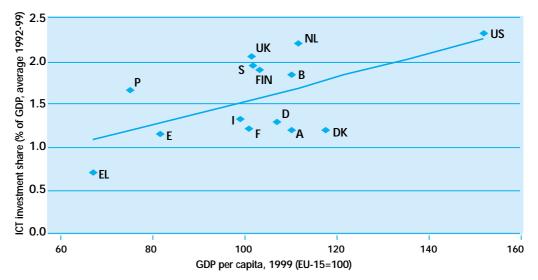
Source: Calculations based on OECD data

4.4 Diversity in Europe - will the rich get richer?

Being a follower can have its advantages for *users* of ICT. It allows companies to adopt only those new business models that have already been proven to work. If investment in IT is focused in the areas of highest pay-off, then a relatively lower investment share does not preclude large productivity gains. However, we must be left with some unease by the fact that large parts of Europe lag far behind the United States in information technology, and that this gap is closing at a very slow pace.

Of course, some European countries have ICT adoption rates that are on par with the US. This is particularly so for Scandinavia. With international ICT production companies, these economies may be just as "new" as the US. But the diversity across EU countries also poses a serious challenge to the goal of economic convergence within Europe. Investment in ICT expenditures appears to have at least some positive correlation with income levels, i.e. richer countries tend to both produce and spend more on ICT (see Figure 12). All of the six EU countries with the highest ICT spending ratios have GDP per capita above the EU average. In so far as there is a causal link from ICT production and investment to growth, the bias to greater ICT spending in higher-income countries may induce divergent economic trends in Europe.





Source: European Commission (1999, 2000a).

Note: As before, Ireland is excluded from the chart for scaling reasons. Its GDP per capita was 111.5 percent of the EU average, while the ICT investment ratio was 5 percent.

The growth of the new economy may also shift regional wealth in a more subtle way by influencing the economic forces that cause economic activity either to concentrate in clusters or to spread more uniformly through space. This could either amplify the rate of regional divergence, or act as a balancing counter force to the direct productivity effects we have been discussing. This question is the topic of the next section.

In so far as there is link from ICT production and investment to growth, the bias to higher ICT spending in higher-income countries may induce divergent economic trends in Europe.

5. The implications of ICT on the spatial distribution of economic activity

The last volume of the *EIB Papers* (Volume 5, Numbers 1 & 2, 2000) dealt with spatial market failures in some detail. Broadly put, there are three reasons why economic activity may concentrate in some locations. These are:

- · Economies of scale in production and technological spillovers across companies.
- Externalities that occur when people and companies move from one location to the other without taking into account the impact they have on local markets (changing prices and demand in each location).
- Coordination failure, when many people and companies must move together to a particular location to launch a new product, but do not have the information or means to organise this.

The net result may be a geographical concentration of economic activity - typically a core and periphery pattern - that is not socially optimal (23).

It has been suggested that ICT can have a major impact on the centripetal forces leading to concentration, with the commonest theme in the popular literature being that the "death of distance" associated with the Internet will lead to a more uniform distribution of economic activity. As we will discuss, this conclusion depends rather on the sector in question.

5.1 The ICT sector

Innovative activity

Returns to scale that support the development of clusters include the shared use of services (such as accountants and lawyers), and a better functioning labour market (as people with the right skills also congregate in the same location). Additional technological externalities come from the "knowledge spillovers" as companies learn new ways of solving problems from their neighbours. Face-to-face meetings are thought to be critical to this process. Hauser (this volume) emphasises that while a well-functioning real estate market, good basic infrastructure and accessible services are all part of any healthy cluster of entrepreneurial activity, a key element is also the existence of "social networks" that can be relied on to help with problem solving. This is particularly the case for start-up businesses. A similar argument applies with bringing venture capitalists, especially wealthy individuals (the so-called "angels"), together with researchers. The use of e-mail, though it makes cheap communication possible over long distances, is unlikely to support the same kind of mutually beneficial relationships. In fact, California's Silicon Valley should be considered exactly as a network for innovation - the manufacture of ICT having migrated to other cheaper locations long ago.

Innovative activity related to ICT is also highly concentrated in a few regions in Europe (Hauser mentions the examples of Cambridge, Sophie Antipolis and Munich). The clustering of industry is not restricted to the high-tech sector (24); however, clustering within ICT is reinforced by two factors.

Innovative activity related to ICT is also highly concentrated. The economic landscape may not change very much, as the process of geographical lock-in has already taken place.

²³⁾ The first two factors, technological and pecuniary externalities, do not always lead to excessive concentration (see Thisse, 2000). For example, firms may not move to the core of they can benefit from less competition in peripheral markets, resulting in insufficient concentration.

²⁴⁾ See the examples described in Krugman (1991), and Porter (1990).

One comes from the link to advanced research, and the role of universities as a source of ideas (25). Clearly, not all universities, and not even some of the most prestigious universities, have been a catalyst for entrepreneurial activity. Hauser believes that having had a successful high-tech business in the vicinity (possibly by chance) as a training ground for future start-ups is important. It is also the case that successful entrepreneurs are likely to choose locations with an attractive environment and social amenities. While the reason why certain regions have become home to innovative clusters is the subject of speculation, there does, however, seem to be a process of lock-in at a relatively early stage.

Gillespie, Richardson and Cornford (this volume), draw the following conclusions. Firstly, high-tech clusters along the lines of Silicon Valley are likely to remain very much part of the scene. Secondly, the economic landscape may not change very much. There will be continued development of existing ICT clusters rather than new clusters springing up in completely new locations, as the process of geographical lock-in for these industries has already taken place. As a result, policy measures that have attempted to recreate knowledge-based clusters in less advantaged regions have not been successful.

"Weightless" goods and services

Quah (this volume) notes that the production of some ICT goods exhibits large economies of scale. This is taken to extreme in the production of computer software. Once the first copy has been programmed, additional copies can be run off at almost zero marginal cost. This could be thought to lead to concentration of the software industry. However, the extent to which economies of scale for a particular product convert into economies of scale at the industry level depends upon whether consumers value diversity. On the one hand, the publishing industry provides an example of a sector with economies of scale, but where there is a strong demand for diversity, and where many competing companies exist. On the other hand, Microsoft provides the example of a market where diversity is not at all valued, as consumers wish to use compatible systems. Thus, the extent to which low marginal production costs convert into industry concentration depends upon whether network externalities are at play. This is by no means the case in all parts of the ICT sector.

However, it may be the case that increased sophistication by consumers is increasing the entry costs to the industry. Even relatively simple products often entail many person-years of programming if they are to be what is now considered as a "standard" quality. Together with economies of scale and scope in marketing, this could lead to a market structure where relatively few major companies dominate the industry (one could think of the film industry as an example).

Quah also notes another specific feature of some ICT goods and services (though obviously not hardware) is that they are weightless, the cost of sending digital information via the Internet being unrelated to distance. Other things being equal, this would tend to lead to the geographical concentration of the industry as, in theory, one location could serve the entire world (26). However, concentration also leads to congestion and high property prices, and it becomes efficient to use the Internet to spread out those activities that do not benefit from proximity. This is reinforced if a

²⁵⁾ More generally, Jaffe (1989) finds a significant effect of US university research on corporate patents, particularly in drugs and medical technology, electronics, and nuclear technology.

²⁶⁾ Of course, time zones could create barriers, as would language and other cultural barriers.

workforce with suitable skills already exists in the peripheral location and there are costs to relocation (27). The main candidate is routine software programming.

Thus, the balance between centrifugal and centripetal forces will depend upon the sector. The highest value added part of the ICT sector is likely to concentrate in a few innovative clusters. For lower value added part of the programming chain, the reverse can be expected, with more uniform production through space (28). The production of ICT equipment is really no different from other parts of the manufacturing sector, and it is to this more general economic activity that we now turn.

5.2 ICT using sectors in general

ICT remains a small, if a profitable and rapidly growing part of the economy. What may the impact of ICT be on the bulk of the economy - those sectors that purchase these technologies? As ICT reduces the barrier of distance to the flow of information, it will tend to increase economic relations between core and peripheral areas. This could support more dispersed economic activity. However, the crux of the matter is not that firms in lagging regions do not know of business opportunities elsewhere (though they may not), but that they are not competitive with respect to firms in more advanced regions. This is particularly the case for small businesses (see Gillespie *et al.*, this volume). Therefore, ICT may equally give the residents of lagging regions greater access to markets in the economic core, with negative consequences for firms in their locality. The analogy, then, is with improved transport infrastructure in traditional models of economic geography. The effect may be either positive or negative depending upon the particular circumstance. In any case, given the other forces at play, the marginal impact of ICT may be very small.

As with computer programming, the situation is substantially changed for the particular set of activities that process data that can be transmitted electronically. Examples are back offices for administrating transactions, translation of documents, etc. Improvements to transmission technologies have reduced costs to the point that even real-time communications (where the capacity of telecommunications networks becomes a factor) are unaffected by distance. Telephone call centres for telemarketing, customer support and technical services fall in this category (29). Here too there will be strong centrifugal forces at least for the next few years. The issue is whether some of the more routine activities may themselves be automated with computers, eliminating this particular window of opportunity for peripheral locations to attract labour-intensive investment (Gillespie *et al.*, this volume).

The conclusion is that rather than directly affecting firm location decisions, the regional impact of the new economy will largely be determined by the extent to which regions reap differential productivity gains from use of ICT. From the investment data of Section 4 we may have concerns that this will be the case. And there are other institutional factors why the pay-off from ICT investment may vary from country to country.

28) Following Quah, this can also be seen as the difference between intangible assets that are codified in patents and copyrighted material (development activities associated with these may spread) and those due to individual human capital (namely, innovation which remains concentrated).

Rather than directly affecting firm location decisions, the regional impact of the new economy will largely be determined by the extent to which regions reap differential productivity gains from use of ICT.

²⁷⁾ The growth of the Indian computer programming industry is the most striking example of this.

²⁹⁾ There are currently about 1.2 million people employed in call centres in Western Europe (EITO, 2001).

6. Institutional preconditions for a new economy

The preconditions for the dynamic development of a new economy are really only threefold. The first is to have an economy that generates new ideas in the development of technology, and has the skills to use them in practical applications. The second is for the economy to be sufficiently flexible that organisational change can take place within existing companies. Since start-ups are an important source of innovation, a third condition is to have institutions, including the availability of venture capital, that support the establishment of new companies. In this section we comment briefly on each on of these goals - all of which are easier to state than achieve.

6.1 Skills and ideas

Innovation - the generation and exploitation of new ideas - is the product of both human capital and research and development. We have already documented the shortfall in R&D spending in some regions of Europe. It is well known that the level of R&D spending is usually less than optimal, as the benefits from a new innovation may not be fully appropriable by the inventor. Thus, there is a logic for public policy intervention, including public spending on R&D.

The other cornerstone of innovation is human capital. It is needed both to generate new technical ideas, and to subsequently turn them into business applications. Clearly, the ICT production sector requires staff with high computer related skills (30). Demand for staff has been growing rapidly and is expected to continue to do so, raising the prospect of increasing skills shortages. A detailed discussion of the ICT workforce is beyond the scope of this paper, but we can say that the main short-term solutions relate to additional on-the-job training. Hauser (this volume) also argues that the immigration of skilled professionals is a solution.

As we have suggested earlier, however, Europe's ICT strategy is likely to be as much user-based as producer-based. This raises the broader question of the need for computer skills in the community in general. Many studies conclude that computer skills are highly rewarded in the economy. A critical assumption in this analysis is that the workers using a computer are the most qualified to do so - the correlation between computer use and higher wages can thus be interpreted as one of causality. However, Soete and Ter Weel (this volume) document a number of research results that are not consistent with this view. They reach the conclusion that causality runs the other way: it is high wages themselves that lead to the adoption of computers. This is because computerisation reduces the time spent on routine tasks, freeing time for workers to use their professional skills in a more productive way. This increases the return from skills and so widens wage differentials (31).

In this sense, what is needed is some basic computer operating knowledge in order to complement more general cognitive skills - a result that is in line with the model of the new economy where ICT is a catalyst for the development of intangible assets. Thus, while courses to acquaint people with

Computerisation reduces the time spent on routine tasks, freeing time for workers to use their professional skills. This increases the return from skills and so widens wage differentials.

³⁰⁾ EITO (2001) reports that there are some 9.2 million ICTprofessionals working in Western Europe, the bulk of which work in applications development (i.e. software programming) and network support. Another 2.3 million people are involved in e-commerce, split more-or-less equally between business strategists (marketing, sales and project managers) and technology specialists (web designers).

³¹⁾ The impact on industrial organisation may be complex. For example, Kremer and Maskin (1996), suggest that there has been greater segregation of high- and low-wage workers into separate teams, while Acemoglu (1999), notes that there are greater incentives for firms to differentiate job descriptions even if this requires more screening of job applicants.

computers are necessary, the technology should be viewed as only a tool (and not particularly difficult one to use since the invention of windowed graphical interfaces) to exploit other skills. As the returns to these skills will increase with widening wage differentials there should be greater demand for education and training. The question for educational systems is whether they will be able to meet this demand.

6.2 Flexibility

Naturally, the use of ICT as a catalyst for organisational change requires a certain flexibility in the economy. This is needed in three areas in particular: in product markets; in labour markets; and in parts of the ICT sector itself.

Competition and product market flexibility

A competitive product market is needed to stimulate product innovation and to encourage constant improvement in work processes. In this context, the US Council of Economic Advisers (2001), has stressed that competition in the US economy was strengthened by a combination of deregulation (such as in telecommunications and finance) and free trade agreements (such as NAFTA and various multilateral agreements within the framework of the WTO) in the 1990s.

In comparison, the general perception is that the EU still lies behind the US in having a competitive economy (32). Cross-country evidence also shows that the European countries showing the strongest progress in innovation and productivity growth in the 1990s, such as the Scandinavian countries and Ireland, have gone through a process of structural and regulatory reform and the liberalisation of previously protected sectors.

Technical change and labour market rigidities

Organisational innovation also requires flexibility in labour markets, without which the productivity gains from investing in new technologies may be more difficult to realise. To the extent that Europe's preoccupation with employment protection is hindrance to organisational flexibility, the costs of shifting towards a new economy in Europe may prove substantially higher in Europe than in the United States (33).

In general, however, the need to protect workers from technologically induced unemployment is overstated. For example, Soete and Ter Weel (this volume) observe that technical progress should not change unemployment over the longer-term. The jobs that are lost by the introduction of a new labour saving process in one sector should be compensated by output growth and additional employment creation in other sectors - with everybody better off in the process (34). However, it is true that there could be a downward pressure on wages for some workers if technical advancement has a skill-bias. This has been cited as one reason for the widening wage inequality seen in the

An excessive level of job protection could lock an economy in a relatively static position.

³²⁾ See, for example, the European Commission (2000b) and the OECD Review of Regulatory Reform (OECD, 1999).33) European employment policies were discussed in more depth in EIB Papers, Volume 3, Number 1, 1998.

³⁴⁾ Put another way, there is no relationship between the level of technology and unemployment. The NAIRU is unaffected, as technical progress influences wage aspirations and productivity equally. There could be a transitory decline in the NAIRU if workers underestimate the growth rate of productivity, but this misconception will inevitably disappear as information on the true state of the economy becomes more widely available.

United States over the last decades (Soete and Ter Weel, this volume). Technical change in sectors where there is little competition would have the same effect if wages have been maintained at above market-clearing level. Workers that are displaced from companies in these sectors will inevitably face lower wages elsewhere.

In Europe, a declining demand for the unskilled together with minimum wage legislation could mean that workers who lose their jobs are unable to find new ones. However, Saint-Paul (1998), finds that there is little evidence for this particular explanation of EU unemployment. In any case, this would be a consequence of technical change to be dealt with through other policy measures, such as training (or more passively by accepting greater inequality in society). Here, labour market policies do not necessarily influence the adoption of a new technology *per se*.

What may be more pernicious is job protection legislation, i.e. restrictions on hiring and firing workers. These increase the costs of company reorganisation if this implies outsourcing certain activities or replacing staff due to changing job descriptions. There may also be dynamic effects. If taking on a new worker has large fixed costs (e.g. several months of severance pay must be paid in the event that a contract is terminated), then it can be considered as an investment decision. Faster growth in corporate profits from reorganisation could reduce the time needed to recover fixed hiring costs, and thus the inclination of companies to create new posts (35). An excessive level of job protection could lock an economy in a relatively static position of low job losses, but also of low economic growth and low job creation. Hauser (this volume) believes that this has been exactly the situation in Europe.

Regulation of telecommunications

Internet host density in OECD countries is inversely correlated with Internet access costs. There is still great dispersion of access costs across Europe. Realising the new economy depends not only on flexibility in labour and product markets in general, but can also be greatly encouraged by a more dynamic and competitive ICT sector. Specifically, the diffusion of ICT equipment is likely to be encouraged by cheap telecommunications costs. As shown in Figure 13, Internet host density in OECD countries is inversely correlated with Internet access costs. This is presumably key for the development of retail e-commerce activities. A broad based use of computers in society could also be important to familiarise the (current and future) workforce with the technology.

Allowing new entrants into the telecommunications sector is the best way of encouraging price competition and innovation (36). Many EU countries have only liberalised the telecommunications sector recently, and there is still great dispersion of access costs. Most of the leading Interneteconomies have Internet access costs below the OECD average. However, Irish telecoms prices were structured to offer cheap transatlantic rates to bulk users (see Gillespie *et al.*, this volume). There is thus a dichotomy in this country between the use of ICT by large businesses and by society at large. Even so, liberalisation of the telecommunications sector in Ireland was accelerated due in part by pressures from inward investors for better and more advanced services.

³⁵⁾ See, for example, Cohen et al., (1997).

³⁶⁾ This point was emphasised by Robert Verrue when speaking at the EIB conference. Gillespie et al., (this volume) also discuss the implications of telecommunications provision in some detail.

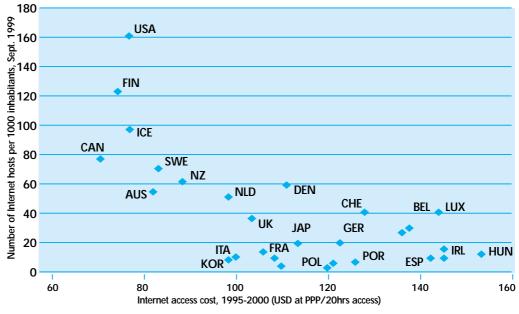


Figure 13. Internet access costs and Internet host density, 1999

Source: OECD (2000a)

6.3 Entrepreneurs and the financing of start-ups

Though a small part of the ICT-sector, start-up businesses are an important source of innovation. This is because of the short gap from advanced scientific research in universities to business applications, together with the completely new opportunities presented by the new technology (the "dot-coms" being the most recent example). As a result, venture capital has played a significant role in developing the ICT sector in the US. Its importance for innovation depends as much on the quality of support provided by the venture capital firms as the amount of funds provided. Indeed, it is this transfer of know-how and direct involvement in the new operations more than just the willingness of investors to make risky bets that makes venture capital different from other forms of financing. This quality element is visible in the patenting data. For example, Kortum and Lerner (1998), found that venture capital-supported firms accounted for less than 3% of R&D spending, but 15% of patenting in the 1990s.

In 1998, venture capital in Europe for the earlier stages of new firms was around half that of the United States as a share of GDP (OECD, 2000a), but had close to the US rate of growth. It is not certain, however, whether such figures are directly comparable across countries. A large gap between the US and Europe is likely to exist with "business angels", those wealthy individuals who invest in new companies at their inception. These investors need to be knowledgeable both of the sector and of the problems of starting new businesses. Consequently, there are cumulative effects as it is often successful ICT entrepreneurs who support the second generation of companies.

This section has shown that realising the new economy goes beyond investing in ICT equipment. Europe's catching-up with the United States is likely to be augmented by its ability to pick best practice directly, i.e. the technological and organisational solutions that have proven successful in

Venture capital has played a significant role in developing the ICT sector in the US. the leading economy. But realising the new economy in Europe may also be impeded by the institutional shortcomings listed here, suggesting that its catching-up with the United States may be a slow process.

7. Conclusions

This exercise began with the observation that there may be something new in the US economy, and that Europe may be missing out on the phenomenon. It is certainly striking that rather than there being catch-up, the world's most advanced economy was able to outpace its followers (such as the EU) during most of the 1990s.

There can be little doubt that the US computer manufacturing sector has made a direct contribution to US growth. It has seen such rapid productivity gains that its performance has pushed up the national average. There is the risk that hedonic, quality adjusted, price indices overstate the real value of the equipment that is being purchased, but correcting for this would only account for a small proportion of what has been seen.

Estimating what has been happening in the rest of the US economy is difficult due to the relatively short time period for analysis (essentially from 1996 onwards). Depending upon the assumptions made to adjust for cyclical effects, productivity gains in the computer using part of the economy can either be significant, or can vanish away.

This being said, the microeconomic evidence shows that companies have been investing heavily in ICT and have been using this technology to develop more efficient organisations. While supply chain management may seem banal (and certainly far from 2001 A Space Odyssey), modest cost savings can generate a large increase in profitability in sectors where margins are thin. Interestingly, it is the computer sector itself (e.g. Dell and Cisco Systems) that have been at the forefront of these changes. It seems inconceivable that firm-level gains of this type are not meaningful in economy-wide terms. Indeed, David (this volume), cautions that conventional growth accounting - the basis for estimating the sources of productivity growth from the macroeconomic data - is "less than wholly enlightening about the behaviour of the economy over the short and medium term".

In comparison with the United States, Europe seems to have a number of important weaknesses. While the European computer industry may lag because US has "first-mover" advantages in sectors where network effects and technological lock-in are important, it is more the case that US companies maintain their dominance by investing much more in R&D. Likewise, the role of start-up companies as a source of innovation is weaker due to less entrepreneurial activity (including venture capital investment). Moreover, the use of ICT as the basis for developing new business models is hampered by fewer incentives (i.e. less competitive pressures in some sectors) and greater costs (for example, due to rigidities in labour markets).

But the most striking feature of a closer look at the EU is how much the production and use of ICT varies across the continent. While some economies - notably in the north and north-western fringe of the Union - are as heavily involved in ICT as the US, there are large areas of the EU that lag far

behind. If there is such a thing as a new economy, this could mean widening regional income differentials. This does not, however, imply that there is a role for governments in promoting national ICT champions. It would be impossible to demonstrate that exporters in other countries are unfairly benefiting from anti-competitive practices, a necessary condition for distorting trade through subsidies or tax incentives.

What of regional development in this environment? The evidence suggests that not much has changed with the advent of ICT. Innovative clusters along the lines of Silicon Valley will largely remain where they are today. Policies aimed at the creation of new clusters in lagging regions are doomed to failure in all but the most exceptional cases. Likewise, new communications possibilities will not open up huge new market opportunities for firms in lagging regions as they are mostly not competitive outside their local markets.

However, ICT has rendered a part of the economy footloose. This includes corporate back offices, call centres, and some computer programming activities. Lagging areas can also try to attract computer production facilities just as they could any other manufacturing plant. Policy instruments include the traditional tools of subsidies, the provision of infrastructure, and training of the local workforce. Unfortunately, the ICT sector may not be ideal for regional development. Equipment manufacture may not be appropriate in the sense that it does not have the kind of linkages to local companies needed to develop indigenous enterprises. And call centres and other standardised operations may not provide sustainable development if these activities are progressively automated in the future. In any case, their very footloose nature means that any home may be temporary.

We can say that ICT is likely to provide the technical basis for keeping the economy on an upward growth path, though performance is unlikely to match the golden eras of the past.

Our definition of a "new economy" is a modest one. It means that ICT will support robust productivity growth, but mainly by improvements to the practices of existing companies. Eventually, the effect must peter out when all companies have moved to best practice. Permanently higher productivity growth would only be possible if the rate of innovation in society increases. This could be the case due to the greater access to information provided by the Internet. The possibility to generate new information related goods and services also seems unlimited. Most of the authors in this edition of the *EIB Papers* tend to take this relatively optimistic view of the longer term.

However, this is a question for tomorrow. For today we can say that ICT is likely to provide the technical basis for keeping the economy on a long-run growth path towards greater prosperity, though performance is unlikely to match that of the golden eras of the past. The main engine for increased productivity will be greater efficiency in the private enterprise sector of the economy. The right economic environment is a necessary condition, and it is certain that ICT does not remove any of the difficult policy trade-offs in society. In this sense, an old truth remains: "there is nothing new under the sun" (Ecclesiastes, 9:1).

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Productivity growth prospects and the new economy in historical perspective



Paul David

1. Introduction: getting the right questions about the "new economy"

Today there are many questions about the nature and the future of the so-called "new economy". The term "new economy" itself has acquired a variety of quite different connotations. For many commentators, it continues to refer primarily to the altered macroeconomic performance of the US economy during the 1990s, when an accelerating rate of growth of real GDP and a steadily falling unemployment rate, unexpectedly, did not give rise to inflationary pressures on wages and prices. Some connected this with evidence of the revival of labour productivity growth, which became increasingly visible in the aggregate statistics for the private sector, as the key development heralding an escape from the US economy's puzzling and worrisomely poor productivity performance of the preceding two decades.

For others, however, the productivity growth picture below the aggregate level was less than entirely clear, and the core of the "new economy" was bound up with the growth of output and employment in "hi-tech" industries, particularly those involving information technologies and computer-mediated telecommunications, and with the on-going restructuring of business organisations and markets that are driven by advances in the latter (ICTs). The high and rising stock market valuations of companies in this sector, and the wave of venture capital that poured into new enterprises launched after 1993 to exploit the commercial possibilities of the explosively expanding Internet, seemed for still other observers to be the very essence of what was new and positive in these developments. Indeed, in the exuberance that marked the century's close, the NASDAQ stock market index came to be identified with the "new economy", whereas the comparatively weak performance of the Dow Jones index was disparaged as representative of the "old economy".

This welter of associations only serves to multiply the potential issues that might be addressed in responding to such a question as "Whither the new economy?" Not the least among these is the logically anterior issue of whether or not, and in what sense (or senses) such a thing usefully can be said to exist. In June of 2000 the OECD was taking a "wait and see" position on the question of whether or not there was a new dynamic of growth among the world's industrial economies, particularly those in Europe. There appeared to be less doubt that if the "new economy" existed anywhere, it was thriving in the US (1). Nevertheless, by the following autumn, Internet business watchers, stock market analysts, and the surviving "dot-com" principals themselves no longer were so convinced, even on the latter point; the leading publication of the Silicon Valley trade press, *The Industry Standard*, offered its anxious readers an assortment of expert opinion on its question: "Has the death of the dot-coms been greatly exaggerated?" (6 November, 2000, pp. 133ff).

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¹⁾ See OECD (2000), page 1: "The question in the title [Is There a New Economy?] is promoted, in particular, by the remarkable performance of the US economy in recent years....The answer is probably 'yes - in some respects'. Some of the features associated with the 'New Economy' can actually be observed: stronger non-inflationary growth linked to a rising influence of ICT. But this picture applies mainly to the United States and does not generalize across countries [in the OECD]."

But, if one seriously sought to respond to even so seemingly specific a query as that, the nature of the answers would seem to turn upon the interpretation of the term "dot-coms". Were that label construed as referring to the mass of novel enterprises launched during the *fin du siècle* stock market run-up, the numbers and market valuation of which now dwindle by the day, it would be hard to be optimistic about the prospects for their collective survival. On the other hand, if the term "dot-com" is accepted as shorthand for the general class of Internet-based enterprises that enter e-commerce markets with new business models, then, it is unlikely that we have seen the last of them. That much seems sure, even though in the future their financial backers are going to have a very hard-eyed look at their business plans.

A more intriguing set of issues are those concerning the sustainability of the high and rising rates of aggregate productivity growth in the US economy. Is the latter, too, a phenomenon that will pass into the annals of history (along with "the dot-com bubble") as a remarkable but transient phase of the protracted economic expansion that is currently drawing to a close? This question, and particularly its connection with the role that digital information technologies are playing in transforming the structure of the US economy, has held my interest for quite some time now. Its significance for long-term economic growth and welfare improvements in American society is both obvious and important. I believe it should be regarded as no less compelling as a subject for the attention of economic analysts and others whose primary concerns lie with the implications of the ICT revolution for Europe's economic prospects. In any event, this is the topic that I tackle here: How ephemeral is the productivity surge that developed in the US during the 1990s?

2. Towards understanding the productivity growth revival of the 1990s

A quick look at the recent US statistics of labour productivity growth and total factor productivity (TFP) growth, will suffice both to make that question more concrete, and to suggest the beginnings of an answer. According to the Bureau of Labor Statistics' estimates (see Table 1), the average rate increase of real output per person hour worked in the private business economy during 1995-98 was a full percentage point above the 1.5 percent per annum rate maintained during the first half of the decade (1990-95). Hence, it exceeded the average productivity growth rate that characterised the decade of the 1980s by essentially the same 1 percentage point margin. The corresponding data for TFP growth records almost as big an acceleration in absolute terms, that is, a jump of 0.8 percentage points. Relative to its previous level (of 0.5 - 0.6 percentage points), this measure of the pace of TFP growth therefore underwent a proportionate recovery in the late 1990s that was considerably more pronounced than the revival in the labour productivity growth rate (2).

In the private business non-farm sector the acceleration of the corresponding TFP measure (from the same BLS source) was slightly less pronounced between 1990-95 and 1995-98: the rate rose from 0.6 to 1.3 percent per annum. There had been a more substantial pick-up in the pace of TFP advance, however, amounting to a 0.3 percentage point rise between the average rates during 1979-90 and 1950-95. Thus, reckoning from the experience of the 1980s as a base, the following decade saw a quickening, two-step acceleration that cumulated into a 1 percentage point gain in the annual pace of TFP increase, accounting for nearly all the gain registered by the labour productivity growth rate of the private business non-farm sector.

Labour productivity growth during 1995-98 exceeded that of the 1980s by 1 percent. The data for TFP growth records almost as big an acceleration.

²⁾ As noted in Table 1, the most recent BLS TFPgrowth rates (cited above), are "semi-refined" whereas the "refined" data in Table 2 reflect full adjustments for the contribution to output growth attributable to changes in the composition of capital inputs.

	1973- 1979	1979- 1990	1990- 1995	1995- 1998			
BLS Measures	Ave	Average annual percentage growth rates of GDP productivity measures for the Private Business Economy					
Output per person hour	1.3	1.6	1.5	2.5			
Capital services per person hour: Information processing	0.7	0.7	0.5	0.8			
equipment and software	0.3	0.5	0.4	0.8			
All other capital services	0.5	0.3	0.1	0.0			
Labour input composition	0.0	0.3	0.4	0.3			
Semi-Refined TFP Residual (a)	0.6	0.5	0.6	1.4			

Table 1. The US productivity growth revival of the late 1990s in perspective.

Notes: a) Compositional change corrections are made for labour inputs, but in the case of capital inputs the only compositional changes accounted for are those between IT and non-IT capital, and changes in the quality of the IT capital stock.

Source: Derived from US Department of Labor, News Release USDL 00-267, September 21, 2000.

The picture just drawn serves to focus our attention upon the prospects for future total factor productivity (or multifactor productivity) gains, because these were the proximate agencies responsible for returning labour productivity growth during 1995-98 to the long-term average pace that was achieved over the whole period stretching from 1948 to 1995 (3). The other side of this coin, however, is the duration and severity of the <u>deceleration</u> in the growth of measured TFP that had marked the decades following the 1960s. The latter experience is brought out more starkly by a slightly different, and more exacting set of BLS measures for "refined" TFP growth in the private business non-farm economy. Those figures (in Table 2) reflect a more complete correction for the effects of compositional changes in capital inputs, as well as in the labour inputs.

	Ũ						
Annual Percentage Growth Rates of GDP Productivity Measures for the US Private Non-Farm Business Economy							
BLS Measures:	1950-72	1972-88	1988-96				
Output per work hour	3.08	1.32	0.83				
Crude TFP	2.38	0.94	0.70				
Input quality effect	0.40	0.59	0.59				
Refined TFP	1.98	0.35	0.11				

Table 2. The extended slowdown of US TPF growth after 1972

Source: US Department of Labor, News Release 98-187, May 6, 1998.

3) The average annual rates reported for TFP during 1948-98 are 1.4 percent in the private business sector, and 1.2 in the private business non-farm sector; the corresponding rates for 1995-98 are 1.4 percent and 1.3 percent. See US Department of Commerce, News Release USDL 00-27, September 21, 2000.

As can be seen from Table 2, the revival in the 1990s was not sufficiently strong to erase the effects of the preceding "slowdown": the average annual growth rate of measured TFP for the period 1988-96 actually continued to fall to the negligible 0.11 percentage point level - lower than the average rate recorded for the long interval of the "productivity slowdown" itself (1972-88).

The foregoing observations permit an initial response to the original question: clearly, these productivity indicators for the US economy aren't going to go on *accelerating* in the way they have done since the early 1990s. The BLS has yet to release its estimates for TFP growth beyond 1998, and so we must wait a while to learn whether the acceleration continued throughout the twentieth century's final years. Nonetheless, while it is not inconceivable that a further acceleration by as much as 0.5 percentage points could have been achieved in the private business non-farm economy, it seems most unlikely that the higher growth rate which would have been established by such a change could be sustained as a new long-term trend.

One way to arrive at this conclusion is to notice that the result of such a scenario (i.e., continued acceleration) would be tantamount to the US economy staging a cumulative productivity revival amounting to 1.3 - 1.5 percentage points, thereby bringing the average annual rate of aggregate (refined) TFP growth all the way back up to the trend rate that had characterised the post-World War II era, the so-called "golden age of productivity improvements" (4). We know that in the latter era, however, many quite special conditions circumstances prevailed in both the US and the international economy which contributed to boosting productivity growth; that in their very nature those conditions were not self-renewing, and so gave way eventually to a subsequent macroeconomic environment characterised by reduced investment rates, sluggish productivity advance and recurring inflationary pressures (5).

Should we entertain the notion that the "Age of the Internet" will be another "golden age" of productivity improvement? Should we entertain the notion that the consequences of the technologies of digital computing and computer-mediated communications - associated with the dawning of the "Age of the Internet" - constitute the basis for the return of another extraordinary episode, featuring a comparably strong surge of productivity advance? That, of course, is the view advanced by some advocates of the "new economy" hypothesis who see new information processing and telecommunications technologies as having played the central role in accelerating the US economy's growth while holding inflation in abeyance (6). The most recent Economic Report of the President placed itself quite forthrightly in this camp, declaring (7):

"At the heart of the New Economy lie the many dramatic technological innovations of the last several decades. Advances in computing, information storage, and communications have reduced firms' costs, created markets for new products and services, expanded existing markets, and intensified competition at home and abroad.... Indeed, the rapid growth of the information technology sector was one of the most remarkable features of the 1990s".

7) Economic Report of the President, (2001); Chapter 3, page 95; on productivity growth, see Chapter 1, pp. 25-33.

⁴⁾ This point (conveniently) holds in regard to the array of variant TPF growth measures in Tables 1 and 2. The "golden age" of post-WII growth referred to in the text is dated variously as 1948-73 and 1950-72.

⁵⁾ See Abramovitz (1989), for a compact but comprehensive exposition.

⁶⁾ Former Federal Reserve Board member Alan Blinder (2000), for example, noted the temporal coincidence in referring to the "tantalizing fact - that productivity accelerated at just about the time the Internet burst on the scene". But, he cautiously hesitated to infer that there was a causal connection: "Whether or not the Internet was the cause of the speedup in productivity growth will be a matter for economic historians to sort out some years from now....For now, however, it appears that the economy can sustain a higher growth rate than most people thought plausible just a year or two ago. In that limited respect, at least, we appear to be in a 'New Economy'".

Yet, that conclusion also has been criticized as lacking in solid empirical foundations, and not only by economists who have steadily expressed scepticism about the "ICT revolution", (8). Rather than engaging with the technical details of that debate, I want to devote the following sections of this paper to a somewhat more analytical look backward, before venturing upon some concluding conjectures about the road that lies ahead. This approach reflects more than the historian's characteristic diffidence when asked to predict. We are likely to form a better grasp of the present prospects for sustained rapid productivity growth, and hence for the continuation of the US economy's remarkable non-inflationary expansion in the years immediately ahead, by making the effort to delve first into the causes of the recovery in measured TFP growth that occurred during the second half of the 1990s. Furthermore, as will become evident, without a satisfactory account of what happened in the preceding period of the productivity slowdown, it is going to be difficult to understand the underlying sources of the revival.

3. Links between new technologies and sources of recent acceleration in measured TFP

There are at least three proximate sources of the revival of measured TFP growth that occurred during the later years of the 1990s that we may link with the effects of technological change, and, more specifically, with innovations in information processing and computer-mediated telecommunications. The connections to which I wish to draw attention here, however, are rather less direct than those, which economists typically emphasise when they interpret the TFP growth rate itself as measuring "the rate of technological innovation".

Some part of the apparent speed-up certainly was due to the strength of demand growth, fuelled by the higher gross private domestic investment rate, and the wealth effects upon consumption that derived from the stock market boom. The move toward more intensive utilisation of the employed labour force, and of the existing stock of plant and equipment, has contributed to increasing measured productivity. In one sense, this aspect of "the new economy" isn't really new, because there is a long historical record of pro-cyclical movements in the growth of TFP as well as of average labour productivity (9).

But, how large an effect this can be said to have contributed to the recent surge of productivity growth remains a matter of some controversy among economists. By extrapolating from the US historical record, Robert Gordon (2000a), arrived at estimates showing the "cyclical component" accounted for almost two-fifths of the post-1995 acceleration. For the non-farm private business economy, according to Gordon, this component contributed 0.5 percentage points of the 1.3

9) This has been recognized in the literature at least since Hultgren (1960); and, since Oi (1962), it has been explained in terms of the changing intensity with which "quasi-fixed" elements of the work force, as well as other fixed factors of production are utilised.

⁸⁾ Paul Krugman's (2000a), enthusiasm about the reality of a technology driven surge in productivity did not suffice to quell his scepticism (2000b), about the soundness of the macroeconomic arguments advanced by believers in the existence of a "new paradigm". Robert Gordon (1999, 2000b), has maintained, on a variety of grounds, that the "information revolution" is not an economic phenomenon whose consequences will approach the magnitude of the transformations wrought by technological innovations in the late 19th and early 20th centuries. See also, for example, Cassidy (2000), for a review of the recent recurrence of ICT-scepticism. On a rather different level is Gordon's (2000a) observation that labor productivity growth failed to recover in many sectors of the US economy, so that the sharp acceleration of the late 1990s actually has been quite patchy, and concentrated heavily in the computer and telecommunications equipment, and software branches within manufacturing.

percentage point rise observed in the annual rate of growth of real GDP per hour; and the corresponding share was as much as three-fourths of the smaller (0.86 percentage point) acceleration experienced in the part of the non-farm private business sector not engaged in manufacturing durables.

Gauged by historical standards the strength and duration of the procyclical upswing appear to be something new. Jorgenson and Stiroh (2000b), however, take the view that Gordon's estimate over-states the "cyclical" correction, and therefore yields too low a residual figure for the "structural component" of the acceleration in the TFP growth rate. Disagreements of this kind reflect the deeper problem of extrapolating from statistical relationships that prevailed in the past, when the pace and manner in which technologies are diffused, and their effects upon the structure of the economy all have been changing. Gauged by historical standards the strength of the pro-cyclical upswing on this occasion, and the duration over which the productivity rises have continued to offset upward pressure on input costs, would appear to be *something new*. Moreover, there are some good reasons to believe that the large "cyclical component" arrived at by Gordon's calculations itself may reflect the application of digital information technologies (from computers and databases to broadband telecommunication networks).

For example, these applications contributed to reducing required levels of inventory holdings of both goods in process and finished products. In the durable goods industries the inventory-sales ratio has exhibited a secular decline since the early 1980s, but after the early 1990s its downward course became particularly pronounced (10). In addition, "smarter" scheduling of transportation and production operations, and better coordination of work within and among business firms, reduces the need to hold "inventories" of partially utilised workers and avoids plant and equipment being idled while awaiting the delivery of supplies. All of that makes possible the fuller utilisation of the capacity of the "fixed" inputs in production, and it shows up in measured TFP gains.

These sources of accelerated productivity growth, however, are the kind that are unlikely to be sustainable. In the first place, the aggregate demand may not keep up with the expansion of supply capacity, and the resulting accumulation of unwanted inventory holding is then likely to reduce utilisation rates. A further consideration, also suggesting the limited sustainability of rapid productivity gains achieved in response to demand pressures on capacity, is that the easier changes in the organisation of production and distribution tend to be the first ones to be exploited. As the low-hanging fruit get picked off first, so the incremental gains become smaller and smaller. Similarly, when experienced workers no longer will take on more overtime, new workers need to be found, hired and instructed, and that means the employing firms must incur the added fixed labour costs, which such activities impose.

The difficulty of making detailed time-series adjustments for the influence of such changes on measured productivity growth encourages cautious practitioners of the growth accountants' art to view their results as most reliable for gauging the longer-term trend rates, particularly those which emerge from

¹⁰⁾ See McConnell and Perez-Quiros (2000), who attribute the decreased short-term volatility of real GDP growth in the US after 1983 to this development in the durable goods sector. Between the successive peak levels of the inventory-sales ratio in the years 1981-83, and 1991-92, the proportional decrease amounted to 10 percent, but the downward trend resumed thereafter and brought the ratio down by another 25 percent, to an unprecedentedly low level of 1.5 by 1998. Interestingly, the 1990s also witnessed the first persisting departure of the movements in the inventory-sales ratio for durable goods. The latter continued to fluctuate around a stationary level (approximately 1.14) throughout the 1990s.

comparisons between points in the growth record where the economy is found to have been operating at equivalently high rates of capacity utilisation. Applying growth accounting methods for the analysis of economic performance over comparative short time intervals, therefore, must be regarded as somewhat more of a "risky business" than casual readers of the results often are left to suppose (11).

There is a second "new" element to be noted in the recent US productivity growth story, one that is not unconnected with the strength and the nature of technological changes accompanying the recent economic expansion. A much larger share of aggregate production now involves intangible goods, such as software and other digital information-goods, whose unit costs of production tend to fall rapidly with growth in the volume of production. This has undoubtedly contributed to reinforce the pro-cyclical productivity effect. In this sense one may say that the information technology revolution has been contributing towards maintaining the importance of the sector of the US economy in which production is characterised by conventional, old-fashioned economies of scale. Of course, the downside is that this source of productivity growth is likely to be jeopardized by a weakening of demand and declining sales volumes in the new information-goods sector industries.

Summing up the foregoing discussion, one may remark that trying to quantify the various "sources of growth" on the supply side, in the way that conventional growth accounting encourages us to do, is less than wholly enlightening about the behaviour of the economy over the short- and medium run, which is to say, within the course of normal 4-5 year business cycle movements (12). Much of what has been taking place within the time frame on which recent analysts have been focusing, appears to reflect interactions between demand side and supply side changes, and the interactions among various supply side phenomena. Under rather exacting assumptions, each of the latter factors could be quantified as neatly as they may be distinguished for purely conceptual purposes. But, in practice, the conditions required to separate them for purposes of measurement are more typically not fulfilled. Thus, it has been noted that the effects of technological innovation can alter the quantitative importance at the aggregate level of productivity gains that are derived from economies of scale; whereas the latter in turn may alter the sensitivity of macroeconomic performance to changes in demand conditions.

We should turn now to examine a third, and rather different development that underlays the acceleration recently observed in measured productivity, one that is more likely to persist, if only because it brought the cessation of increasingly serious measurement errors that had been contributing to the apparent "slowdown" of the productivity growth rate during the 1970s and 1980s. It will be seen that this, too, has a connection with developments in the sphere of information technologies and the manner of application. But on this point the argument is somewhat more intricate than it was in the first two cases, and to present it properly requires that I first provide a little background on the vexed subject of productivity measurement errors.

Ever since the emergence of the "computer productivity paradox", or "the productivity slowdown puzzle" as it should properly be called, economists recurrently have discussed the possibility that the

Much of what has been taking place within the time frame on which recent analysts have focused appears to reflect interactions between demand side and supply side changes and interactions among supply side phenomena.

¹¹⁾ See, for example, the chronology developed for this purpose by Abramovitz and David (1999); Jorgenson and Stiroh (2000b) make essentially the same point in connection with their application of growth accounting at lower levels of aggregation.

¹²⁾ This caveat may be taken to apply equally to the contributions of Gordon (2000a), Oliner and Sichel (2000), and the US Department of Labor (2000), to the interpretation of the sources of the post-1995 acceleration in productivity growth.

shrinkage of the TFP residual was in whole or part an artefact of biases in the indices of aggregate real product growth (13). Among the more popular suspects in this regard is the problem of obtaining unit prices for the products of service industries, and the consequent difficulty of measuring real product movements in a part of the US private business economy whose share in the current value of production has been expanding. Suspicion also has fallen on the likely failure of the price series used as deflators for the current value of production in a large number of commodity producing industries and services to take sufficient account of the improvements in product quality. As a result, the rate of price increases would tend to be overstated, leading to a downward bias in the measured growth of real output and productivity (14). The magnitude of the difference in measured real output growth that resulted when the Bureau of Economic Analysis (in the US Commerce Department) introduced quality adjusted (so-called "hedonic") price deflators for just one industrial branch - the manufacture of computer equipment, has served to underscore this more general worry (15).

The first of these two suspicions of serious measurement bias was emphasised by Griliches (1994), who drew attention to the existence of a substantial gap between average labour productivity growth rates in the better-measured, commodity-producing sector on the one hand, and a collection of "hard-to-measure" service industries, on the other. He suggested that the expanding share represented by the FIRE bloc (Construction, Trade, Finance, Insurance, and Real Estate), and miscellaneous other service industries, would have exerted an increasing drag on the economy's aggregate labour productivity growth rate. To the extent that the differentially slower productivity growth in services was the consequence of the understating the growth of services output, the magnitude of the overall downward bias would have increased during the 1970s and 1980s.

Now, it is not immediately apparent how these particular sources of measurement bias might bear upon our understanding of the subsequent *revival* of productivity growth. Taking them in reverse order, the hypothesized impact of the economy's structural drift towards "un-measurability" turns out to be quantitatively weak; at most it could have could have been responsible for only a tenth of the 1.3 percentage point slowdown in the average annual rate of measured aggregate productivity growth after the 1960s (16). Consequently, even if the relative expansion of "poorly measured"

¹³⁾ Abramovitz and David (1999), Part 2, Section 3, provide a critical review of the literature on this issue.

¹⁴⁾ It is important to make it clear that this problem is quite distinct from the main source of upward bias in the official "inflation rate" for the US, to which public attention was drawn by the 1997 report of the so-called "Boskin Commission", which criticized the BLS methodology formerly used in constructing the US Consumer Price Index (see Madrick, 1997). Of the approximate 1 percentage point per annum "overstatement" in the CPI's average growth, about 0.7 percentage points were ascribed to the effect of employing fixed quantity weights, i.e., calculating the (Laspeyres) price index for an invariant "basket of goods." The GDPdeflator, by contrast, is defined as a (Paasche) variable weight price index, to which this critique did not apply.

¹⁵⁾ See, for example, Moulton (2000), pp. 36-38. This correction for quality improvements, however, being confined to one branch of manufacturing (and extended subsequently to cover digital telecommunications equipment and software, creates statistical distortions in the "real" (constant price) measures of the structure of the economy, and also has made the interpretation of comparative international indicator of output growth and productivity much more problematic than it had been formerly. For an excellent treatment of this little-recognized issue, see Wycoff (1995).

¹⁶⁾ The effect on the weighted average rate of labor productivity of the shifting the output shares can be found in the following way. Gross product originating in Griliches' (1994), "hard-to-measure" bloc within GPDP averaged 49.6 percent of the total over the years 1947-1969, whereas its average share was 59.7 percent in the years 1969-1990. These averages were calculated from the underlying NIPA figures as geometric means of the terminal year values in each of the two intervals. The observed trend difference (over the whole period 1947-1990) between the labor productivity growth rates of the "hard-to-measure" and the "measurable" sectors identified by Griliches (1994), amounted to about 1.40 percentage points per annum. Thus, simple re-weighting of the trend growth rates lowers the aggregate labor productivity growth rate by 0.13 percentage points between 1947-1969 and 1969-1990, which amounts to rather less than 12 percent of the actual slowdown that Griliches was seeking to explain. See David (2000), Section 2.2, for further discussion of this issue.

service industries had halted completely after the early 1990s, which was not the case, the effect could not have contributed much to the apparent rebound in productivity (17).

A comparable difficulty is encountered by proponents of the other suggestion, namely the objection that quality improvements have been going largely unrecorded in the official figures for real product growth until lately. In other words, it was not so easy to come up with persuasive reasons for supposing that the downward bias on this account had become *more pronounced* after the 1960s, and so was responsible for the appearance of slower productivity growth. Indeed, according to Bresnahan and Gordon (1996), the rate of unmeasured quality improvements in durable goods was high during the early post WW II decades, and there were no *a priori* grounds for believing that the dimensions of the overall problem became more serious during the 1970s and 1980s - especially not in view of the introduction by the Bureau of Economic Analysis of GDP deflators that reflected "quality adjusted price indices" for computer and peripheral equipment (and, more recently for telephone switching equipment, semiconductors and some types of software) (18).

The point that deserves recognition here, however, directly contests the latter view, identifying both analytical and empirical reasons to support the hypothesis that the relative magnitude of the underestimation of quality improvements, and the consequent understatement of the real output growth rate, have not remained constant. Even though the argument is somewhat novel, the two-fold claim advanced in the following paragraphs can be summarised simply: firstly, the downward measurement bias in the US real output growth rate grew significantly after the early 1970s, but by the early 1990s its magnitude had stabilised; secondly, this temporal pattern arising from the underestimation of productivity quality improvements, was related causally to the course of the ICT revolution.

From the middle of the 1970s through to the early 1990s new information technologies increasingly were being applied in ways that enabled firms to cut the costs of introducing new goods and services, thereby encouraging firms to shorten their average product life-cycles, and to experiment with "mass customisation" (19). The proportion of sales revenues that were generated by newly introduced products was therefore increasing. As economists have long been aware, the official government price series tend to miss a good portion of the rapid fall that typically occurs in the relative prices of new products when they still are very young. Because those price series are used to deflate the total sales revenues of the industries introducing these novel goods, the resulting estimates of growth in the industry's real output, and in their productivity, tends to be understated.

Although this was not a "new" problem in the qualitative sense, it became a quantitatively more serious source of bias, precisely because the relative importance of new goods and services was

Through the mid-1970s to early 1990s, IT enabled firms to cut the costs of introducing new goods and services.

¹⁷⁾ A different and deeper set of unresolved measurement issues, nonetheless, deserves to be noticed. As Diewert and Fox (1999) have pointed out, these particularly affect the expanding provision of customised information services - whether in free-standing form, or in bundled with tangible commodities. The core problems involve those of measuring the incremental utility that consumers derive from applications of information technologies that lower the costs of reducing risk, whether by increasing the availability of information to decision-agents, or by reducing marginal costs of providing highly specialized forms of insurance.

¹⁸⁾ See Cole et al., (1986), on the introduction of quality corrections using the "hedonic" price index methodology; Moulton (2000), pp. 37-39, for subsequent extensions of this initiative by the BEA.

¹⁹⁾ See David (2000, pp. 61-65) for further discussion and references on mass customization, and on the data supporting the particular hypothesis about measurement bias that is advanced here.

The growing importance of new products had a perverse effect. "Mass customisation" worked to depress measured productivity even further than had been the case historically. increasing. During the rapid transition to mass customisation that was underway in the US during the 1980s, the average age of product lines was falling and the downward measurement bias in the output growth rate therefore became more and more pronounced. These developments reflected in good measure the application of new information technologies, and related organisational reconfigurations in R&D-intensive businesses. By enabling the integration of market research, new product design, production engineering, and marketing, ICT use contributed to reducing the fixed costs of new product innovation, and shortened the innovation cycle.

The phase in the evolution of digital technology that characterised the 1980s as the era of "the PC revolution" may not have done much to promote readily measurable gains in task productivity, for reasons that I have considered elsewhere. Yet, what is of importance here is that it unshackled innovative product design and marketing groups within many large organisations, in part by freeing them from dependence upon (and, hence, from the tighter constraints imposed by) hierarchically structured, mainframe-based information systems that served the control functions of central management.

Therefore, mass customisation, along with all that it entailed in the way of modern manufacturing and inventory control, justly can be regarded among the palpable consequences of the ICT revolution of the 1980s. This was not appreciated at the time by economic analysts who tended to regard the proliferation of PCs on office desks as little more than the miniaturisation of mainframe computing; a development which they saw as failing to deliver the sort of measurable productivity payoffs that had been realised in the late 1960s and 1970s, when mainframe systems released labour by taking over many back-room "number crunching" functions in banking and financial transactions, payroll and record processing, and the like.

The growing relative importance of new products in the economy, had a perverse effect upon measured productivity. This was the result of its interaction with the prevailing, official routines for tracking the prices of new products. Putting the matter most simply, the mass customisation movement in this phase of the computer revolution, paradoxically, worked to widen the gap between the actual and the measured productivity growth rate even further than had been the case historically. How big was this added downward bias? The preliminary estimates that I have made indicate that during the 1977-92 interval the increase in the magnitude of the underestimation bias may have been very substantial: perhaps big enough to push the measured annual growth rate in the private non-farm business economy downwards by 0.3 - 0.5 percentage points, in comparison to what would have been recorded had the effect of the bias in the price deflators remained unchanged (20).

This ballooning of the gap between the actual and the measured growth rate of productivity does not seem to have continued after the early 1990s, certainly not at anything approaching its former pace. Under the conditions envisaged for the calculations that I have just cited, the magnitude of the upward bias of the official price deflators was being enlarged simply due to the enlarged share

²⁰⁾ See David (2000, pp. 62-63), for discussion of underlying estimates of the movement in the share of newly introduced products in the total product flow through US retail distribution channels: this fraction was stable over the 1964-75 interval, rose dramatically between 1975 and 1992, and appears to have substantially stabilized thereafter. A memorandum is available on request from the author, setting out the assumptions and preliminary calculations used to derive the implications of those movements for the temporary expansion during 1975-1992 in the magnitude of the understatement of the rate of growth in real GDP.

that sales of newly introduced goods represented in the total value of commodities goods (other than computers and peripheral equipment). For that to have continued, the pace of new product innovation would have had to gone on *accelerating* sufficiently to continue the upward trend in the average rate at which product lines turned over. But, by the early 1990s the force of the wave of "mass customisation" appears to have been largely spent: the average age of product lines no longer was dropping as quickly as had been the norm in the 1980s, and the proliferation of variety within product lines began exerting stronger downward pressure on the mark-ups initially commanded by newly "customised" products.

Consequently, this source of downward bias in the measured productivity growth rate was once again stabilised - albeit at a substantially higher level (namely by the added 0.3-0.5 percentage points) than that which characterised the era preceding the "slowdown" of 1974-1990. Had the drag exerted on the measured growth rate continued to increase through the 1990s, it would have masked some part of the revival in the rate of growth of measured TFP that has been observable in the years since 1992. At this point, perhaps, it should be emphasised that the burden of the preceding argument is that the magnitude of the slowdown in measured TFP growth from the rates maintained during the "golden age" (variously dated 1948-69, or 1950-72), was exaggerated by the worsening bias in the price deflators. Yet, the recent acceleration of measured TFP growth - compared to the pace of the latter during the late 1980s an early 1990s - cannot be attributed to a reduced degree or underestimation of the true rate of growth of output.

The implication to be drawn from this is that *the rebound* of the measured TFP growth rate is rightly viewed as a real phenomenon, calling for an explanation as such. But, a second implication is that if we want to make historical comparisons with the "golden age" of productivity growth, it would be necessary to adjust for the enlargement in the gap between the "true" and the measured rates of output growth that had contributed to the apparent productivity slowdown. One may then notice that adding an upward adjustment of as much as 0.3-0.5 percentage points to the growth rates presently found (in Table 2) for the entire period from the mid-1980s onwards, would bring the estimated pace of TFP growth during the most recent sub-period back up into the neighbourhood of the high average rates recorded for the 1950-72 "golden age" (21).

As has been previously remarked, a substantial component of this "historically comparable" adjusted TFP growth rate of 1.5 to 1.7 percent per annum in the years 1996-1999, is cyclically inflated above the sustainable trend. But, because the source of the upward adjustment is one that can be read as reflecting total factor productivity growth in sectors of the economy other than the vertically integrated computer sector, this correction carries the further implication that the direct impact of product quality improvements in the computer sector now appears less crucial a source

measured TFP growth cannot be attributed to a reduced degree of underestimation – the rebound of TFP is a real phenomenon.

The recent acceleration of

²¹⁾ To make this rough calculation on the basis of the BLS estimates in Table 2, one can start simply by adding 0.3 to 0.5 percentage points to the 1.4 percent per annum figure shown for 1996-1998, obtaining a "corrected" range of 1.7-1.9 percent per annum for the latter period. But the Table 2 estimates are "semi-refined", whereas the 1.98 percent per annum average rate shown for 1950-72 by Table 1, is the BLS's "refined" estimate. Two further "adjustments" are thus in order. In place of the BLS figure for 1996-98, we may start from the fully refined TFPgrowth rate of 1.2 percent per annum that Oliner and Sichel (2000, Table 4), provide for 1996-1999. That yields an "corrected range" of 1.5 -1.7 percent per annum for this recent period. Secondly, in place of the rather high BLS estimate in Table 2 for the period 1950-72, we may substitute the more "refined" TFPgrowth rate estimate of 1.7-1.8 for these years. The latter accords with the underlying (input composition adjusted) estimates used by Gordon (2000a).

of the elevated rate of TFP growth. According to the estimates made by Oliner and Sichel (2000, Table 4), total factor productivity growth in "other non-farm business" contributed 0.5 percentage points to the total growth rate attained during 1996-1999. The adjustments for the under-estimated quality improvements (apart from semiconductors, computer and peripheral equipment) would thus push the other non-farm business sector's contribution up toward the 0.7 to 0.9 percentage point level (22).

This goes some way towards removing the puzzling concentration of total factor productivity growth in the "computer-producing" industries, and its corresponding absence from the "computer-using" sectors, which has been remarked upon by a number of recent studies. Stiroh (1998), and Jorgenson (2000), have taken the view that the low rates of total factor productivity growth outside the computer-producing sector are no "puzzle", but an entirely understandable consequence of the rapid fall in the relative (quality adjusted) price of computer capital services, which has induced substitution of the latter for the services of labour inputs. It is through that channel that they, along with Oliner and Sichel (2000), now see the information revolution as contributing indirectly to raising the growth rates of output and labour productivity in the economy at large; whereas it is the direct effects of multifactor productivity advances concentrated in the industries producing semiconductors and "computer investment-goods" that have been responsible for the spectacular fall of the price-performance ratios in those products.

One begins to form the view of the IT revolution as a source of efficiency improvements that have been gradual increasing in magnitude and permeating the economy. By re-balancing that rather lop-sided picture in the way I have suggested here, one begins to form a view of the digital technology revolution as a source of efficiency improvements that gradually have been increasing in magnitude and permeating the economy. Such a view conforms more closely with our expectations of the way in which fundamental technological breakthroughs eventually precipitate cascades of technical and organisational innovation, which, in turn, are reflected in surge-like movements of the economy's total factor productivity growth rate. Whether or not the recent acceleration is to be seen as a harbinger of developments of this kind remains a matter of speculation. The study of historical experience, however, can afford us considerable guidance in understanding the mechanisms, and the conditions that may promote such far-reaching transformations of the economic regime.

4. General purpose technologies and productivity surges: an interpretive framework

Putting aside the issues of measurement, and the disentangling of transitory from the sustained components in measured productivity growth rates, we must now give closer consideration to the longer-term processes linking technological innovation, capital formation, structural change and sustained productivity growth. Consequently, it seems quite appropriate for me to draw upon some of the interpretive insights that historical research can offer, and to focus particularly upon the ways in which the advent of "general purpose engines" may precipitate a transition to a new techno-economic regime in which significantly higher levels of productivity become attainable.

The notion of a general-purpose engine, constitutes the primitive of the more extended concept of a GPT, or "general purpose technology" - a conceptualisation that has been gaining popularity

²²⁾ The proportionate contribution attributable to the "other non-farm business" sector after making these corrections also is raised somewhat: it lies in the range from 47 to 52 percent, whereas the fraction (0.5/1.2) suggested by the figures from Oliner and Sichel (2000, Table 4), implies a contribution of 42 percent.

recently in the literature of endogenous economic growth models. According to the formulation proposed originally by Bresnahan and Trajtenberg (1995, page 84):

"Most GPTs play the role of 'enabling technologies', opening up new opportunities rather than offering complete, final solutions. For example, the productivity gains associated with the introduction of electric motors in manufacturing were not limited to a reduction in energy costs. The new energy sources fostered the more efficient design of factories, taking advantage of the newfound flexibility of electric power. Similarly, the users of microelectronics benefit from the surging power of silicon by wrapping around the integrated circuits their own technical advances. This phenomenon involves what we call 'innovational complementarities' (IC), that is, the productivity of R&D in a downstream sector increases as a consequence of innovation in the GPT technology. These complementarities magnify the effects of innovation in the GPT, and help propagate them throughout the economy".

"General purpose engines" may precipitate a transition to a new techno-economic regime in which significantly higher levels of productivity become attainable. Economists working in the spirit of the new growth theory have sought to generalise these ideas, by identifying a range of GPTs that not only find applications in diverse sectors of the economy, but which act as catalysts, inducing complementary innovations in those other sectors. The interest in generalisation has in turn stimulated efforts to extend the list of historical examples, as well as to consolidate our understanding of the defining features of GPTs (23). According to the carefully developed criteria proposed by Lipsey, Bekar, and Carlaw (in Helpman, 1998), GPTs share the following characteristics: (1) wide scope for improvement and elaboration; (2) applicability across a broad range of uses; (3) potential for use in a wide variety of products and processes; (4) strong complementarities with existing or potential new technologies.

James Watt's (separate condenser) steam engine design springs to mind readily as an example of an innovation that meets these criteria, and, indeed, it is widely accepted as the GPT that is emblematic of the first industrial revolution. One might notice that while this seminal invention dates from the early 1780s, the elaboration of steam power technology extended over the next three quarters of a century: the automatic variable cut-off device, invented by the American, George Corliss, who patented the device in 1849, resulted in very significant gains in fuel economies; it also greatly enhanced the effectiveness of this power source in applications requiring both regular continuous rotary power, and adjustment to sudden variations of the load placed on the engine.

As Rosenberg and Trajtenberg (2000), recently observed, the widespread industrial utilisation of steam power in the US was a phenomenon that properly belongs to the second half of the nineteenth century, and in considerable part was the consequence of the diffusion of Corliss' engine design. Prior to 1850 much the greater part of the stock of steam power capacity was devoted to marine transportation (steam boats on the lakes and rivers), and to overland railway transportation, rather than large-scale manufacturing. Factory production of textiles in the US had begun by

²³⁾ Lipsey, Bekar and Carlaw (in Helpman, 1998, pp. 38-43), identify an extensive list of historical and contemporary GPTs, from power delivery systems (waterwheel, steam, electricity, internal combustion) and transport innovations (railways and motor vehicles) to lasers and the Internet. The concept has been extended to encompass "organizational techniques" (the factory system, mass production, flexible manufacturing, and even the unit system for continuous process production. David and Wright (1999b), on the other hand, argue against indefinitely lengthening the list, and recommend seeking in each historical context to understand the hierarchical structure of the technological elements that were formed into systems around a core GPT.

harnessing waterpower at sites along the Appalachian "fall-line" in New England, just as England's mechanised cotton-spinning factories of the later eighteenth century had arisen initially along the swift-flowing streams of the Derbyshire dales. The great urban-industrial agglomerations of the Lancashire cotton textile industry emerged only subsequently, when the falling costs of steam-power released the mills from those rural surroundings and the constraints of inelastic local supplies of labour.

Numerous additional observations concerning the technical and economic implications of steam power would deserve a separate treatment (24). But, the line of argument I wish to develop is better served by focusing on the parallels between the modern digital computer (microprocessor) and another general-purpose engine, one that figured prominently in what sometimes is referred to as the "Second Industrial Revolution". Of course, as on previous occasions (David 1990, 1991a), I refer here to the electric dynamo (25).

5. The electric dynamo as a GPT, and the dynamics of the 1920s productivity surge

The transformation of the American factory involved more than the simple diffusion of the electric motor. A new system of manufacturing, characterised by higher and more rapidly rising efficiency, emerged. The electric dynamos of the late nineteenth century, like modern-day computers, formed nodal elements of physically distributed (transmission) networks. Both of them occupy key positions in webs of strongly complementary technical relationships that give rise to "network externality effects" of various kinds, and so make issues such as induced innovation and compatibility standardisation important for business strategy and public policy (26). In both instances we can recognise the emergence of a temporally extended trajectory of incremental technical improvements, the gradual and protracted process of diffusion into widespread use, and the confluence with other streams of technological innovation - all of which are interdependent features of the dynamic process through which a general purpose engine acquires a broad domain of specific applications. In each epoch, the successful exploitation of the new technology's evolving productivity potential has entailed the design and financing of investment projects whose novelty, in terms of scale, technical requirements, or other characteristics, posed significant challenges for the existing agencies supplying capital goods and the established capital market institutions.

The transformation of industrial processes by electric power technology was a long-delayed and far from an automatic business. It did not acquire real momentum until after 1914 to 1917, when the rates charged consumers by state-regulated regional utilities fell substantially in real terms, and central station generating capacity came to predominate over generating capacity in isolated industrial plants. Rapid efficiency gains in electricity generation during 1910 to 1920 derived from major direct investments in large central power plants, but also from the scale economies realised

²⁴⁾ For example, it may be pointed out that the greatly increased engine speeds that were attainable with Corliss-type steam engines in the closing decades of the nineteenth century, made these machines very attractive as the power source for generating electric current in the era before the emergence of the steam turbine power plant. This illustrates the general propositions (discussed below) that the process of deploying and exploiting a GPT is typically quite prolonged, and much of its economic impact derives from the confluence with, and enhancement of the benefits derived from other technological and organisational innovations.

²⁵⁾ See David (1991b), on the important economic respects in which information and electricity are not analogous; David (2000, pp. 77-82), for discussion of a number of other, mis-directed criticisms that have been leveled against drawing parallels between the computer and the dynamo revolutions.

²⁶⁾ With specific reference to the appearance of these issues in the context of network activities such as the electricity supply industry, see, for example, David (1987), David and Bunn (1988).

through integration and extension of power transmission over expanded territories. These developments were not simply matters of technology, but also reflected political and institutional changes that allowed utilities largely to escape regulation by municipal and town governments, facilitating the flow of investment capital into holding companies presiding over centrally managed regional networks. Together these supply-side changes propelled the final phase of the shift to electricity as a power source in US manufacturing, from just over 50 percent in 1919 to nearly 80 percent in 1929 (27).

But, the protracted delay in electrification was not exclusively due to problems on the supply side of the market for purchased electrical power. The slow pace of adoption prior to the 1920s was attributable largely to the unprofitability of replacing still serviceable manufacturing plants adapted to the old regime of mechanical power derived from water and steam. Coexistence of older and newer forms of capital often restricted the scope for exploiting electricity's potential. Prior to the 1920s, the "group drive" system of within-plant power transmission remained in vogue. With this system - in which electric motors turned separate shafting sections, so that each motor drove related groups of machines -- primary electric motors often were merely added to the existing stock of equipment (28). When the favourable investment climate of the 1920s opened up the potential for new, fully electrified plants, firms had the opportunity to switch from group drive to "unit drive" transmission, where individual electric motors were used to run machines and tools of all sizes.

The advantages of the unit drive technology extended well beyond savings in fuel and in energy efficiency. They also made possible single-story, linear factory layouts, within which reconfiguration of machine placement permitted a flow of materials through the plant that was both more rapid and more reliable. According to the surveys of American manufacturing directed by Harry Jerome (1934: pp.190-91), rearrangement of the factory contributed to widespread cost savings in materials handling operations, serialising machines and thereby reducing or eliminating "back-tracking".

It is important to emphasise (especially for the benefit of economists engaged in modelling the dynamics of growth driven by GPTs) that the transformation of the American factory involved more than the simple "diffusion" of a particular general-purpose engine in the form of the electric motor. Rather, a new system of manufacturing emerged from the confluence, or convergence, of factory electrification with other trajectories of industrial innovation. The transformation of American manufacturing practices during the Interwar era, quite obviously finds a modern counterpart in the "information revolution's" converging advances in the technology of semiconductors and microprocessor fabrication, in fibre-optic cables, laser applications (for reading and recording digitised data in compressed formats, and in laser-pumped broadband optical networks), low-power cellular digital telecommunication systems, and myriad innovations in computer programming and data storage and retrieval technologies.

The package of electricity-based industrial process innovations that came into use during the 1920s could well serve as a textbook illustration of *capital-saving* technological change. Electrification saved fixed capital by eliminating heavy shafts and belting, a change that also allowed factory buildings themselves to be more lightly constructed, because they were more likely to be single-

27) See David and Wright (1999a), Figure E1, and text discussion.

The transformation of manufacturing practices in the Interwar era finds a modern counterpart in the information revolution.

²⁸⁾ For further technological details see Devine (1983), and Devine (1990).

storey structures whose walls no longer had to be braced to support the overhead transmission apparatus. The faster pace of material throughput amounted to an increase in the effective utilisation of the capital stock. Further, the frequency of downtime was reduced by the modularity of the unit drive system and the flexibility of wiring; the entire plant no longer had to be shut down in order to make changes in one department or section of the factory (29). Notice too that Henry Ford's transfer-line technique, and the speed-up of work that it permitted, was a contributory element of the high throughput manufacturing regime, as were the new continuous process technologies that grew in importance during this era.

The consequent effects of factory electrification upon industrial productivity are confirmed by the sharp fall recorded in the manufacturing sector's capital-output ratio during the 1920s, a development that contributed significantly in the early twentieth-century to reversing the nineteenth century trend towards economy-wide capital deepening. A pattern of capital-saving movements emerged quite pervasively throughout American manufacturing: all but two of seventeen major industry groups experienced a fall in the capital-output ratio during the 1919-1929 interval, whereas the ratio had been rising in every one of these groups during 1899 to 1909, and in twelve of the seventeen during 1909 to 1919. Furthermore, as David and Wright (1999b), recently have shown, this increase in the average productivity of fixed capital in industry was directly associated with the electrification of primary horsepower, and that correlation became stronger in the course of 1920s.

At the same time, there was an equally pervasive surge in the growth average labour productivity. The aggregate productivity growth rate for manufacturing in the 1920s was over 5 percentage points higher than the trend rate in the previous two decades, and, rather than being concentrated in a few lines of industry, the contributions to this acceleration were very evenly distributed among all the industrial groups. With both capital productivity and labour productivity rising concurrently throughout manufacturing, it is not surprising that even when total factor productivity growth is calculated for each of the major branches - thereby making allowance for the growth in purchased inputs of energy in the form of electricity supplied by central power stations - a widespread acceleration is observed to have occurred in the rates of growth of TFP between the "'teens" and the "'twenties".

Moreover, a significant statistical relationship is found between the magnitude of the acceleration in the rate of TFP growth and the increase in the fraction of mechanical power derived from secondary electric motors. The latter ratio in this era provides an indicator of the diffusion of the unit drive system of factory electrification. Its positive cross-section relationship with the measure of acceleration in the TFP growth rate implies that at least one-half of the temporal acceleration during the 1919-29 interval can be attributed to this phase of the electrification process (David 1991a).

A "yeast-like" like process is exactly what would be expected when productivity growth is surging due to a new general purpose technology.

In terms of the metaphors recently employed by Harberger (1998), to characterise two contrasting ways in which aggregate productivity growth occurs, the 1920s productivity surge was a "yeast-like" expansion that involved essentially the entire US manufacturing sector, rather than the result of rapid efficiency gains that had popped up in a small number of industries for idiosyncratic reasons, like "mushrooms" shooting up a random places in a field. David and Wright (1999a, 1999b), recently have suggested that a "yeast-like" process is exactly what would be expected where rapid productivity

29) Schurr et al., (1990), especially pp. 29-30 and 292-93.

growth was surging under the coordinating influence of a new GPT, whereas the "mushroom-like" pattern that Harberger (1998), observed in US manufacturing during the 1970s and 1980s was more typical of interludes when the overall pace of productivity advance remained sluggish.

If we may reasonably characterise the pattern of total factor productivity advances in the US economy during the 1990s as moving from "mushrooms" toward "yeast", is there warrant for anticipating a future surge? Should we accept the view of the "new economy" as a restricted sector comprising a handful of industries that are achieving spectacular growth and productivity gains in the production of ICT-intensive goods and services? Or, discard that picture in favour of the more "yeasty", GPT conceptualisation of the entire economy being "digitally re-newed". In the following section I will conclude by venturing to tackle these intriguing questions.

6. Historical reflections on the future: from ICT productivity growth paradoxes to payoffs

We shall have to look to the further development of ICT to sustain the trend growth rate at recent levels. Fortunately, several promising technological trajectories still offer largely untapped potential. We shall have to look to the further developments of digital information technologies, and their diffusion throughout the economy to sustain the future trend growth rate of TFP at the levels that have been achieved in the US economy at the very close of the 20th century. Certainly, any further acceleration in TFP growth would have to come from that direction. This is not meant as a discouraging view, either for the US or for the western European economies. Even in the immediately foreseeable future, several promising technological trajectories appear to offer still largely untapped potentials for productivity growth, especially productivity gains of the kind that our conventional statistical indicators will be able to register.

My vision of these has not been formed simply by extrapolating from previous historical experience with the diffusion and elaboration of general-purpose technologies. Nevertheless, from the following comments on three of these emerging areas of ICT application, it will be apparent that I do anticipate the recurrence of a pervasive alteration in the bias of factor efficiency growth - toward augmenting the efficiency of conventional tangible capital inputs, and of routine labour services. The effects of this upon measured TFP in many branches of the economy would then bear a resemblance to the productivity effects associated with the diffusion of the unit drive system of factory electrification during the 1930s.

One of the more rapidly emerging among these trajectories is the much-discussed expansion of inter-organisational computing via the Internet for the mass of transactions involving purchase ordering, invoicing, shipment tracking, and payments. All of those activities presently absorb much specialist white-collar labour time, and it is not clear that its displacement can be managed so easily by companies whose day-to-day operations depend in some degree upon the un-codified expertise of those employees. Nevertheless, recent estimates indicate that in many branches of economic activity 10-15% cost savings in procurement activities will be available through the diffusion of business-to-business e-commerce. Still higher percentage cost-savings in procurement and related inter-firm transactions are estimated, not only for manufacturing, but for service activities such as freight transport, and media and advertising. Service occupations such as these might be viewed as the modern day counterparts of the ubiquitous materials-handling tasks in the manufacturing sector, which became the target of innovative dynamo-based mechanisation during the 1920s (30).

30) See David and Wright (1999b), for fuller discussion of the interrelatedness of mechanization of materials handling and factory electrification in the U.S. during the 1920s and 1930s.

A second significant cost saving trajectory is likely to emerge with the development and increasingly widespread diffusion of new, specialised, robust, and comparatively inexpensive digital "information appliances". This new generation of appliances includes not only the enhanced PDAs (personal digital assistants) that already are coming into use among PC users, but a variety of function specific hand-held devices and other specialised tools that will be carried on belts, sown into garments, and worn as head-gear. They will embody advanced microprocessors and telecommunications components that enable them to be linked through sophisticated networks to other such appliances, as well as to mainframe computers and distributed databases, thereby creating complex and interactive intelligent systems (31).

The proliferation of interconnected special-purpose applicants of this sort also is likely to be reinforced by "network externality" effects upon demand, and so would expand new market niches for vendors of successive generations of "computer-related" hardware - the quality-adjusted prices of which are likely to fall far faster than the costs of the inputs used in their manufacture (32). But perhaps even more significantly, this emerging trajectory of convergent information and communications technology developments is one that is likely to directly impinge upon the performance of workers equipped with such devices, and hence boost conventional measures of productivity improvement in a widen array of industries.

The diffusion of tele-working represents a third trajectory with a potential to yield substantial longterm gains in measured total factor productivity, most notably from savings in infrastructure capital, as well as through the reduction of the costs of measures required to abate pollution and environmental degradation in congested urban areas. At present, "tele-working" remains still far from fully deployed in the US: only about a fifth of the workforce time in large service sector firms are providing data communications network links with employees' homes, and many of those are trying out "mixed systems" of central office and "outside" work. As was the case historically with the group drive system of factory electrification, substantial duplication of fixed facilities characterises this stage in the new GPT's diffusion. So, significant capital-savings through reductions of required commercial office space and transport infrastructures, are likely to result for the whole service sector only as "tele-working" becomes much more widely and completely deployed. Moreover, many of the workers who are participating in tele-working continue to travel on some days in the week to company offices where they share a "hot desk" with co-workers who are on a different schedule. In such situations, the promised productivity gains derived when workers are relieved of the wear and tear of extended "commutes" remain at best incompletely realised.

It remains a good bet that economists who continue proclaiming their scepticism about the information revolution's ability to deliver major long-term productivity pay-offs are going to be proved wrong.

For these and still other reasons, it remains a good bet that economists who continue proclaiming their scepticism about the information revolution's ability to deliver major long-term productivity payoffs are going to be proved wrong. Yet those payoffs will not come freely; they will entail much learning and further, costly organisational adaptations. Nor should they be expected to materialise overnight - even if a domestic macroeconomic environment conductive to long-term investment were to be maintained, and were we lucky enough to escape real and financial shocks in the international economy.

³¹⁾ See Gibbs (1997), and especially Norman (1998), Chapter 11.

³²⁾ The implication, then, is that analysts who apply the "dual" approach to measuring the rate of multifactor productivity, such as Oliner and Sichel (2000), for example, are likely to find this growing branch of manufacturing "contributing" to the aggregate TFPgrowth rate as the "vertically integrated computer sector" presently does.

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Measuring economic growth and the new economy

"In essence the question of growth is nothing new but a new disguise for an old-age issue, one which has always intrigued and preoccupied economics: the present versus the future". – James Tobin, AER, 1964



Patrick Vanhoudt



Luca Onorante

1. Introduction

For years the economics profession has been puzzled by one of the most perplexing economic problems – the overall slowdown in the growth rate of labour productivity since 1973. Not only was the deceleration a worldwide trend, the growth of productivity also turned out to be markedly slower in the US than in any other industrialized nation. In spite of many hypotheses, the phenomenon has remained, however, much of an academic mystery, often labelled with the analogy "death from a thousand cuts".

Yet today a reverse situation seems to have occurred. The contemporary brainteaser is indeed no longer why the US has been suffering from the slowest expansion of output per worker among the highly developed economies. Now the question is rather how the rapid increases in US labour productivity in the 1990s can be explained, and why other nations do not perform equally well.

At least there are some new hypotheses. Especially in the non-academic literature the most fashionable catchphrase is that a "new" economy has arrived in – and that it has been limited to – North America. Many commentators have now come to the belief that the prolonged expansion of the 1990s in the US owes something to innovative production and distribution processes, allowed by the use of computers, electronics and telecommunications in general, and to the wonders of the Internet in particular.

There may be some truth in this view. However, the cornerstone of the new economy idea – new technologies make firms more productive – is fiercely debated. Robert Gordon (2000), for instance, reports that in the US, productivity growth has been concentrated almost exclusively in the 1% of the economy that produces computers. Thus, computers have boosted productivity in the (re)production of more computers, but have not fostered comparable gains in other sectors of the economy. While Gordon's study cannot rule out future productivity increases, it debunks the celebrated conjecture that information and communication technology (ICT) productivity will trickle down to the whole economy – that is at best yet to come, but far from ascertained.

The current article adds to the growing literature that asks whether the performance gap between Europe and North America is really so large. Our main point is one of measurement issues. To be precise, we will document that a recent change to the system of business and national accounts, in combination with a different way of deflating ICT investment, may have substantially distorted perceptions regarding productivity growth. Against this background we will be able to put Europe's economic performance somewhat better into perspective.

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This paper investigates to what extent changes in statistical definitions have influenced measures for economic growth. In order to do so, the paper is organized as follows. In the next section we will more rigorously define what we mean by a new economy, and investigate whether the official data confirm the implications. The main point, however, will be made in Section 3. Here, the latest modification to the system of national accounts is introduced. Also the impact of a hedonic deflator for ICT investment is presented. Against this background it is then investigated to what extent such changes may have affected measured total factor productivity growth. A final section summarizes and concludes.

2. The new economy gospel

What is in fact meant by a *new* economy? The popular buzzword has meanwhile been rigorously narrowed down in mainstream economics, as an economy in which *continued* – as opposed to temporary – gains in efficiency induce a more rapid expansion of labour productivity than in the economy that preceded it. As a consequence, at any given growth rate inflationary pressures are lower, and the NAIRU is also lower.

Thus, in a new economy one would like to observe a *permanent* upward trend shift in both total factor and labour productivity *growth*, without inducing higher inflation (1). But before we dive into deeper new economy waters to test these hypotheses, it is perhaps worth explaining why labour productivity growth is so crucial to an economy.

2.1 Why labour productivity growth is crucial to an economy

The following simplified identity may be helpful to answer this question.

 $\frac{\text{output}}{\text{hour}} = \frac{\text{wage}}{\text{hour}} = \frac{\text{profit}}{\text{hour}}$

The identity merely says that in equilibrium firms will charge a mark-up over the wage cost when selling their turnover. In a capitalist environment – and in the absence of large productivity shocks that would induce substitution of capital for labour – competition and arbitrage possibilities will force profit rates to be fairly stable in the aggregate. Real wages and labour productivity must then clearly go hand in hand. Since most people receive the lion's share of their income from wages and salaries, productivity growth will hence determine how fast living standards are able to increase. Combined with the growth rate of the labour input (numbers of hours worked), the rate of growth of labour productivity also indicates how rapidly the economy's capacity to supply goods and services is increasing. The resulting figure is, of course, nothing but the growth rate of potential real GDP.

¹⁾ In fact, the definition also has two implications for the labor market performance. Firstly, the relation between growth and unemployment ("Okun's law") should show a significant change in a "new" era. Okun's law refers to the fact that as output rises in a cyclical recovery, additional workers are hired to produce it. As output falls in a recession, some workers are no longer needed and temporarily lose their jobs. This relationship thus is an obvious feature of the supply side of the economy, in the absence of productivity shocks. New technologies that would produce a benefical productivity shock - thereby triggering off a "new economy" - will clearly not affect this cyclical regularity. What would change is that the break point - the rate of growth at which unemployment neither raises nor falls - would become higher. Casual inspection of the data does not seem to suggest such a shift (see, for example, Krugman 1997). Secondly, the natural rate of unemployment should be affected.

So what can a society do to raise labour's productivity? There are – no more and no less – four alternatives:

- Physical capital deepening i.e. to equip its workers with more and better physical capital (machines, tools, infrastructure and the like);
- Knowledge capital deepening i.e. to improve the quality of the workforce through education and training;
- Foster a new economy i.e. to improve the productivity of all the factors by introducing new technologies, so that given inputs produce more output;
- Grease the institutional cogwheels i.e. to facilitate the working of the labour market, to limit
 economic distortions caused by taxes and passive labour market policies, to facilitate access to
 capital markets and so forth.

There are a number of European countries that outperform the American "new economy" as measured by the increases in TFP growth. The first two options imply that some resources will be forgone and re-injected in the economy under the form of several types of investments. As a result more output will be reaped in the next period. Most empirical cross-country exercises tend to conclude that – together with a smooth working and competitive institutional setting (option 4) – continuous investment by the business sector has in fact been the most important force behind labour productivity growth in the "old" economy times (see e.g. Mankiw, Romer and Weil, 1992, or Barro and Sala-I-Martin, 1995). A previous edition of the *EIB Papers* (2000) has tackled this issue in greater detail. A "new" economy, by contrast, would be mainly characterized by a shift in total factor productivity growth – as mentioned in option 3 – due to network affects and the like. In the next section we will, therefore, focus on the structure behind labour productivity growth, that is, on the importance of capital deepening versus total factor productivity growth.

2.2 Casual empiricism

The official statistics on US growth performance have shown an astonishing performance for quite some time. With the current phase of expansion having started off in March 1991, the country's real GDP growth has increasingly outperformed the ones observed in the EU until mid-2000 (see Figure 1). For a mature economy, such a sustained accomplishment is unusual. Moreover, the United States have experienced a cycle that goes well beyond the economy's typical average of 45 to 50 months, and even surpassed what was observed in the golden 1960s.

The surge in real labour productivity growth, however, mainly took place in the second half of the 1990s. The left panel in Figure 2 reveals for instance that the US was consistently lagging behind Europe until 1996 regarding its growth of output per worker. By contrast, in the second half of the 1990s the US trend has boosted well beyond what was observed across the Atlantic. Also the evolution of the trends is interesting. Whereas the EU has experienced a continuous slow down in real labour productivity growth, the US figures now fluctuate around 2.5 percent – more than twice as much as what was observed in the 1970s and the 1980s.

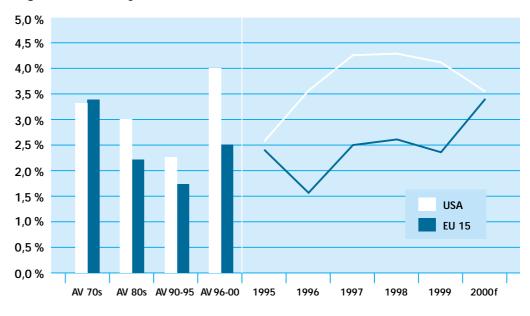


Figure 1. Real GDP growth

Source: AMECO

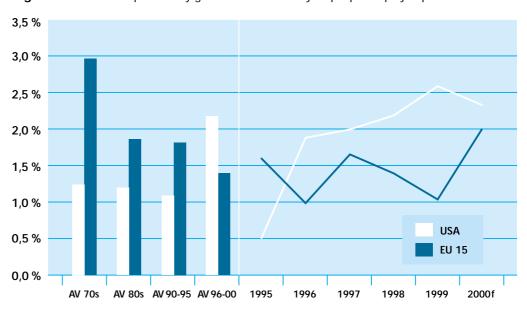


Figure 2. Real labour productivity growth as measured by output per employed person

Source: Staff calculations based on AMECO

Yet it would be too easy to infer from such a casual look at the official data that a fundamentally "new" economy is to stay in the US, or is skipping Europe. As we pointed out earlier, one should at least disentangle the performances into effects from capital deepening and other – fundamentally "new" – factors.

Business of	cycle	Duration in months				
Trough from previous Peak	Trough to Peak	Contraction	Expansion			
October 1945	November 1948	8	37			
October 1949	July 1953	11	45			
May 1954	August 1957	10	39			
April 1958	April 1960	8	24			
February 1961	December 1969	10	106			
November 1970	November 1973	11	36			
March 1975	January 1980	16	58			
July 1980	July 1981	6	12			
November 1982	July 1990	16	92			
March 1991	???	8	117 (December 2000			
Average,	all cycles					
1854-1991	(31 cycles)	18	35			
1945-1991	(9 cycles)	11	50			
Average, pea	ce time cycles					
1854-1991	(26 cycles)	19	29			
1945-1991	(7 cycles)	11	43			

Table 1. Length of American business cycles in the "old" and "new" economy

Source: Table taken from the NBER "US Business Cycle Expansions and Contractions".

Note: The NBER does not define a recession in terms of two consecutive quarters of decline in real GNP (i.e. negative growth). Rather, a recession is a period of significant decline in total output, income, employment, and trade, usually lasting from six months to a year, and marked by widespread contractions in many sectors of the economy.

2.3 A "new" economy? Capital deepening versus a structural change in total factor productivity

Perhaps the best tool in order to grasp the driving sources behind growth performance still is the old – yet elegant and well-established – technique of growth accounting. In this section we will present the results of such an exercise.

The standard framework starts off from the assumption that the evolution of output in the economy can be adequately captured with a production function of the Cobb-Douglas type:

(1)
$$Y_t = A_t \cdot K_t^a \cdot L_t^{1-a}$$

where Y_t , K_t and L_t denote respectively output, physical capital and labour. The term A_t reflects efficiency gains that are not due to changes in the amount of employed production factors, and is referred to as total factor productivity (TFP). Note that this variable can capture anything ranging from technological change, over changes in the quality of labour to a more efficient institutional

A "new" economy is characterised by a permanent upward shift in total factor productivity growth. setting. While the parameter α denotes the degree to which the accumulation of production factors is subject to diminishing marginal productivity, the sum of the exponents for *K* and *L* reveals the extent to which there are returns to scale.

Moreover, if perfect competition prevails, then the marginal product of each input equals its factor price, so that:

- (2) $\alpha = \frac{r \cdot K}{Y}$, the share of capital in output;
- (3) $1-\alpha = \frac{w \cdot L}{Y}$, the share of labour in output

with r and w respectively the rate of return to capital and the wage rate.

Dividing both sides of the production function by the number of employed people yields an expression for labour's productivity:

(4)
$$\frac{Y_t}{L_t} = A_t \cdot K_t^a \cdot L_t^{-a}$$

Taking logarithms and differentiating with respect to time results in growth rates (), which leads us to the following decomposition for labour productivity growth:

(5)
$$\underbrace{Y_t}_{L_t} = A_t + \alpha \cdot K_t - \alpha \cdot L_t$$

Thus, productivity growth ($_{Y/L}$) is the weighted sum of the percentage change in the net capital stock ($_{K}$) and employment ($_{L}$), plus the progress in total factor productivity ($_{A}$).

Other things being equal, a new economy would imply that its rate of growth of TFP ($_A$) would have settled at a higher level and explains now more of the labour productivity than before. Does it really? At least this framework suggests a straightforward way to check these hypotheses. From the previous equation it follows that TFP growth can be computed as the difference between labour productivity growth and the rate of change of the capital stock and the labour supply – each weighted accordingly.

Data on real labour productivity, employment and capital are readily available from the national accounts, for which we rely on the official AMECO database produced by the European Commission's DG EcFin. Time varying factor shares can be computed from that source, too. For instance, to obtain labour's share $(1-\alpha)$ it suffices to divide the wage-sum by GDP – this value is typically round 2/3.

It should be noted that in these computations one assumes that the economy is operating at full capacity. Hence, some cyclical differences may affect the results and persistent underutilisation of some factors of production (i.e., EU unemployment) can also distort the overall picture. Another drawback of the approach is that all forms of capital are supposed to yield the same economic rate

to return. Presumably public capital, private durables and ICT equipment differ in that respect substantially.

Bearing in mind these limitations, the implications of this exercise for TFP growth in the EU and the US are graphically presented in Figure 3. Table 2 below unveils the absolute and relative importance of both capital deepening and changes in TFP in the developments of their labour productivity over the last decades. The figures suggest that the TFP growth pattern and that of real GDP go hand in hand in recent years.

				Capit	al Deep	ening				
	Absolute contribution, in percentage points				% of LP growth					
	70s	80s	90s	90-95	96-00	70s	80s	90s	90-95	96-00
US	0.37	0.28	0.48	0.37	0.63	29.13	22.76	29.45	32.17	28.38
EU	1.16	0.66	0.68	0.87	0.44	39.59	36.46	42.50	48.88	31.88
				+ T	FP grov	vth				
	70s	80s	90s	90-95	96-00	70s	80s	90s	90-95	96-00
US	0.90	0.95	1.15	0.78	1.59	71.87	77.24	70.55	67.83	71.62
EU	1.77	1.15	0.92	0.91	0.94	60.41	63.54	57.50	51.12	68.12
			= Re	al labou	r produc	tivity gro	owth			
	70s	80s	90s	90-95	96-00	70s	80s	90s	90-95	96-00
US	1.27	1.23	1.63	1.15	2.22	100	100	100	100	100

Table 2. Labour productivity (LP) growth in the EU and US decomposed

Note: Capital deepening is the contribution of capital-contribution of labour. Source: Author's calculations based on AMECO data.

1.78

1.60

The results also suggest a structural change in measured TFP growth in the US since 1996. It should be noted, though, that TFP continues to account for most of the labour productivity growth with a rather constant order of magnitude – it has explained a good 70 percent of the growth figure in the US and 60 percent in the EU throughout the last decades. The striking observation, however, is that both the contributions of TFP and capital deepening virtually doubled across the Atlantic during the last part of the 1990s. Recent research on the US economy reinforces our findings, as indicated in Table 3. The fast acceleration of TFP in the US needs to be contrasted with the rather stagnant TFP growth rate in Europe, and a falling capital deepening effect due to sluggish investment (2).

1.38

100

100

100

100

100

Nonetheless, the position of the EU should be put somewhat into perspective. For instance, it turns out that if one does a similar exercise at the level of Member States, a cluster can be detected that outperforms the American "new economy" as measured by the increase in TFP growth. Figure 4 reveals that this cluster mainly contains the Nordic countries, and also includes Ireland and

A striking fact is that TFP growth and capital deepening virtually doubled in the US in the last part of the 1990s. EU

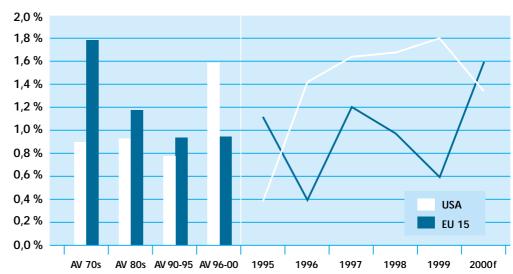
2.93

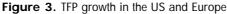
1.81

²⁾ For instance, public investment went down from roughly 3 percent of EU GDP in 1990 to about 2 percent in 1998, because of restrictive fiscal policies due to EMU. See the EIB Papers (2000).

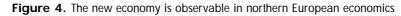
US labour productivity growth lagged behind Europe until 1996. However, the trend in US has been strongly reversed since then, whereas the EU has been facing a further slow down. Luxembourg. The Netherlands and the UK follow the US closely, but their TFP growth has fallen somewhat behind what was observed in the 1970s. The largest EU economies, by contrast, have clearly suffered from a lower gear of their long-run growth engine compared to the 1970s. They have also experienced less acceleration in TFP growth than the other EU countries, which obviously affects the average for Europe as a whole negatively.

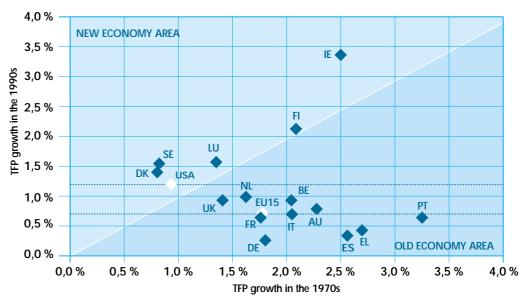
Finally, more refined calculations for TFP growth – that in various ways aim to correct for enhancements in human capital and labour force participation – turn out to be somewhat lower in general, but the pattern is the same.





Source: Staff calculation based on AMECO





	Contribution of TFP growth to LP growth in US			
	Period	not adjusted for labour quality	adjusted for labour quality	
	1990-00	1.15 %	_	
This study	1990-95	0.78 %	_	
	1996-00	1.59 %	-	
Scarpetta et al (2000)	1990-97	1.00 %	0.80 %	
Jorgenson and Stiroh (2000)	1990-98	0.97 %	0.63 %	
CEA * (2000)	1990-99	1.20 %	-	
Oliner and Sichel * (2000)	1990-95	0.79 %	0.37 %	
	1996-99	1.46 %	1.14 %	
Bassanini <i>et al,</i> (2000)	1995-98	1.50 %	1.40 %	
Gordon (2000)	1995-99	1.79 %	1.25 %	

Table 3. Findings for US TFP growth rates

Note: *: non-farm business.

Can it be true that the new economy pattern is in part due to differences in accounting principles? Hence an interesting fact remains: the US growth performance in terms of its total factor productivity – however measured – shows a much better picture since 1996 than what was recorded in earlier periods. Yet, if Gordon (2000), is right American TFP growth did not show up because of ICT network effects or external benefits that trickled down in the whole economy. According to his analyses it was rather the result of unusual growth in demand for computers and software. But is it really a mere coincidence that the principal acceleration in TFP growth happened in 1996 (see Figure 2)? Wouldn't one have expected a smoother transition given the fact that ICT equipment has been operational in the economy for decades already? To answer this, let us pursue here a different line of thought: can it be true that the recent apparent "new" economy pattern is due to differences in accounting principles?

3. A "new" economy? The impact of recent definitional changes in accounting principles

Three events may give this hypothesis at least some credibility. Firstly, private businesses have been allowed to capitalize software expenditures only since 1996. That is, whereas outlays for in-house developed as well as licensed and pre-packaged software were treated as any other business expense before 1996, they can now be amortized over their expected life time (see the Financial Accounting Standards Board). Such definitional changes will henceforth result in apparently rapidly increasing business investment when software expenditures grow swiftly, even when the quantity of goods produced per worker and total factor productivity remain constant. Secondly, the comprehensive revision in 1999 of the American National Income and Product Accounts (NIPAs) and their European counterparts (ESA) (3)

³⁾ ESA is the Union's version of the United Nations system of national accounts (SNA), for which the guidelines are described in the United Nations' publication A System of National Accounts (SNA). This document was first released in 1968 and substantially revised in 1993 under the auspices of the Intersecretariat Working Group on National Accounts, which consists of officials from the OECD, the International Monetary Fund, the United Nations Statistical Division, the World bank and the Commission of the European Communities. The first edition of the ESAwas in principle applied from 1970 (ESA70) and was followed by a second edition in 1970 (ESA79). In 1999, the third edition of the ESA(ESA95) was launched, and the new definitions are applicable for data starting from (at least) 1995. Eurostat collects ESA data by means of standardised questionnaires 6-13 months after the end of the year. When Member States do not provide all the required information, Eurostat attemts to produce estimates for the values, based on comparable trends and recent information.

have only recently started to recognize outlays for software as gross fixed capital formation. Spending on software did not contribute to measured investment prior to these revisions, because it was considered to be an intermediate input like raw materials or electricity. Thirdly, since 1996 the US has moved away from using traditional deflators for IT and software.

The US national accounts have been modified to incorporate software outlays in aggregate investment. Europe has only recently begun to implement such definitional changes. In what follows, it is useful to bear in mind that real GDP is computed as the sum of real consumption, real investment, real government expenditures and real net exports. Real labour productivity is subsequently derived as real GDP per worker (or per hour worked). Obviously, the change in accounting principles affects both nominal and real investment aggregates (gross fixed capital formation). In the rest of this section we will document in somewhat more detail how severely the aggregates have been influenced, after which we will analyse the impact of such modifications on measured TFP growth.

3.1 Software outlays are now considered as gross fixed capital formation

Both the private sector and the government spend large amounts each year on information technology. A study by the Bureau of Economic Analysis (Parker, 2000) reveals for instance that in the US, outlays on "hardware" (computers and peripheral equipment) amount to nearly 10 percent of that nation's non-residential investment – the equivalence of about 1 percent of its GDP.

Estimates show that current dollar investments for software by businesses and government increased rapidly from very small amounts in the late 1950s to about 1 billion USD in 1966. It continued to grow swiftly to more than 10 billion USD beginning 1979, and to some 180 billion in 1999 – that is roughly 2 percent of nominal GDP. Although growth rates have been large, they have diminished over time until the mid 1990s and increased rapidly thereafter.

Period	Nominal growth		
1960-69	33.2%		
1970-79	17.1%		
1980-89	16.1%		
1990-99	15.4%		
1990-94	10.5%		
1995-99	21.6%		

 Table 4. Nominal average annual rates of growth for software investments in the US

Source: Parker, 2000.

All this makes, of course, that in addition to a level effect, shifting estimated software outlays from expenditures to investment also has an effect on rate of change of aggregate gross fixed capital formation. As a result, the revised treatment of software has increased the growth rate of GDP beginning with the first available year for software estimates in 1959. The impact of the changes on nominal GDP growth is presented in Figure 5, which shows a gain of about 1 percentage point to measured GDP growth during 1995-00.

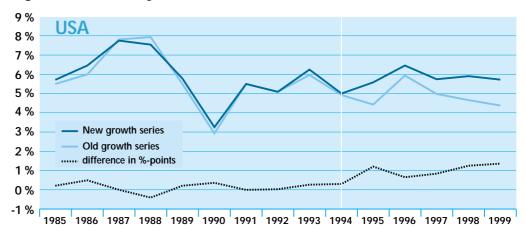
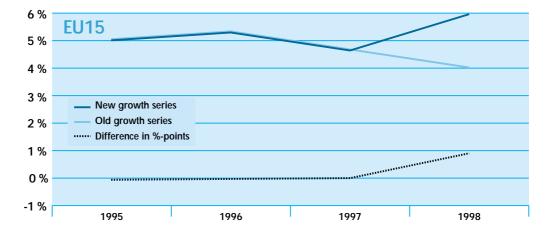


Figure 5. Nominal GDP growth, new versus old NIPAs



Source: New Cronos, Eurostat.

Unfortunately the European System of Integrated Economic Accounts (ESA) has not yet gone through similar updates. That is, the framework has been developed (ESA95) and passed on to the Member States, but the actual data collection has only started recently. Based on rough estimates, the series on gross fixed capital formation has been recomputed back to 1995 to recognize software and hardware as investment. The collected information so far indicates that the benefits of measuring the EU economy better show up only as from 1997.

3.2 Hedonic pricing of ICT equipment and software since 1996

In order to disentangle what part of the increase in nominal GDP is due to higher quantities, rather than to higher prices, one needs to correct for inflation of the various components of GDP. Statistical offices therefore build up the major aggregates from a large number of disaggregated component series, for which price information is collected at the same time. Real GDP at market prices is later constructed by adding up all the deflated aggregates. Yet cross-Atlantic differences for the computation of these deflators – in particular for ICT-equipment and software – importantly bias real growth and TFP comparisons between the EU and US.

One difficulty in splitting nominal increases in expenditures in their real and price components arises from changes in the quality of goods. This is a particular acute problem with ICT given the

Cross-Atlantic differences in deflators used for the computation of real investment in ICT may bias the comparison of real productivity growth in the EU and US rapid technical advances that there have been. In the United States a so-called hedonic pricing mechanism – a theory pioneered by Zvi Grilliches, 1961 – has been employed for ICT goods since 1996. The main assumption behind the hedonic pricing technique is that the quantity of a particular commodity may be resolved into a number of characteristics that determine its quality. By means of regression analyses, part of the price is subsequently associated to each of the characteristics, so that variations in quality may be valued. For instance, suppose that a computer costs EUR 1 500 this year, and that one would pay the same price for a computer next year. However, the new PC would come with a processor of twice the capacity. Under a traditional method, the computers would be treated as the same volume with the same price. In a simplistic one-characteristic hedonic way, the real volume would have doubled while the price would have fallen to one-half.

The hedonic method is the main reason why the statistical price of computers has collapsed in the United States – notably by as much as a cumulative 80 percent in the 1990s (see Figure 6). Such fast decreases imply, of course, swiftly rising *real* IT expenditures and investment, which contribute to a higher measured *real* GDP. By contrast, the modest fall or even slight increases in producer prices of office, accounting and computing equipment in many European countries may be due to the predominant "conventional" method in deriving price indices. But just how different are the methodologies in Europe in this respect? A Task Force at Eurostat has tried to take stock of the discrepancies regarding the used approaches in the participating countries. Table 5 summarizes their findings, and has been augmented with information obtained from a study by the Board of the Federal Reserve, 2000.

Country	Hedonic Price Index?	Source	
Austria	No **	Eurostat	
Belgium	No	Fed	
Denmark	Yes *	Fed	
Finland	No	Fed	
France	Yes	Eurostat	
Germany	No	Eurostat	
Ireland	No	Eurostat	
Italy	No	Fed	
Netherlands	No	Fed	
Spain	No	Fed	
Sweden	Yes *	Eurostat	
UK	No **	Eurostat	

 Table 5. Deflation practices for IT hardware in the Union

Source: Eurostat, 1999, Federal Reserve Board, 2000.

*: Uses current US hedonic index, exchange-rate adjusted.

**: Quality adjustments are done on a judgemental base.

In order to make the relative position of the US vis-à-vis the EU regarding real IT investment somewhat more comparable, we have computed an IT price index as nominal IT expenditures divided by number of shipments of new computers. The resulting "average" prices are contrasted with the hedonic series in Figure 6. Our index is clearly the opposite of a hedonic deflator, as it does not correct for quality changes whatsoever. But then again, with mainly new whistles and bells appearing in updated versions of software packages, have we really been doing different and more productive things over the last decade as newer generations of computers became available? Although correcting for quality improvements is attractive, hedonic pricing has indeed been criticised along these lines (see Gordon, 2000, for example). The discussion is unfortunately too cumbersome and would bring us beyond the scope of this paper.

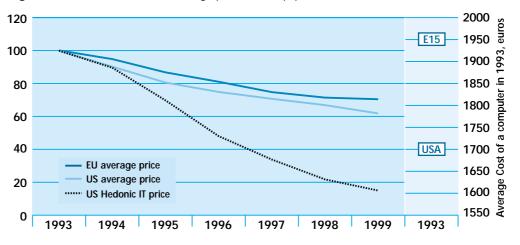


Figure 6. A hedonic versus an average price for IT equipment

Source: OECD, 2000 and Staff calculations based in EITO 2000 data.

However, the interesting tendency that appears from our exercise is that real IT investment has grown only little faster in the US than in the EU if one uses a common average price (4) (see Figure 7).

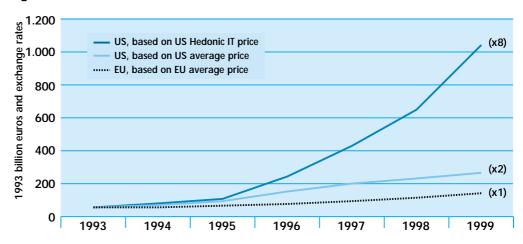


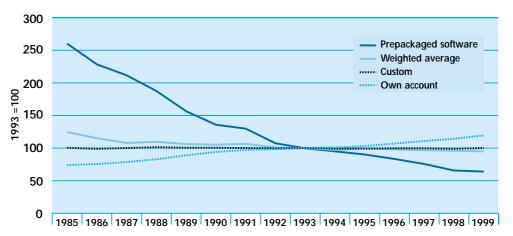
Figure 7. Real IT business sector investment

Note: IT business sector investment as a percentage of IT spending is taken from Daveri, 2000, who provides data for 1992 and 1997 (respectively 42.1 and 41.6 for the EU, and 36.4 and 44.3 for the US). To obtain investment figures, these data were interpolated in a linear way for other years, and then multiplied with IT expenditures as reported in EITO, 2000. The resulting series was subsequently deflated using the price indices reported in Figure 6.

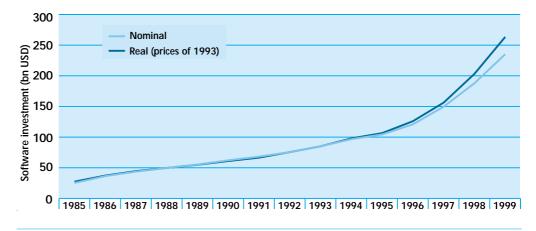
4) In 1996, the US Department of Commerce also began using a new method to construct all aggregate "real" series in the NIPAs, that employs the so called "ideal chain index", which to some extent softens the hedonic impact. Whelan, 2000, shows however that mistaken calculations with the new "real" NIPAs have become very common. A more careful treatment of these data shows for instance that, in terms of actual dollars spent, the increase in the role of information technology has been more modest than one might think: "While the (essentially meaningless) ratio of real 1992-dollar information processing investment to aggregate real equipment investment goes from 0.07 in 1970 to 0.50 in 1998, the corresponding nominal ratio only changes from 0.22 to 0.34 over the same period. As a result of the introduction of software as a capital asset in the October 1999 revision, the most recent NIPA data show this share increasing from 0.24 in 1970 to 0.44 in 1998".

As regards software, three different types are distinguished: 1) pre-packaged software - i.e. software intended for non-specialized uses, sold or licensed in standardized form - 2) own-account software software developed within a company for their own use by means of in-house expenditures - and 3) custom software - a mixture of new programming and existing programs or program modules that are incorporated into new systems, tailored to the specifications of a business enterprise or government unit. The deflators used for each category vary between the two extremes. Price corrections for pre-packaged software, for instance, are done in a hedonic way. For own account software investments, an input-cost index is used that is calculated from a weighted average of a) compensation rates for computer programmers and system analysts and b) the intermediate inputs associated with their work. Finally, the price index for custom software is constructed as a weighted average of the previous two. The weights, which are selected arbitrarily, are 75 percent for changes in business own-account software prices and 25 percent for changes in pre-packaged software (see Parker, 2000). The various price indices are shown in Figure 8. With pre-packaged software accounting for roughly 30 percent of the total in the 1990s, the average price deflator for recent software investment is for nearly two-thirds estimated under the assumption of no gain in productivity. As a result, the difference between nominal and real investments for software is not as spectacular as that observed for hardware (see Figure 9).





Source:Parker (2000).





In sum, although the new system of national accounts may perhaps describe the economy better than the old one, the combination of using a rapidly falling hedonic price deflator for hardware and – to a more limited extent – software investments also has an important drawback. It introduces a potentially serious bias in international comparisons with countries where such techniques are not (yet) used.

3.3 Do modifications in the accounting principles affect measures for TFP growth?

Let us now come back to our initial question: can it be true that the gap between the EU and US in terms of an apparent "new" economy pattern – a surge in TFP growth – is in part caused by simple accounting principles? If so: how much is attributable to measurement issues?

In order to investigate this, recall that TFP growth is typically computed in a neoclassical framework as described earlier. Thus, what we need to investigate is twofold. Firstly, how are measures for changes in TFP and capital deepening in a growth accounting exercise affected by adding software expenditures to both GDP and the capital stock? Secondly, how does the deflator for software and hardware influence those measures?

The formal derivations of the impact of such changes on growth accounting outcomes are presented in the Box. Apparently a more rapid price decline for information technology has two direct effects on the sources of growth. The intuition is that adding in software investments as well as the alternative investment deflators raises real output growth by reallocating nominal growth away from prices towards quantities. In addition, larger investment quantities each year increase the growth rate of the capital stock. Since output is not a linear function of the capital stock, the modifications may have an impact on both capital deepening and TFP growth. It is worth stressing that changes in the accounting principles as well as pricing hedonics permanently revise measured TFP growth and the capital deepening effect upward.

Guestimates based on plausible numbers for the US economy reveal that the impact of these changes in definition was non-trivial. For instance, the Box shows that the theoretical gains of adding software for the period 1996-98 mounted to slightly over four tenths of a percentage point for TFP growth – hedonics added another two tenths of a percentage point. The impact on capital deepening has remained small.

As for the acceleration of TFP and capital deepening between 1990-95 and 1996-98, the final effect is significant. If one adjusts for pricing hedonics, the "real" acceleration is at best only half the size of what the current official data reveal. The change in capital deepening drops to zero if one also filters out the impact of adding software, and, in that case, the increase in TFP stands only at a quarter of the officially measured acceleration. With these findings we are now better able to compare like with like, that is, to compare the growth accounting findings for the EU with the corrected ones for the US. Table 6 reports these results – more details can be found in the Box.

Table 6. The impact of definitional changes

1996-98	Capital deepening	TFP growth	LP growth
US official data	0.43 %	1.60 %	2.03 %
less impact of hedonics =	0.41 %	1.19 %	1.60 %
less impact of software =	0.37 %	1.02 %	1.39 %
EU official data	0.45 %	0.84 %	1.29 %

The various statistical alterations permanently revise measured capital deepening and TFP growth upwardly. The stagnant TFP growth for the EU as a whole that arises from a casual look at the official data should therefore be interpreted with great caution, and should not be taken as a dramatic fall behind yet. Based on TFP growth performances our findings rather suggest that the "Nordic cluster" in Figure 3 – where hedonic pricing is not used apart from Denmark and Sweden – may perhaps be a better example of a "new" economy than the US.

4. Conclusion

In this paper we started off from the observation that official data reveal an extraordinary shift in US total factor productivity growth (TFP) in 1996, which led to important gains in labour productivity growth in the second half of the 1990s. Europe as a whole did not benefit from such a structural break. The continent's national accounts rather show a stagnant TFP growth, and a falling capital deepening effect. However, it was shown that a Nordic EU cluster substantially outperformed the US in terms of TFP growth in the 1990s.

At the same time, swelling expenditures for ICT have gone hand in hand with a surge in the American economic performance. The perception therefore is that the growth of digital economic activities has been unprecedented and has been a major contributor to this phenomenon. Since Europe's business investment in IT is lower than the one observed in the US, the fear is that the EU will fall behind regarding labour productivity growth.

We then wondered whether it was really a mere coincidence that the principal acceleration in American TFP growth happened precisely in 1996. After all, one may have expected a smoother transition given the fact that ICT equipment had been operational in the economy for decades already. The line of thought that was followed subsequently raised the question whether the structural shift may have had something to do with the change in business and national accounting principles – now software expenditures are considered to be fixed capital formation – and the move away from traditional deflators towards hedonic pricing techniques. All these events incidentally also started in 1996, but the hedonic pricing techniques are not yet adopted by the Member States (except for Denmark, France and Sweden).

Our analysis shows that such definitional changes do have an impact on measured TFP growth – they will *permanently* revise TFP and labour productivity growth upwards. Guestimates based on recent data reveal that the bonus has been four tenths of a percentage point since 1995. Hedonic pricing has added another two tenths of a percentage point. In any case, the accelerations in TFP growth are at best only half the size of what is implied by the official data.

In international comparisons one should compare like with like. If one corrects for differences in definitions, the gap between the EU and US becomes smaller.

Our results do not intend to put the recent statistical changes in a bad daylight – the modifications undoubtedly contribute to a more accurate measurement of the economy. However, international comparisons should compare like with like. We documented that if one does correct for the increase in growth due to changes in definitions, the gap between the EU and the US becomes smaller. The trend in TFP and labour productivity growth in the US remains, however, positive.

Box 1. Impact of the definitional changes on TFP growth and capital deepening

Let Y_{old} denote real GDP and K_{old} the capital stock –i.e. the sum of non-IT and IT equipment – before software outlays were added as investment. Clearly,

$$Y_{new} \equiv Y_{old} + \frac{S}{p_s}$$
 and $K_{new} \equiv \frac{K_{old}}{p_K} + \frac{S}{p_s}$.

In these definitions S stands for the current stock of software capital with the associated price level $p_{S'}$ while p_K symbolizes the weighted average price level for total capital. Hedonic pricing of IT-equipment obviously has an impact on p_K proportional to the weight of IT in the total capital stock. In terms of a growth accounting exercise, the production function now is:

$$\mathbf{Y}_{\text{new}} \equiv \mathbf{Y}_{\text{old}} + \mathbf{S}/\mathbf{p}_{\text{S}} = \mathbf{A}_{\text{new}} \cdot \left(\mathbf{K}_{\text{old}}/\mathbf{p}_{\text{K}} + \mathbf{S}/\mathbf{p}_{\text{S}}\right) \alpha \cdot \mathbf{L}^{1-\alpha}$$

Consequently, the level of labour productivity that needs to be decomposed reads:

$$\frac{Y_{new}}{L} \equiv \frac{Y_{old}}{L} \cdot \left(1 + \frac{S/p_S}{Y_{old}}\right) = A_{new} \cdot \left(\frac{K_{old}/p_K}{L}\right)^{\alpha} \left(1 + \frac{S/p_S}{K_{old}}\right)^{\alpha}$$

In what follows we will use lower case letters to denote per capita variables. Taking logs and time derivatives, and using the approximation $\ln(1+x)\approx x$, yields an expression for the growth rate of labour productivity (g_v) :

$$g_{y_{new}} \equiv g_{y_{old}} + \frac{d}{dt} \left(\frac{S/p_S}{Y_{old}} \right) = g_{A_{new}} + \alpha \cdot \left(g_{k_{old}} - g_{p_K} \right) + \alpha \cdot \frac{d}{dt} \left(\frac{S/p_S}{K_{old}/p_K} \right)$$

After having worked out the time derivatives, one finally obtains:

$$g_{y_{new}} \equiv g_{y_{old}} + \frac{S/p_S}{Y_{old}} \cdot \left(g_S - g_{p_S} - g_{Y_{old}}\right)$$
$$= g_{A_{new}} + \alpha \cdot \left(g_{k_{old}} - g_{p_K}\right) + \alpha \cdot \frac{S/p_S}{K_{old}/p_K} \cdot \left(g_S - g_{p_S} - g_{k_{old}} + g_{p_K}\right)$$

It becomes visible that the definitional changes affect both TFP growth and capital deepening. The table bellows summarizes the impacts.

System:	Capital deepening	TFP growth
Old	$\alpha \cdot \left(g_{K/L_{old}} - g_{p_{K}} \right)$	$g_{Y/L_{old}} - \alpha \cdot \left(g_{K/L_{old}} - g_{p_K}\right)$
New	$ \alpha \cdot \left(g_{K/L_{old}} - g_{p_{K}} \right) $ $ + \alpha \cdot \frac{S/p_{S}}{K_{old}/p_{K}} \cdot \left(g_{S} - g_{p_{S}} - g_{K_{old}} + g_{p_{K}} \right) $	$\begin{split} g_{Y/L_{old}} &- \alpha \cdot \left(g_{K/L_{old}} \cdot g_{p_{K}} \right) \\ &+ \frac{S/p_{S}}{Y_{old}} \cdot \left(g_{S} - g_{p_{S}} - g_{Y_{old}} \right) \\ &- \alpha \cdot \frac{S/p_{S}}{K_{old}/p_{K}} \cdot \left(g_{S} - g_{p_{S}} - g_{K_{old}} + g_{p_{K}} \right) \end{split}$
Bonus	$+ \alpha \cdot \frac{S/p_{S}}{K_{old}/p_{K}} \cdot \left(g_{S} - g_{P_{S}} - g_{K_{old}} + g_{P_{K}}\right)$	$\frac{\frac{S/p_{S}}{Y_{old}} \cdot \left(g_{S} - g_{p_{S}} - g_{Y_{old}} - \alpha \cdot \frac{Y_{old}}{K_{old}/p_{K}} \cdot \left(g_{S} - g_{p_{S}} - g_{K_{old}} + g_{p_{K}}\right)\right)$

Introducing hedonics – resulting in a faster negative growth rate for p_K and p_S than obtained with a traditional deflator – has clearly an impact on both capital deepening and TFP growth. Both factors are also put on a higher level than what was previously observed due to accounting software outlays as investment. For instance, the TFP growth path is a function of both the size of real software outlays relative to the (old) real GDP, and the growth rate of software outlays. The capital deepening effect is multiplicatively related to the size of real software investment as a percentage of the real (old) capital stock, and the growth rate of software investments.

Just how large is the bonus? The table below reports in this respect the necessary figures for the computations. They are taken from Parker, 2000, Jorgenson and Stiroh, 2000, and Eurostat for the ESA79 definitions. In combination with these data, the IT hedonic and average price indices reported earlier in this paper were used in order to compute the weighted price index for capital. As for software, the non-hedonic price index applied is the one for own-account software while the hedonic series refers to the weighted average of the indices for own-account, custom and pre-packaged software as mentioned in the main text.

	S (bn USD nominal)	g _s (% nominal)	Y _{old} (bn USD real, p95)	g _{Y_{old} (% real, p95)}	K _{old} (bn USD nominal)	g _{K_{old} (% nominal)}
1998	422.03	18.50%	7744.51	2.70%	27367.80	7.00%
1997	364.04	15.93%	7453.81	3.90%	25555.79	7.09%
1996	323.26	12.62%	7198.31	3.55%	23837.81	7.21%
1995	289.94	11.49%	7029.60	2.40%	22925.98	3.98%
	p _s index 1995=100	g _{sh} index 1995=100	p _K index 1995=100	p _{Kh} index 1995=100		
1998	104.78%	94.30%	109.57%	109.09%		
1997	103.14%	96.50%	105.42%	105.05%		
1996	100.81%	98.37%	101.23%	101.01%		
1995	100.00%	100.00%	100.00%	100.00%		
	g _{ps} %	g _{PSh} %	g _{pK} %	g _{PKh} %		
1998	2.85%	0.15%	3.74%	3.50%		
1996	1.60%	-2.28%	3.94%	3.85%		
1996	2.31%	-1.90%	4.14%	4.00%		
1995	0.81%	-1.63%	1.23%	1.01%		
		the su	Ibscript h denot	tes hedonic pric	ing	

Plugging these figures into the above formulas, and assuming 1/3rd for α , leads to the following impacts:

Bonus	capital deepening	TFP + growth =	LP growth	capital deepening ⁺	TFP growth ⁼	LP ∎ growth
	no	n-hedonic pr	ices	h	edonic prices	\$
1998	0.07%	0.61%	0.67%	0.09%	0.82%	0.90%
1997	0.05%	0.44%	0.49%	0.08%	0.65%	0.72%
1996	0.03%	0.27%	0.30%	0.05%	0.45%	0.50%
1995	0.03%	0.31%	0.34%	0.04%	0.40%	0.44%
average	0.04%	0.41%	0.45%	0.06%	0.58%	0.64%

If one adds these bonuses to the actual reported averages for 1990-95, the predicted averages for 1996-98 are 0.43% for the capital deepening effect, 1.36% for TFP growth – in sum a labour productivity growth of 1.79%. Again, the increase in these figures is only due to the changes in definitions. Incidentally, with the official statistics on labour productivity growth standing at 2.03%, a growth accounting exercise shows a measured average increase of 0.43% for capital deepening and 1.60% for TFP growth.

	Capital deepening	TFP growth	LP growth
	theo	pretical averages for 1996	o-98:
(A) official average 90-95	0.37 %	0.78 %	
(B) plus software =	0.41 %	1.19 %	1.60 %
(C) plus hedonics =	0.43 %	1.36 %	1.79 %
	O	fficial averages for 1996-9	98:
(D) official average 96-98	0.43 %	1.60 %	2.03 %
	official ac	cceleration between 90-95 a	and 96-98:
(D)-(A)	0.06 %	0.82 %	0.88 %
	"real	 acceleration between 90- 96-98 after correcting for 	95 and
hedonics [(D)-(B)]	0.02 %	0.41 %	0.43 %
nedonics and software [(D)-(C)] 0.00 %		0.24 %	0.24 %

This would imply that the "real" gains in the economy – that is, after having filtered out gains from changes in the accounts and pricing techniques – mount to zero for capital deepening and approximately a fourth of a percentage point for TFP growth. If one only corrects for hedonic pricing techniques, by contrast, the gains are two tenths for capital deepening, and four tenths for TFP growth. However, the "real" accelerations are at best only half as large as what the official statistics reveal.

With these findings we are now better able to compare like with like. Since neither hedonic prices nor software investments were apparent in the EU accounts before 1998 we may compare the European growth accounting findings with the fully corrected ones for the US:

			Capital de	epening				
		а	Common definition					
	90-95	96-98	Acceleration	90-95	96-98	Acceleration		
US	0.37	0.43	+0.06	0.37	0.37	+0.00		
EU	0.87	0.45	-0.42	0.87	0.45	-0.42		
	TFP growth							
	Official data			Common definition				
	90-95	96-98	Acceleration	90-95	96-98	Acceleration		
US	0.78	1.60	+0.82	0.78	1.02	+0.24		
EU	0.91	0.84	-0.07	0.91	0.84	-0.07		
	Labour product				ctivity growth			
		Official data	а	Co	ommon defin	ition		
	90-95	96-98	Acceleration	90-95	96-98	Acceleratior		
US	1.15	2.03	+0.88	1.15	1.39	+0.24		
EU	1.78	1.29	-0.49	1.78	1.29	-0.49		

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ICT clusters in development: Theory and evidence



Danny Quah

1. Introduction

Many observers suspect economic growth to be inextricably associated with inequality: growth alone need not bring about unalloyed, uncontroversial increases in economic well-being because rising average income levels might come together with increasing disparities between rich and poor.

Prominent theories on the sources of economic growth reinforce these concerns. Theories that especially do so are those that relate growth to increasing returns — where the more production occurs, the greater is productive efficiency — and to technological progress — where advances in science and knowledge are what drive economic growth (e.g., Aghion and Howitt, 1998; Grossman and Helpman, 1991; Romer, 1986, 1990). Versions of these theories imply a path dependence, where success breeds further success — those already rich or technologically advanced become more so; while those poor, similarly, become progressively poorer (Durlauf, 1993). Put another way, economic growth inevitably brings greater inequality.

While increasing returns and technological progress are conceptually distinct, both theory and evidence suggest they often come together and result in technological lock-in (David, 1985) so that technologies that initially have an advantage — real or imagined, substantive or accidental — tend to endure.

The same circle of ideas arises prominently in two other distinct areas: first, economic geography and second, information and communications technology (ICT). Arthur (1994) and Krugman (1991a, b) have emphasized that the concept of increasing returns allows insightful analysis of the location in space of economic activity. Spatial agglomeration — geographical clusters — then can result from the same forces as technological lock-in. Geographical concentration is just another form of inequality, only in a spatial dimension, rather than across people or across countries. The higher the clustering in only a small number of areas, the greater the income inequality.

Economic analysis of ICT takes the ideas one step further. ICT is, on the one hand, the most recent, most exciting manifestation of general technological progress — hence contributing directly to economic growth — and, on the other hand, generally seen to be an industry where increasing returns are pervasive: creating the first copy of a new working piece of software or the first design of a new semiconductor chip is costly, but running off further copies costs virtually nothing. In this reasoning, agglomeration and lock-in characterise ICT while at the same time ICT contributes to overall economic growth. Again, growth brings greater inequality.

The description here, admittedly, emphasises more certain parts of ICT than it does others. Some readers might question whether computer hardware manufacturing, say, displays the same increasing returns nature as computer software. I have chosen nonetheless to proceed broadly, for

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ICT is an industry where increasing returns are pervasive: for example, running off further copies of software costs virtually nothing. three reasons. First, software is only the extreme case of many other high-tech products where intangible ideas are accounting for progressively more of the economic value than is the physical material hardware — mobile telecommunication products, network infrastructure, financial and entertainment content, and so on all show the same essential dematerialised, weightless properties. Second, in the computer industry, of software, hardware and services, it is the first that is the fastest-growing and thus will be most important. Third, the concept of increasing returns is often used even in non high-tech sectors — see e.g., Krugman (1991a) and Section 2.2 below — just to begin the analysis of economic growth and geography: there is nothing special about applying it to computer hardware.

This set of apparently disparate ideas thus connects ICT development, growth, and economic inequality — inequality across space in particular. Combining them, one is led naturally to ask if rapid developments in computer and communication technologies are driving overall economic success in the US; whether these developments are leading to the US economic performance leaving behind the European Union (EU) and all other countries in the world; whether spatial agglomeration within nations is integral to ICT success; and what policies towards technology and clusters are appropriate to economic growth and social cohesion as ICT continues to advance. Such questions encompass concerns about inequality at all levels: international, regional and individual. The concerns are long-standing; the additional issue here is whether ICT magnifies the tensions between inequality and growth.

However, a further set of issues — although relatively unexplored still — makes ICT's role in growth and agglomeration especially intriguing. ICT differs from being just yet another industry that is high-tech and displays increasing returns. Two differences seem to me key.

First, ICT output typically has little physical manifestation — computer software is the quintessential example. That the output is intangible is, by itself, not particularly significant: haircuts and janitorial services are also intangible, but understanding their impact on agglomeration and growth is not difficult.

Where ICT differs conceptually is its putative disrespect for geographical distance, a feature not shared by many other industries where output is intangible. This, then, is a first critical distinction. In principle, ICT goods and services can be transmitted costlessly, without physical degradation, over arbitrary distances: transportation costs do not matter. Internet transmission, wireless or otherwise, makes possible the most extreme spatial dissemination of work inputs and output distribution. That this must influence growth and geographical agglomeration seems clear; how exactly it does so is less obvious.

Second — again unlike janitorial services — the intangible output from ICT is *non-rival* or *infinitely expansible*. Think of computer software. Once located on a network or satellite server, its use by one consumer detracts not at all from its use by yet a different consumer. In this, ICT output behaves like knowledge (Arrow, 1962) or intellectual assets more generally. It is not just that scientific knowledge is an input in ICT production, but ICT output itself acts like knowledge. (Music and video entertainment and much other media content all are similarly infinitely expansible, and are typically not considered scientific knowledge either).

What has been just described — the "weightless" properties of the ICT sector — applies in an extreme for computer software and media content. While not literally true for other ICT goods, services, and activity, they provide a useful organising framework for thinking about the sector.

This paper provides an overview of the evidence — empirical and theoretical — on these questions, relating ICT to economic growth and spatial agglomeration. Looking ahead, some of the paper's conclusions are as follows: while, as widely thought, in ICT the US is ahead of the EU in many ways, in a number of significant dimensions, parts of the EU more than match the US. Clustering in ICT businesses and activity is pronounced within the EU, but whether significantly more or less than within the US remains to be studied. US regional evidence suggests, however, that geographical clustering in ICT activity is due more to two features of ICT, its drawing on a highly skilled labour force and its being a fast-growth activity, rather than to anything intrinsic to ICT itself. Put differently, there is nothing special about ICT's spatial clustering: other industries with similar skill and growth profiles will also be similarly concentrated. Some relatively low-tech manufacturing in the US is more spatially concentrated than ICT activity, although media content production does almost invariably entail high concentration and spatial inequality.

The remainder of this paper is organised as follows. Section 2 discusses, in a little more detail than available above, the relation between technology, growth, and inequality in general, but spatially in particular. The goal is not to repeat discussion elsewhere but to highlight those features salient to the current analysis. The discussion is mostly conceptual. Section 3 presents empirical evidence on ICT activity in the EU and elsewhere, and relates those facts to the ideas discussed in Section 2. Section 4 concludes with an attempt to answer some policy questions on ICT development and social cohesion in the EU.

2. Economic growth and agglomeration: Theory and general evidence

When economic growth was understood as just the accumulation of physical capital (Solow, 1956), the inequality and policy implications were direct. Those individuals, regions, and countries that had more physical capital were richer; investing in machines, buildings, roads, bridges and factories was the route to prosperity. If there were impediments to accumulating physical capital, remove them. By force or reward, strengthen incentives to save and invest. Historically, this view informed policies ranging from Third World economic development — across varied experiences such as India and Singapore — to Joseph Stalin's experiments with building steel factories in a competitive race with the capitalist West.

2.1 Endogenous growth: Technology, increasing returns

When endogenous growth theory challenged this conventional wisdom, disputing the significance of physical capital, research effort shifted to *total* or *multi factor productivity* (TFP or MFP). Previously, TFP had been taken to be just a nuisance residual or a measure of the analysts' lack of understanding. Now, it is the engine of economic growth.

What makes ICT different from other intangibles is its disrespect for geographical distance. To see this more formally, suppose aggregate output Y obeys the production function

(1)
$$Y = F(K, N \times A),$$

where *F* is increasing and concave, *K* denotes the stock of physical capital, *N* denotes the quantity of labour employed, and *A* the residual factor needed to make (1) hold, given what we observe for *Y*, *K*, and *N*. The term *A* has an interpretation as the *state of technology;* it is this that is TFP.

An opposing view, as mentioned earlier, holds that A is merely a residual from econometrically fitting the production function (1). It would then be misleading to consider A as technology, in turn driving economic growth. The intermediate position is that A might well be comprised mostly of technology, but other determinants shape A as well. In particular, any institutional feature of an economy that interferes with the efficient use of factor inputs could well be part of A. The difficulty with this view is that it is unclear why these other features necessarily lead to A increasing steadily through time when economies grow — as happens naturally if A is technology.

Write y = Y/N for labour productivity or output per worker and k = K/N for the capital-worker ratio. Then provided that *F* satisfies constant returns to scale, equation (1) implies

(2)
$$\dot{y}/y = (1 - s_K) \times \dot{A}/A + s_K \times \dot{k}/k$$

With factor markets competitive, the term s_K is physical capital's income share. Over long timespans, s_K has been roughly constant at approximately 40%. Equation (2) decomposes growth in output per worker into contributions due to technology and to physical capital.

While TFP has always been present in economists' thinking, early attention focused on the second term on the right of equation (2) — the contribution of physical capital — with TFP left unspecified. But even as early as Solow (1957), the simplest versions of (2) already showed \dot{A}/A to contribute up to 90% of growth in output per worker, with physical capital accounting only for the remaining one-tenth (1). More recent contributions — e.g., Romer (1994) and Lucas (1990) — carry out yet other suggestive calculations to show that understanding A is critical for understanding economic growth (2).

With increasing returns, economic activity can display technological lockin. The most convincing models of TFP suggest that TFP either reflects increasing returns in the economy or represents the outcome of science and R&D, i.e., of advances in knowledge accumulation and engineering (e.g., Aghion and Howitt, 1998; Grossman and Helpman, 1991; Romer, 1986, 1990). While the two possibilities are not logically inconsistent, they can be conceptually distinguished. Increasing returns might arise from just externalities or simple Marshallian economies

¹⁾ Given this imbalance, the economics profession in the 1960s and 1970s responded, not by re-orienting focus onto TFP's 90% contribution, but instead by attempting to re-measure and re-define variables to reduce its significance (see, e.g., Keely and Quah, 2000). But if capital has its units re-defined to include technological improvements, or labour is re-measured to incorporate increases in knowledge, what are those changes but technology? The more recent, arguably now mainstream interpretation of A as TFP recognises the early Solow (1957) measurements to be likely the right ones, and identifies successful economies as economies that show large, significant A's, for these are the economies with high productivity. 2) Quah (2001a) summarises those arguments. Not all researchers agree on the importance of technology as thus described. Opposing perspectives are given in, for instance, Jones (1995) and Mankiw et al., (1992).

of scale, not science and technology. Improved engineering technology might just mean better physical machines, each used in isolation, with no scale effects resulting. Most researchers, however, follow Romer (1990), and suppose that technological change evolves endogenously due to an economic activity — namely R&D — that involves increasing returns.

With increasing returns, economic activity can display technological lock-in (Arthur, 1994; David, 1985): once a certain technology establishes a beach-head presence, every individual producer or consumer finds it unprofitable to switch technologies, even after a socially preferred alternative becomes available. This is not to deny that a sufficiently superior technology can displace older inferior ones, only to say that there might be socially inefficient thresholds — arising endogenously from the decisions of people and businesses — that need to be overcome before that substitution can occur.

2.2 From growth to clusters: Economic geography

New economic geography exploits the same insights across physical space. The central underlying ideas remain those of increasing returns. New economic geography (Fujita *et al.*, 1999; Krugman, 1991a) exploits the same insights, now not dynamically or in the space of technologies, but instead across physical space. Regional specialisation in specific industries, the evolution of cities and urban systems, and geographical agglomeration more generally, become the objects of analysis, but the central underlying ideas remain those of increasing returns or technological lock-in.

If, whether by historical accident or coordinated expectations, one geographical region becomes specialised in, say, button manufacturing, then increasing returns to scale implies that button manufacturers find it especially advantageous to cluster there, and will continue to do so even as the economic and technological landscape changes about them.

As described here, these spatial clusters can be in just a single industry, not necessarily an entire spectrum of inter-related activities. Thus, these ideas, while related to those in Porter (1990), are simpler, if more rigorously formalised. Porter's descriptions invariably involve essential intricate connections and complex inter-relationships across entire production chains. Richer models, such as Venables (1996), make those inter-connections available — the point, however, is that, in the new economic geography, spatial clustering and agglomeration can arise even absent those linkages (3).

In the theory, geographical agglomeration emerges as an equilibrium outcome to resolve the tension between centripetal and centrifugal forces. The former leads to economic activity concentrating in space; the latter, to its dispersing. As described thus far, with increasing returns to scale, only centripetal forces manifest. To understand ICT's impact on geographical concentration, we now describe centripetal tendencies more explicitly, then add in centrifugal forces, and finally analyse how ICT affects each of them in turn.

Following the exposition of Marshall's ideas in Krugman (1991a), most researchers have considered the problem of a firm making a choice on where to locate. The firm faces three potential sources of centripetal forces: pooling of skilled workers, availability of specific intermediate goods

³⁾ Le Blanc (2000) has studied how, in the US, across states, Porter-type co-location mattered for employment growth in the 1990s in the information technology industry. In the current paper I focus on the more stripped-down concept of agglomeration, to keep distinct the different notions of clustering.

and services, and knowledge spillovers. For the purposes here, we can group together skilled workers and specific intermediate goods and services into just one category, specialised factor inputs. The term *knowledge spillovers* is shorthand for the presumption that ideas travel better locally than they do globally: Marshall's "mysteries of trade . . . in the air" (Krugman, 1991a, p. 37) are specific to particular locations.

Describing the economic problem as one where a firm seeks to locate somewhere imposes immediately an implicit assumption of increasing returns. Under constant returns to scale, firms don't need to locate anywhere; they can chop up operations arbitrarily finely, and locate instead everywhere. It is only with increasing returns that a single large operation works more efficiently than many small ones — a firm seeking to place its operations in one location reflects an extreme version of this effect. And, with increasing returns, factor inputs are better compensated going where businesses happen to be more concentrated.

We will return to knowledge spillovers in Section 2.3 below, but turn now to centrifugal forces. There are three obvious considerations. One, output must be transported from where it is produced to where consumers wish it. This can be costly for bulky products: output (like, say, icebergs) can deteriorate from transportation. Thus, if consumers are dispersed, then other things equal, production will attempt to locate similarly. Two, areas that are relatively, over-serviced see greater price competition in the market for the industry's output. Thus, again, if transportation costs matter and consumers aren't clustered, production will tend to disperse. Three, high concentration engenders congestion: rents and wages rise; the environment deteriorates.

The first two of these considerations hinge on transportation costs. Without such costs, some of the strength of the centrifugal forces should disappear. In the theory, geographical clusters emerge to balance the tradeoff between centripetal and centrifugal forces.

2.3 Knowledge spillovers

The assumption that technology or knowledge spillovers are localised contrasts with an assumption typical for studying economic growth across countries. In the latter, "'human knowledge' is just human, not Japanese nor Chinese nor Korean" (Lucas, 1988, p. 15), and thus specific to neither location nor country.

But, if we identify technology with knowledge, economists' views differ on its location-specificity: Coe and Helpman (1995) evaluate cross-country technological progress by relating R&D to domestic and foreign productivity. They find that large and significant cross-economy spillovers occur, mostly through cross-country trade; however, technology levels certainly remain countryspecific (4). Jaffee *et al.*, (1993) use patent-citation microevidence to show that geographic localisation of scientific knowledge spillovers is considerable in US metropolitan statistical areas. Thus, empirical evidence suggests that knowledge and technology — codified in R&D and patents — do spread, but only incompletely and gradually, not fully and instantaneously.

4) Keller (1998) disputes the first of these statements: he argues that whatever mechanism it is that brings about cross-country technology dissemination, it is not international trade.

Geographical clusters emerge to balance the trade-off between centripetal and centrifugal forces. ICT influences the balance between these forces. In contrast to this work, analyses such as in Lucas (1988) take country-specific technology levels to denote instead human capital, thereby assuming technology to be embodied in labour. Technology is then specific to individual economies as long as labour remains immobile. But even if knowledge embodied in human capital were to spread through cross-country spillovers, its dissemination mechanism must necessarily differ from that for the codified knowledge described by R&D or patents.

The distinction corresponds to a similar one between tacit and codifiable knowledge (e.g., David, 1992), although here the margin between embodied and disembodied must, to some degree, be an object of choice. What is embodied in human capital might well be codifiable, and thus made disembodied. Developing economies might, for reasons of relative price, choose to contain codifiable knowledge within human capital, while richer economies choose the opposite, to preserve scarce, expensive leisure time and, instead, save codifiable knowledge as disembodied blueprints.

2.4 What have we learnt?

How useful are the preceding ideas for analysing ICT clusters in particular or high-tech clusters more generally?

Krugman (1991a) emphasizes that the centripetal and centrifugal forces in economic geography are not specific to technology-intensive activity. He describes geographic concentration in activities as diverse (and low-technology) as carpet manufacturing, jewelry production, the shoe industry, and the rubber processing industry. Industries localize, even (or perhaps especially) in sectors that are far from high technology. Devereux *et al.*, (1999) document that for the UK the most spatially agglomerated industries are relatively low-tech.

Across countries, the distinction between high-technology and low-technology is not typically explicitly considered. More common, as just describe above, is distinguishing the technology embodied in human capital from that codified in patents and R&D.

I take two lessons from this review of earlier work to inform the subsequent discussion on growth and agglomeration. First, ICT influences the balance between centripetal and centrifugal forces. Second, distinguishing different kinds of technologies matters — even within only high-technology sectors. In cross-country economic growth, the dissemination mechanisms vary, depending on whether the high technology being considered is that codified in R&D and patents or that embodied in human capital. Similar differences will therefore figure in clusters and agglomeration.

3. ICT in growth and agglomeration

ICT is not just high technology. It is high technology with significant and peculiar properties.

ICT is sometimes portrayed as skill-biased, and an instance of a general-purpose technology. If so, however, those features are shared by other technologies, and so ICT is not special in either regard. Moreover, it is debatable whether ICT is more skill-biased than many other technological improvements. For instance, the whole point of developments like windowed graphical user interfaces is precisely to lower skill thresholds for manipulating information on computers. Two other

Dissemination mechanisms vary depending upon whether knowledge is codified in patents or embodied in human capital. features, instead, seem to me key for analysing ICT. First, many ICT products are, in the main, disrespectful of physical distance and geographical barriers. Transportation costs are irrelevant. Why then clusters, or more specifically, why then particular patterns of location in ICT activity — not just total randomness or, the other extreme, complete concentration and agglomeration?

Second, ICT products show, moreover, the same infinite expansibility or non-rivalry displayed by intellectual assets generated by R&D and typically protected by intellectual property rights (IPR) such as patents. However, such ICT output is unlike many R&D-produced, patent-protected intellectual assets in two respects (Quah, 2001c): first, it is not usually an input into a further production process, but instead directly used by the consumer. Second, it is typically not protected by patent, but by copyright. Computer software displays both these features. In this respect, the ICT sector can, potentially, differ in its behaviour from the localised, gradual spillover dynamics documented in Coe and Helpman (1995) and Jaffee *et al.*, (1993).

The Internet is a medium by which these features — the disrespect for geographical barriers and the tenuousness of standard IPR systems — become especially pronounced.

3.1 Death of distance in economic geography

Internet development alters the balance between centripetal and centrifugal forces for key (and perhaps most important) ICT sectors.

Transportation costs for output delivery no longer vary in physical distance. Either the customer is on the Internet, or is not. Consumers off the Internet are effectively out of reach, so that transportation costs for them are infinite. When they are on, however, transportation costs are zero, so that centrifugal forces decline dramatically. Thus, as Internet access grows, centrifugal forces progressively fall. Other things equal, there should then be *increasing* spatial agglomeration of ICT production (5).

The opposing view describes incipient decline in centripetal forces. As Internet and telecommunication infrastructures improve, workers no longer have to be together in one physical place for certain collaborative communications. This hypothesis allows some communications still to be better achieved face-to-face; it just does not require that all be so. The hypothesis bears most centrally on that centripetal force described by Marshall's "mysteries of trade in the air". It implies a weakening of such knowledge spillovers, and so, other things equal, predicts *decreasing* spatial agglomeration.

An implication distinct from both centripetal and centrifugal force reasoning is that, for global location, time zones might come to matter progressively more, and physical distance not at all. Conditional on natural geographical variation in climate and land, clusters form within distinct time bands on Earth, without regard to latitude. Quah (2000) provides, as far as I know, the only formal discussion of such effects: he shows how time zone clusters can arise from dynamic collaborative production activity. The analysis, however, is entirely conceptual, with only impressionistic empirical evidence on the effects studied (6).

Internet in a medium in which the ICT features of disrespect for geography and the tenuousness of standard intellectual property right systems is especially pronounced.

⁵⁾ The Silicon Valley phenomenon — as described, say, in Saxenian (1994)— is typically thought to illustrate this.

⁶⁾ Cairncross (1997) explores the same possibilities in a more wideranging but less formalised way.

Kolko (2000) considers the distribution and geographical dynamics of Internet industries in the US. He notes that the concentration and persistence of locations like Silicon Valley might reflect not just ICT's unique features, but instead simply the high-skilled, fast-churn nature of that industry — characteristics shared with many other industries. This is not to say that high skills and rapid turnover directly explain concentration and persistence, but that ICT is no different from other industries in showing slow-changing clusters of activity.

Using cross-region growth regressions, Kolko (2000) establishes that after conditioning on the skills mix and high birth rates of firms in Internet industries, it is *centrifugal* forces that are more pronounced. This result is an empirical regularity; the mechanism whereby high skills and rapid turnover lead to persistent clustering remains to be studied. Conditional on that, however, one can conclude tentatively that clusters are relatively less likely to remain for Internet (and by extension other ICT) industries. Instead, the economic landscape will tend to become progressively less agglomerated.

3.2 ICT Clustering across the EU and elsewhere

On a larger geographical scale, we can also assess the degree of ICT clustering across countries and within the EU.

The definition of ICT used here is given in OECD (2000, p. 7), and comprises segments of both manufacturing and services industries. In manufacturing, to be included, the industry must either perform information processing and communications or use electronic processing to measure or control a physical process. In services, the industry must enable information processing and communications by electronic means (7).

In 1997, in the EU the fraction of total business employment in ICT industries matched that in the US: both equalled 3.9% (Koski *et al.*, 2000; OECD, 2000). This means, however, that a select group of EU member states had ICT employment concentration *higher* than the US: Sweden, 6.3%; Finland, 5.6%; Denmark, 5.1%; and the UK, 4.8%. Low ICT employment EU member states included Portugal (2.7%) and Germany (3.1%).

Overall ICT productivity is considerably higher in the US. In 1997, ICT contributed 8.7% of total business value added in the US, but only 6.4% in the EU — a ratio of 1.4. In the EU, the greatest ICT fraction of value added was in Sweden (9.3%), the UK (8.4%), and Finland (8.3%), while the lowest was in the Netherlands (5.1%) and France (5.3%). (Figures were unavailable for Ireland, certainly a candidate for the high end of the value-added range.)

Not unexpectedly, US R&D spending in ICT industries as a fraction of total business R&D expenditures exceeded that for the EU — in 1997, the former spent 38% of total business R&D on ICT, the latter only 24%, a ratio of 1.6. Several EU member states, however, devoted proportionally more R&D

Clusters are less likely to remain for Internet industries.

⁷⁾ The definition includes six ISIC 4-digit codes for manufacturing and four ISIC 4-digit codes for services. Notable among these is ISIC 3000 (office, accounting, and computing machinery) from manufacturing and ISIC 6420 (Telecommunications) from services, as well as TV and radio equipment and receivers and computer- and related activities across a range of ISIC codes.

spending to ICT than did the US: highest was Finland (51%), followed by Ireland (48%). Lowest ICT R&D member states were the Netherlands (20%) and Germany (20%).

A remarkable fact emerges in the trade balance statistics (Koski *et al.*, 2000; OECD, 2000). Popular impression has it that because the US is such an ICT powerhouse, it must export ICT to the rest of the world. In reality, in 1998 the US was a net ICT *importer* by USD 35.9 billion. Ireland, instead, is that country whose ICT exports exceeded imports by USD 5.8 billion; Ireland is the economy with the greatest ICT trade balance among the US and all EU member states. Finland and Sweden, with USD 3.6 billion and USD 2.8 billion net ICT exports, similarly had ICT trade balance greater than the US.

Different reasons might, of course, explain this. US consumers might demand proportionally more ICT than EU consumers, suggesting that part of the reason for US success could be its strong demand base (Quah, 2001b, c). Outsourcing along different parts of the ICT value chain might have led lower valued-added production to locate outside the US. Note, however, that the ICT trade numbers are in terms of value not volume. Even if it were only very low value added work moving outside the US, enough of it occurs, evidently, that the value adds up to be significant.

Closely related, the deficit numbers likely reflect nothing more than comparative advantage along different parts of the ICT value chain. If so, the picture that emerges of ICT success is one of specialisation and exploiting comparative advantage. There is no one model of ICT-driven economic success.

Finally, ICT might now be too large a segment to be economically meaningful: telecommunications expertise and comparative advantage in the EU might overwhelm the information technology part of ICT trade. But if so, then that obviously matters too, so the ICT net trade numbers meaningfully and correctly show that. This reinforces the conclusion that diversity and comparative advantage matter — in ICT as elsewhere.

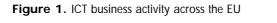
3.3 Big blocs, small blocs

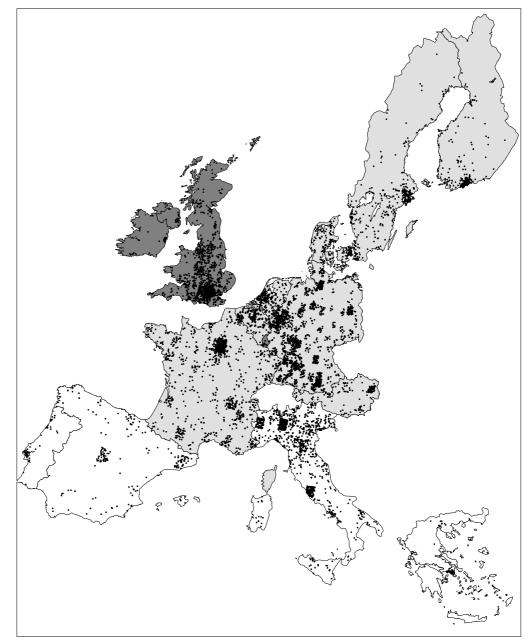
An important lesson emerging from this discussion — the trade balance statistics, in particular — is that ICT success in countries is difficult to assess reliably. Few doubt that the US is a successful ICT economy. Yet its international trade position in ICT might suggest otherwise to a casual observer.

Similarly, examining ICT success (or failure) in the EU as a whole disguises smaller-bloc pockets of excellence — in Ireland, Finland, Sweden, and, to a lesser degree, the UK.

Figure 1 shows, from Koski *et al.*, (2000), the 1999 spatial distribution by postal code of over 11 000 ICT businesses across the EU. Two geographical agglomerations are prominent. First is a large central crescent, beginning in London in the west, proceeding counterclockwise via Randstad in the Netherlands through industrial areas in German, Switzerland, to northern Italy. Second is a smaller Nordic pole, covering the metropolitan areas of Helsinki and Stockholm, and comprising primarily mobile and telecommunications activity.

Examining the ICT success - or failure - of the EU disguises smaller-bloc pockets of excellence. Dynamics at the national level may also miss critical elements of what is important.





From Koski *et al.*, (2000), and www.europages.com. Over 11 000 ICT business establishments are displayed, each establishment producing a dot in the map, appropriately located within postal code. EU member states are shaded by ICT concentration: dark grey (over 4% of non-distributors/non-retailers are ICT firms); light grey (2.5 –4%); and unshaded (less than 4%).

Figure 1 gives the stylised impression of significant clustering about the major European urban centers. However, not all urban centers see associated ICT activity, nor do all clusters surround only cities. Further, the crescent concentration proceeds in a way that practically ignores EU member state boundaries — national borders seem permeable in that geographical sweep (Quah, 1996). Is this spatial pattern unique to ICT? Does this pattern show ICT merely mirroring urbanisation across space? Thus, would, for instance, the spatial sweep of hairdresser activity look markedly different?

Tracing through these connections and understanding the dynamics of emerging ICT development must consitute research that remains high on the agenda. However, even now, we can see that studying those dynamics at only national levels is likely to miss critical elements of what is important.

3.4 Inequality

The final set of questions I consider abstracts from the fine details of agglomeration across economic units but treats directly the dynamics of inequality.

Whether it is increasing returns or technology spillovers that matter, if ICT magnifies their effects, then inequality must be increasing with ICT's increasing pervasiveness. Moreover, how these effects matter — at location, city, region, country or on individual level — is potentially the same. We can thus gauge ICT's impact on inequality by looking at a range of evidence, at varying levels of disaggregation.

Across countries, inequality has been increasing steadily since 1960 (see, e.g., Quah, 2001a); inequality across EU regions, similarly, over all of the 1980s (Quah, 1997). While ICT has been studied as a leading cause of increasing wage inequality across US workers, its impacts in micro data remain controversial (Autor *et al.*, 1998; DiNardo and Pischke, 1997; Krueger, 1993). However, over long time periods at an aggregate level, US family and household income inequality have been steadily rising since the late 1960s and early 1970s (Wolff, 2000). Two factors account for most of this: unemployment fluctuations and deunionisation. Wealth inequality, measured as the fraction of wealth owned by the top 1% of US households, has been rising steeply since the mid 1970s, from a low of 22% in 1976 to 38% in 1998. The high inequality in 1998, however, only matches its level from 1965. From 1965 through the low of 1976, wealth inequality practically halved; before 1965, it had been constant for at least a decade. Over this entire time span, changes in wealth inequality have been due primarily to movements in the stock market and house prices.

Inequality has increased. However, there is little evidence that recent ICT progress has been at all critical to this.

By contrast, changes in economic performance from ICT in the US are only observable, if at all, from the mid 1990s (Gordon, 2000; Oliner and Sichel, 2000), a full three decades after inequality had already begun to rise. Inequality cannot have risen ahead of time in anticipation of ICT's impact. This does not say, of course, that ICT cannot have exacerbated the already rising inequality. But it does say that many other factors have mattered importantly.

To emphasize this, regression of the critical stockmarket/house price measure on ICT variables achieves an R^2 of no more than 50% (Wolff, 2000). When both asset prices and ICT indicators enter the right hand side of a regression explaining wealth inequality, it is only asset prices that matter: ICT indicators are invariably insignificant.

To summarise, for economic units ranging from countries to individuals, inequality has increased, almost uniformly throughout the world. However, this rise of inequality began long before ICT developments took hold. There is thus little evidence in the data over longer stretches of time that recent ICT progress has been at all critical to increasing inequality.

4. What should Europe do?

If increasing returns and endogenous technical progress are central to economic growth, spatial clusters too must be important — the same forces that drive growth generate agglomerations in space. But this statement applies independently of whether we are analysing carpet manufacturing or ICT. Put differently, nothing special about new technologies is implied by or central to the conclusion. More to the point, however, the statement speaks only to the presence or absence of such forces. Whether the forces are quantitatively dominant is an empirical question, not a theoretical one.

What makes ICT different from other technologies is important, and understanding that must be critical to policy formulation. Theoretically, "death of distance" and "weightless economy" effects, taken together, can predict either greater or less spatial clustering. Empirically, the evidence suggests greater dispersal of economic activity — lower regional inequality — is likely.

The concentrations that succeed seem to do so at finer levels of disaggregated economic decisionmaking than the nation state. Policy, therefore, might need to focus on regional levels rather than national. The idea that entire nations should concentrate on ICT for successful economic growth is incorrect. Even the US is a net importer of ICT. Moreover, successful regional clusters appear to propagate across national boundaries in the EU.

Although not central to the current discussion, the analysis above has also pointed to how systems for managing intellectual property — incentives for their creation, simultaneous with mechanisms for their widespread dissemination — will be critical.

As in any other knowledge-intensive activity, local education and research and development are key to successful economic performance in the ICT sector. This will be true as long as tacit knowledge, human capital, and even codified ideas remain localised. In ICT, those impacts are magnified as skills and sophistication matter not just in production but also consumption (Quah, 2001b,c).

Is economic growth in Europe diverging? Do agglomeration effects from ICT mean that inequality is increasing across regions and countries in Europe?

It is a myth that all nations need to develop ICT similarly for successful economic growth.

This paper has pointed to how the same factors — increasing returns, technology spillovers — underly both economic growth and spatial agglomeration. We therefore cannot rule out the possibility that we have to answer yes to the policy questions above. However, this paper has also argued that it is a myth to believe that all nations need to develop ICT similarly for successful economic growth.

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Nothing ventured, nothing gained



Hermann Hauser

1. Introduction

Even though the industrial revolution started in Europe, many commentators suggest that European entrepreneurship has become an oxymoron. The facts of the case are, however, growing against them. For instance, Europeans nowadays run a fair share of Silicon Valley companies. Examples include *phone.com* – one of the most successful new mobile software companies – or LSR logic, a major semi-conductor business. At the same time Europeans have established enterprises that have become respected leaders in mobile telephony as well as in the data communication sector – well known examples here include Ericsson, Nokia and Vodafone. The "old" continent clearly is swiftly re-discovering its entrepreneurial genes in creating a number of successful companies worldwide. It is, however, venturing in a different direction. While the era of the PC belongs to the US, Europeans are betting far more heavily a future era of wireless communications.

Nonetheless, it seems that Europe as a whole has progressed less speedily in the digital economy than the US. This paper aims at examining two key factors supporting the arrival of new technologies. More specifically, it will focus on the role of venture capital on the one hand, and entrepreneurial mentality on the other.

The remainder of the text is organised as follows. The next section will go into the differences between the engine-rooms of the EU and US high-tech business – i.e. the availability of venture capital. Some asymmetries in entrepreneurial attitudes on both sides of the Atlantic will be briefly described in Section 3. A final section summarises and concludes.

2. The role of venture capital

"What would life be if we had no courage to attempt anything?" Vincent Van Gogh

2.1 Trends in venture capital investment

Although cultural differences exist and should not be ignored they cannot be the sole reason why Europe has progressed less speedily than the US. Much of the explanation has to do with the availability of investors that are willing to take on the risk of financing new innovations. Commercialising new technologies is indeed characterised by considerable risks. Firstly, high technology is often a business in which the "winner takes all". At the same time, there is always the possibility of business stealing – that is, that another company builds upon a patent and launches a more advanced version of the original product. Obviously, this would render the original design worthless. When, *in extremis*, a high probability of business stealing is expected, innovative activity may vanish.

Venture capitalists are willing to buy such risks in exchange for shares in a company and a sufficient expected rate of return. Overall risk is managed by having a diversified portfolio of

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This paper examines two key factors behind the arrival of the digital economy - venture capital and an entrepreneurial mentality. companies. As alternative sources of finance are limited, venture capital can play an important role in fostering economic growth. As has been set out elsewhere in this volume, the state of the art of technology determines possible total factor productivity (TFP). Increasing the supply of venture capital may influence the rate of technological change, and hence TFP, which is the most important source of long-run growth.

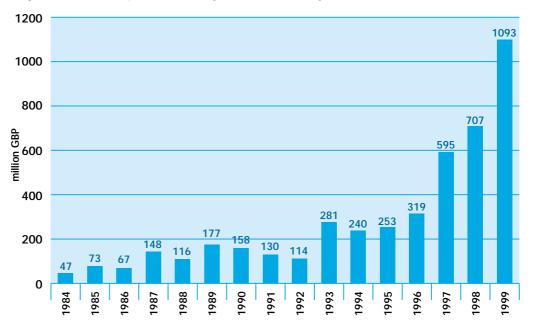
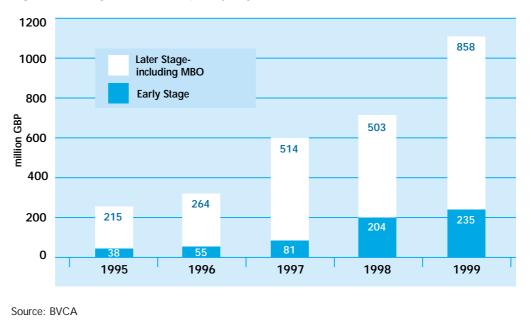


Figure 1. Venture capital in the UK high-tech sector (all stages)

Source: BVCA

Figure 2. UK high-tech venture capital by stage



European venture capital investments are still dwarfed by what is seen in the US. However, venture capital investments were until recently rather uncommon in Europe. Figure 1 shows, for instance, that in the UK – which accounts for 50 percent of Europe's total venture capital – investments increased rapidly from approximately GBP 50 million in 1984 to just over GBP 1 billion in 1999 – an average compound growth rate of about 23 percent a year. During the second half of the 1990s, between 85 and 90 percent of the total went to investment at a later stage of the company's life (see Figure 2), for example to finance management buy-outs (MBOs). Yet, the fastest growth – about 60 percent a year on average in the last part of the 1990s – took place in high-tech seed-money investment, that is, early stage finance for high-tech start-ups.

Nonetheless, European venture capital investments are still dwarfed by what is observed in the US. Measured as a percentage of GDP, the UK currently stands only at one-third of the US ratio, as shown in Figure 3. Since the UK makes up half of the European venture capital market, it can be conjectured that Europe is lagging far behind the US with regards to venture capital investments.

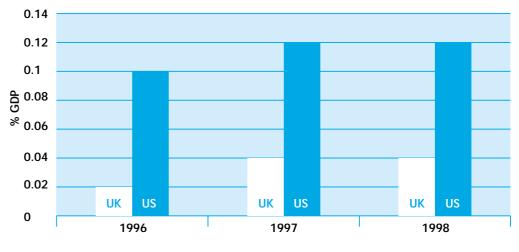
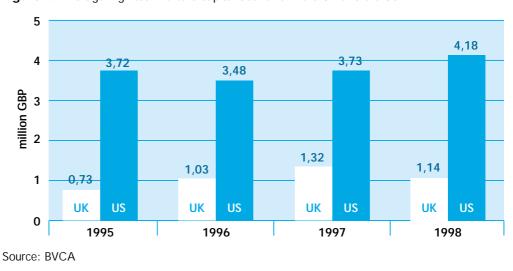
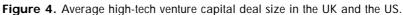


Figure 3. High-tech venture capital in the UK and the US.

Source: BVCA

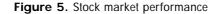


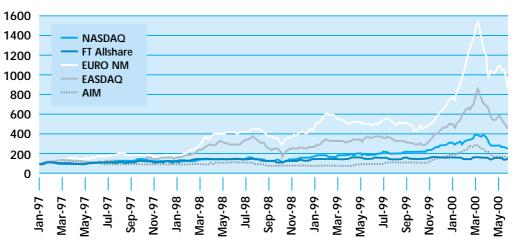


Also in terms of the deal size – that is, the average amount invested per contract – the difference between the US and Europe is noticeable. Figure 4 reveals that the disparity is reducing slowly. But even though the deal size has almost doubled in Europe since 1995, it still only mounts to GBP 1.14 million, compared to GBP 4.18 million in the US.

3. Does it show?

It is well known that technology stocks have done extremely well in the US. For instance, if one compares the evolution of the NASDAQ – a typical high-tech composite index – with the evolution of the FT All Share index – indices in which "old" economy firms have a high weight – the difference is spectacular. But also in Europe the increase in availability of venture capital may already be paying off. Figure 5 shows for instance that the European equivalent of the NASDAQ – the Neue Markt index – has behaved well over the same period, too. In fact, the key message that we learn from the graph is that the premium for European technology companies has been at a record when compared to the traditional sectors.





The rate of technical change will provide plenty of opportunities for venture capital in the future. It is, moreover, likely that the current rate of technological change will go on for quite some time. The power of semiconductors has long followed Moore's law, i.e. a doubling of the computer's processor power every 18 months. Data storage capacity per unit price has been doubling every year, while the performance of fibre optics has been doubling every 9 months. If this trend persists, there will be plenty of market opportunities for venture capital to continue growing as well.

3.1 Venture capital is a necessary, but not a sufficient condition for long-run growth

Although venture capital may enhance the speed of arrival of new technologies, it does not suffice. The most important condition obviously is that an adequate number of ideas are generated in the economy. Consequently, regions or nations that aim at being successful are implicitly engaging in a race for talents and knowledge.

Human capital – as it is generally referred to – can, of course, be developed by maintaining good educational standards, and stimulating on-the-job training programs. However, talent can also be imported from abroad. It is revealing that in Silicon Valley, more than 50 percent of the CEO's are currently non-Caucasian whites. Consequently, the key question should be how policy can make Europe more attractive for highly skilled foreigners as a place where they want to live and work. Craig Barret – Intel's fourth CEO – suggested, for instance, to give a work permit to everyone who has a B.Sc. from a recognized university in the world, because that might be the best way to ensure America's future. Are European policy makers on the same wavelength?

Next to a well-functioning real estate market, good basic infrastructure, and the access to services, high-tech clusters are based upon reliable social networks for problem solving. There can be little doubt that European entrepreneurs face a "skill deficit". Education and training systems provide too few a people with IT competence, while restrictive immigration laws worsen the situation by preventing businesses from attracting the required skills from outside the EU. This deficit is often exacerbated by the way in which European governments tax stock options, bonuses and other types of risk-based pay (e.g. as income rather than capital). Policy makers should not forget that in the current global economy, marginal variations in tax treatments could make the difference between someone wanting to stay in a European country or moving to the US. In modern, knowledge-driven economies, entrepreneurs succeed because they can rely on a pool of talents that constantly exploits new opportunities.

Finally, next to a well functioning real estate market, good basic infrastructure, and accessible services such as legal and accounting advice, most healthy clusters of entrepreneurial activity – Silicon Valley being the example *par excellence* – are characterised by a high degree of social capital. This term refers to the ability of people to be part of a social network, and to be able to rely on it when input for solving problems is required. Technology clusters have started to appear in Europe - examples can be found in the Cambridge region, Munich, and at Sophie Antipolis – though there is much scope to develop these further.

Clearly, universities as centres of excellence are helpful institutions in these networks. They are, however, not sufficient. Silicon Valley developed around Stanford University, but a similar phenomenon did not take place around Harvard, or the older European universities of Leuven, Paris, or Bologna, to name but a few. In fact, the transition from academia to business is often helped by the existence of one or two successful companies. Such companies provide a training ground in business to bright researchers. As these people leave to set up their own companies, they provide fertile ground to develop a powerful network of venture capitalists. Fairchild played this catalyst role in Silicon Valley, and it is possible that my first company, Acorn, helped Cambridge's Silicon Glen to become what it is today.

Thus, aptitude for exploitation of an academic breakthrough is at least as important as anything else. Differences in entrepreneurial attitudes are precisely what the next section will focus on.

4. Entrepreneurial attitudes

"Defeat doesn't finish a man – quit does. A man is not finished when he's defeated. He's finished when he quits" Richard M. Nixon

Attitudes towards entrepreneurship can be sand or grease in the cogwheels that drive the delicate process of innovation. Four differences between the EU and the US may have had an impact on the speed of arrival of new technologies. These are views on job safety versus job creation, academic research versus commercial exploitation, attitudes towards failure, and personal financial control versus broader shareholder ownership.

A notable difference between the EU and the US used to be the attitude towards job safety. According to the stereotype, Europeans care about social protection and job security -Americans only about profit. Although there may be some truth in this statement, and it should be admitted that both views have laudable goals in their own right, it is also probably fair to say that there is a trade-off between the level of individual social protection and overall jobcreation. For instance, according to the World Competitiveness Yearbook, 7 million jobs were destroyed in Europe in the 1980s and early 1990s. In the US, by contrast, as many as 30 million jobs were lost over the same period of time. Yet while the newly created workplaces in the United States amounted to 70 million - a net creation of 40 million - Europe could only offer some 6.5 million new jobs, resulting in increased overall unemployment. In Europe, much of this phenomenon can be attributed to the fact that some unprofitable sectors were artificially kept alive by means of heavy government intervention. In that way, a number of low skilled workers were saved from the personal drama of job loss. The reverse side of the coin, however, were high taxes, resulting in high wage costs and therefore low job creation. However, the rising structural unemployment rate has moved the political way of thinking in Europe away from maintaining old jobs towards fostering job-creation. As a result, Europe now has a betterequilibrated attitude towards labour market policies, and it has established a more favourable environment for employment generation.

Likewise, the European attitude towards commercial exploitation of academic research has only recently started moving in the right direction. Contrary to a decade ago, it is now considered reasonable for an academic researcher to engage in the commercial development of spin-offs from applied research by starting up a company. This has been the case for much longer in the US.

Nonetheless, not everything is all right yet. One should not expect all spin-offs to become superstars. In the high-tech sector, things may fail for a number of reasons such as false market expectations, or because another company was faster in setting the standard. In this respect it is perhaps worth mentioning that the attitude towards failure is still quite different on both sides of the Atlantic. Whereas in the US failure is seen as an opportunity for learning – Henry Ford once said "failure is simply the opportunity to begin again, this time more intelligently"– it is still often stigmatised in Europe as a criminal act of fraud that should be punished. Therefore, bankruptcy and the tolerance of failure in businesses may be areas in which European policymakers could improve current legislation.

Whereas failure in the US is seen as an opportunity for learning, it is still stigmatised in Europe. Europe will have to change its values towards accumulating wealth, towards the immigration of skilled foreigners and towards a respect for failure. Job-creation through entrepreneurship may also have been hampered by the European mentality of having full financial control. Whereas in the US, people are quite happy to end up with, say, 10 or 20 percent of the shares when they start a business, a European entrepreneur feels that he or she should have a substantial majority of the shares, if not full control. From a purely investment point of view, this may not be optimal. Besides the fact that there is no good reason to presume that the view of many shareholders would be inferior to that of one, a large shareholder base usually also means that more resources can be raised – venture capital being one of the options. As a result, the company may grow faster into becoming an important market player.

5. Conclusion

This paper has related the European and American positions regarding the arrival of new technologies, to two key factors – the availability of venture capital and entrepreneurial attitudes.

The greatest benefit from venture capital is that it shifts risk away from the entrepreneur to the venture capital company, which diversifies the individual risk away in its portfolio. Consequently, this way of financing start-ups, in particular high-tech ones, may substantially affect the speed of development of new technologies, and thus long-run economic growth. However, in spite of a swift increase, the supply of venture capital in Europe is still dwarfed by the levels that are observed in the US. Lack of this type of capital may be one of the reasons why Europe as a whole has progressed less speedily in the digital economy.

Yet even with the institutional framework in place – the UK is, for instance, not particularly more risk averse than the US – closing the gap will require more than just venture capital. Increasing the rate of technological change first and foremost depends on the supply of new ideas. Therefore, regions need to have a sufficient amount of the right skills in their economy to generate and exploit new opportunities. Consequently, generating economic growth will be preceded by a race for talents. If Europe wants to end up among the top performers, it will need to accept a change of values towards such things as accumulating wealth as a driving incentive behind innovative activity, towards the willingness to allow the immigration of skilled foreigners, and towards a respect for failure.

Regional development and the new economy



Andrew Gillespie



Ranald Richardson



James Cornford

1. Introduction

In this paper we are concerned with the implications of information and communications technologies (ICTs), and the so-called "new economy" with which they are associated, for regional development. As such, we are concerned particularly with examining the ways in which ICTs may "change the balance" between centralising and decentralising dynamics in the space-economy. A number of starkly different spatial expressions of the "new economy" can be postulated, making our task a necessary one to undertake, in that the overall outcomes in terms of spatial organisation and regional development are not self-evident.

One spatial expression of the "new economy" emphasises the strong clustering effect that can be witnessed in those regions most associated with the emergence of the "new economy", such as Silicon Valley in California, or in the concentration of "dot.com" start-ups in major cities such as London. This version concentrates on a valid, albeit rather narrow conception of the "new economy" as a newly created sector based around a particular technology, that of the Internet.

A second, very different, spatial expression of the "new economy" emerges if we emphasise rather the ways the technologies are *used* within the economy as a whole, and in particular if we concentrate on the distance-transcending capabilities of technologies such as the Internet. Here then our focus is not with the "new economy" as a discrete sector, but rather with the more widespread transformation of the economy as a result of the rapid adoption and diffusion of a cluster of radical innovations in ICTs. The possibilities of being able to distribute information goods and services instantaneously and almost without cost over electronic networks has led some commentators to herald the "death of distance" or the "end of geography". It is, unsurprisingly, this "version" of the "new economy" which seems to hold out the most promise in regional development terms, offering the possibility of peripheral regions and rural areas being able to "break free" of the constraints imposed by the "friction of distance".

There is though another (third) version of the "new economy" which starts from the "use of technology" perspective, but which doesn't emphasise the decentralising potentiality of the technologies to anything like the same extent, or at least not in the same way. This version is more rooted in a political economy tradition, and examines the way in which large companies use technologies within their production and distribution structures and strategies. There is no inevitability that decentralisation will follow from these competitive strategies; however, in as far as the new technologies permit lower cost locations to be "brought into play", there is likely to be a strong cost-based decentralising logic at work in this version of the "new economy".

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In this paper, our intention is, firstly, to explore in more detail these three different "versions" of the "new economy", highlighting their contrasting developmental dynamics in terms of centripetal and centrifugal forces. Secondly, we attempt to draw out the differing implications for regional development which each version represents, and to consider the constraints on these developmental opportunities being realised, drawing on the results of a number of regional case studies and a review of lessons from policy intervention (1).

2. Locational dynamics in the "new economy"

Communications

technologies do not simply pull the balance of centrifugal and centripetal forces in one direction at the expense of the other, but rather simultaneously strengthen both. Over a century ago, Alfred Marshall drew attention to the battle of centrifugal and centripetal forces in the spatial organisation of the economy, and noted that: "Every cheapening of the means of communication alters the action of forces that tend to localise industries". As we will discuss, the dynamics are complex. Communications technologies should not be seen as simply pulling the balance of centrifugal and centripetal forces in one direction at the expense of the other, but rather as simultaneously strengthening both. The locational outcomes "on the ground" are, as a result, going to be complex.

2.1 The "new economy" as an emergent sector of activity

Communication is, of course, intrinsic to any economy and ICTs have applications across all sectors of the economy. However, new communications technologies not only provide new ways of undertaking existing activities, they also generate a range of more or less new opportunities for economic activity, new products and services. Following an initial interest, in the 1970s, on "high tech" hardware production, various labels have been given to economic activity which has emerged specifically around the capacities of ICTs; the labels have shifted over time from "Multimedia" (associated with CD ROMS and standalone interactive software), through "New Media" (focused on multi-user interactive information services based on the Internet) to "dot.com" activity (focused on the transactional capacities of the Internet). What is common to these labels is their focus on the capture, creation, manipulation and distribution of digital content.

In spite of the supposed ubiquity of the technologies, there are distinct spatial patterns of development of this "digital media sector". Working from a range of sources and in a range of countries, researchers have documented the tendencies for firms in the digital content-based industries to cluster in a small number of critical locations. For example Scott (1996, 1997, 1998), drawing on trade directories and official data, has focused on the multimedia industry clusters in California - a more entertainment focused cluster in Los Angeles and a more business oriented cluster in San Francisco. Sandberg (1998), has noted a similar concentration in Sweden, in and around Stockholm. Zook (2000), has used Internet registration data to provide maps of "dot.com" addresses across the United States, generating a picture of widespread, but highly uneven distribution of "dot.com" activity, both across city regions and within them. Research at the Centre for Urban and Regional Development Studies, Newcastle, has used trade directories to map the regional patterns of such firms in a number of "New Media" subsectors (games, web-based advertising, etc.) and has shown a clear over-representation of such activities in four more-or-less

¹⁾ Four case studies were undertaken as background to this paper. These were Cambridge, the Highlands and Islands of Scotland, the North East of England, and Ireland. In this paper, we draw upon the case study material to provide illustrative examples; the full case studies can be found in the research report upon which this paper is based.

adjacent locations - London, the M4 Corridor, East Sussex and the M11 Corridor (Figure 1). This picture closely matches that created by Dodge and Kitchen (2000), using registered addresses of owners of domain name space.

There is broad agreement about the location of the new digital content sector it is overwhelmingly a metropolitan phenomenon. There is, then, broad agreement about the aggregate location of the new digital content sector - it is overwhelmingly a metropolitan phenomenon. There is much less agreement, however, about the reasons for this concentration and the longer-run prospects for the development of the sector. Simple urbanisation economies (the benefits of shared physical and business infrastructures, and labour pool, which all urban, and particularly metropolitan, firms enjoy) obviously play a part in some cases. Yet these, it is felt, do not fully account for the particular patterns of concentration that have been seen.

One set of arguments which seek to explain the agglomeration of such activity has stressed the relationships among such firms. Their constant need for innovation, coupled with the high risks involved with unstable markets and highly differentiated products, it is argued, results in an organisation of new media production focused upon "industrial districts", predominantly comprised of small firms. The agglomeration economies derived from such territorially-based clusters ensure that all producers benefit from localised externalities (Scott, 1995, 1996). In short, such activity clusters around itself.

A second approach has stressed the role of the market for these companies. For much of the digital content industry, the market for their services is predominantly large firms and organisations, led by a few sectors (financial services, media, telecommunications, publishing, etc.). From this point of view, "New Media" are not primarily clustered around each other, but are rather clustered around the key gatekeepers in the large firms that are their main clients. More recently, the emergence of "dot com" companies, focused not on fee-based work for large companies, but rather on venture capital financed development of Internet-based retail and wholesale concepts, has led to the suggestion that the focus of clustering has shifted from customers to financiers.

2.2 The "end of geography" version of the "new economy"

Without a doubt, the strongest thesis that has been advanced with respect to the impact of the "new economy" on the balance between centripetal and centrifugal forces is that the latter will come to predominate, once the *raison d'être* for agglomerated spatial forms is rendered obsolete through distance-shrinking technologies. This thesis has a long lineage, with its exponents seeing the very existence of the city itself as being under threat. Marshall McLuhan, for example, predicted in the 1960s that: "with instant electric technology, (the) very nature of the city as a form of major dimensions must inevitably dissolve like a fading shot in a movie" (McLuhan, 1964, p.366). In the 1990s, the advent of the Internet excited a new round of commentators to speculate upon spatial outcomes, with, inter alia, Negroponte (1995), stating that "the post-information age will remove the limitations of geography", Gilder (1996, quoted in Moss and Townsend, 2000), asserting that "cities are leftover baggage from the industrial era", and Cairncross (1997), heralding the "death of distance".

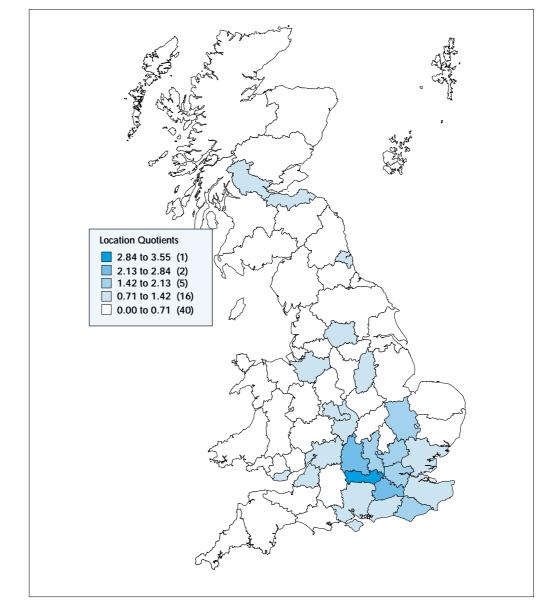


Figure 1. Location quotients for "New Media" firms

Notes: County Level Location Quotients for 4 136 "New Media" firms (1998-9 data from trade directories against 1996 VAT registrations). Source: CURDS Research.

There are a number of inter-related reasons that explain why ICT appear not to undermine existing urban agglomerations. Beyond these anti-urban assertions, the question remains of how exactly might the city be rendered unnecessary by ICTs? The answer lies in a particular conception of the city's *raison d'être*, which is that "*to avoid transportation, mankind invented the city*" (Schaeffer and Sclar, 1975). Quite simply, the argument is that electronic technologies are destroying the spatial monopolies of information and knowledge which have accrued to cities as a result of the difficulties of conveying such information and knowledge other than through face-to-face interaction. With inter-connected computer networks, and vast stores of information in digital form, it is thus argued that conveying

and/or obtaining information no longer depends on face-to-face interaction, and that as a result participation in the knowledge economy becomes, to all intents and purposes, location-independent.

There are, however, a number of inter-related reasons that help to explain why ICTs appear not to inevitably undermine existing urban agglomerations. These include the metropolitan bias in telecommunications infrastructure provision; the role of ICT in contributing to the strengthening of "global cities"; and the persistence, despite electronic networks, of what has been termed "the compulsion of proximity". Below we outline each of these explanations in turn.

Metropolitan "bias" in the provision of telecommunications infrastructures

Although modern communications appear to be so pervasive as to be literally "everywhere", in fact they rely completely on the presence of fixed telecommunications infrastructures, such as switches, wires, dishes and masts. These infrastructures are not provided everywhere, and certainly not everywhere at the same quality, and there is a strong, economic logic to infrastructure provision - a logic in which concentrations of demand attract suppliers - which is serving to reinforce the communications pre-eminence of major urban areas. Far from equalising the supply of telecommunications services across space, the interplay of rapid technological advance, the increasing specialisation of customer demand and the liberalisation of telecommunications (Gillespie and Robins, 1991). As Moss (1987, p. 536), first pointed out, these developments are leading to "the creation of a new telecommunications infrastructure designed to serve the information-intensive activities of large metropolitan regions".

ICTs and the strengthening of "global cities"

ICTs can contribute to both centralisation and decentralisation of economic activity, depending on the nature of the activity concerned. One set of economic activities where ICTs appear to be underpinning a process of centralisation, however, are those referred to as "command and control" functions (2). Knowledge based activities are becoming scattered across the globe, but the upper tier of such activities are being spatially concentrated in what have become known as "global cities". The main motor of this process of concentration, paradoxically, is globalisation.

Crucially then, advances in information and telecommunications technologies are contributing to both the *dispersal* of productive capacity and to the *centralisation* of command and control functions. Thus according to Sassen (1991, p. 5), it is "*precisely because of the territorial dispersal facilitated by telecommunications that agglomeration of certain centralising activities has sharply increased*".

The persistence of the "compulsion of proximity"

There is though an even more fundamental reason why new technologies are not undermining spatial agglomerations, and that is that the assumed substitution of face-to-face communication by electronic communications, on which the urban dissolution argument rests, appears not to be taking

ICT can contribute to both centralisation and decentralisation of economic activity, depending on the nature of the activity concerned.

²⁾ See, for example, Amin and Graham, 1997; Amin and Thrift, 1992; Castells 1996; Sassen, 1991; and Thrift, 1996.

Electronic communications appear to be complementing, rather than replacing, face-toface communication. place. Electronic communications appear to be complementing, rather than replacing, face-to-face communication. According to Boden and Molotch (1994, p. 258), "although in some instances communication is best done by more impersonal means, modernity implies no dilution in the degree that face-to-face - or, more precisely, "copresent" - interaction is both preferred and necessary across a wide range of tasks". They term this "the compulsion of proximity", and recognise that it provides a strong continuing impetus to agglomeration. As Tony Fitzpatrick, the Director of Ove Arup puts it:

"Remote working from self-sufficient farmsteads via the Internet cannot replace the powerhouses of personal interaction which drives teamwork and creativity. These are the cornerstones of how professional people add value to their work. Besides, you cannot look into someone's eyes and see that they are trustworthy over the Internet" (quoted in Amin and Graham, 1997, p. 413).

What of activities in which knowledge can be relatively easily routinised and embodied in technological systems of software and communications technologies? In such cases, there would appear to be more likelihood of technological advances contributing to dispersal. It is to a consideration of such activities that we turn in the next section.

2.3 The corporate spatial organisation perspective on the "new economy"

Beginning in the 1980s and accelerating considerably in the 1990s, large firms have pursued (for reasons including cost-reduction, improved efficiency and market extension) ICT-facilitated spatial re-organisation strategies (3). Although these strategies have resulted, in differing circumstances, in both the centralisation and the dispersal of activities, the overall spatial logic has been that of exploiting the locational flexibility ICTs open up in order to reduce costs through the re-location of "service" activities to lower cost locations. In this sense, ICTs have had similar effects with respect to services as did earlier transport and communication improvements with respect to production activities, enabling new "spatial divisions of labour" (Massey, 1984) to emerge, at both international and intra-national scales. In this process, certain locations previously defined as "peripheries" can become incorporated, given the right attributes in terms of the availability and cost of factors of production, into corporate structures of production.

Telecommunication-based information systems lie at the heart of such processes of re-organisation, enabling the re-location of activities whilst maintaining corporate control over them. In terms of the re-organisation of service activities, so-called "back office" functions, such as payroll and order processing, were first either "hived off" from the head office and located in lower cost locations, or were "stripped out" of branch offices and aggregated into dedicated back office facilities, which could then be optimally located, using telecommunications to link these back offices to corporate headquarters and branch offices. In both cases, these developments can be seen as part of a process of technology-facilitated "industrialisation" of service functions, in that they were associated with the standardisation of operating procedures and working practises, mediated via increasingly powerful information systems.

More recently, in the 1990s, a major new phase of service re-organisation has occurred in those service industries in which face-to-face contact with the customer has been augmented, or even

³⁾ See Hepworth, 1987; Gillespie, 1993; Goddard, 1992; and Li Feng, 1995.

replaced altogether, by tele-mediation (via, in the first instance the telephone), of the customer delivery channel. Since the first teleservice operations began in Europe a decade ago, in activities such as consumer financial services the "front office" function of servicing customers has increasingly been "back-officed" (Richardson, 1994), through the innovation of the telephone call centre.

Again, the separation of production from consumption, the exploitation of economies of scale in "factory-style" environments, and the routinisation and codification of procedures, amount to the "industrialisation" of customer service delivery channels. In locational terms, call centres open up radically new locational possibilities. Services, such as banking, which were previously delivered to customers through branch offices, can be re-organised completely and delivered through far fewer customer service factories, which can then be optimally located in order to exploit spatial divisions of labour and other spatially-differentiated costs, notably land and property.

Call centres generally have high levels of locational mobility therefore, though it needs to be stressed that they are not homogenous in terms of their locational requirements, with those activities requiring multi-lingual or technically-skilled staff (e.g. IT help-desks) being considerably more constrained in their locational options than call centres with more routine skill requirements. Overall, however, the locational outcomes point firmly in the direction of decentralisation from high cost locations. Given the availability of a sufficiently high-grade telecommunications infrastructure to provide intelligent network services across national territories, or at least the more urbanised parts of these territories, other factors - notably labour, property, incentives and welcoming development agencies - all tend to favour non-central, non-capital city locations (4). This is certainly true of the UK where regions such as Scotland, North East England and North West England have attracted a large number of call centres relative to their size and traditional employment structures (Richardson *et al.*, 2000; Richardson and Belt, 2001). This also seems to be the case in other European countries such as Germany and Sweden (Graef, 1998; Lorentzon, 1998).

What ICT has done is to render a greater proportion of the economy footloose, with a key innovation being telemediation of service delivery channels. For those activities at least at the lower end of the tacit knowledge spectrum, such as call centres, the "new economy" is not necessarily very different from the "old" in terms of the locational decision-making calculus of firms (i.e. infrastructure, labour, property, incentives and institutional support). What the "new economy" element of ICTs has done is to render a greater proportion of the economy *footloose*, with a key innovation being tele-mediation of service delivery channels. For relatively routine knowledge-based activities then, there is a strong, cost-based, impetus to dispersal, a process which is both made possible and enormously facilitated by ICTs. This dispersal is taking place from high cost metropolitan regions to lower cost metropolitan regions, and, within metropolitan regions, from urban cores to suburban or exurban peripheries.

In discussing locational dynamics in the "new economy", therefore, we need to place this "alternative" perspective alongside both the knowledge-based clusters leading to agglomeration interpretation and the (somewhat overstated) "end-of-geography" interpretation. This third interpretation of locational dynamics in the "new economy" has emphasised the greatly increased range of locational configurations and options which ICTs are offering corporate organisations in

⁴⁾ The exception is for call centres requiring multilingual labour, where a capital city may provide higher levels of availability of such labour than can be found in other parts of the national territory. The concentration of Ireland's pan-European call centres in Dublin is a good example of this effect.

their management of territory and in their market-serving strategies. The outcome of this enhanced locational flexibility appears to be resulting in ICT-facilitated decentralisation, both between and within regions.

3. Regional development in the "new economy": Lessons from policy interventions

Each of the three perspectives on the "new economy" outlined above is associated with differing opportunities for regional development, with differing constraints on realising these opportunities, and with differing policy approaches and outcomes. Our purpose in this section is to examine these contrasting opportunities, constraints and policy approaches, for each of the three "new economy" perspectives considered in the previous chapter.

3.1 Regional development and "new economy" activities

The first phase of regional policy engagement within the "new economy", which we can trace back to the late 1970s or early 1980s, but which is still alive and well in many regions, is founded on the notion of the "new economy" as being concerned with the emergence of a new sector, or more extensively a new and propulsive socio-technical wave of innovation, built around digital technologies. The notion of "new" that is invoked has, of course, developed over the last quarter century as the novelty of particular sets of economic activity waxes and wanes. Broadly, we can see a shift of emphasis over time, in part driven by the changing technological background, from a focus on computer and communications hardware, through software, to information, and most recently Internet-based transactional services. Through each of these phases the regional development opportunity was understood to arise from the very novelty of the sector. The inherited historical competitive advantage of the core regions in established sectors, was (mistakenly) seen as weakened in the context of new activities, "levelling the playing-field" between core and periphery, between favoured and less favoured regions. What was envisaged was a "window of opportunity" through which to capture a rapidly growing sector of economic activity that was, as a result of its very novelty, understood to be more or less footloose, in that it was not already tied into an established geographical pattern.

Two main variants of this approach emerged. One more or less based on (an image of) the model of Silicon Valley, focused on the clustering of generally indigenous "high tech" activities, both hardware and software, in an innovative milieu. The second, perhaps best exemplified in Europe by the central belt of Scotland, focused more on the attraction of branch plants of the major IT producers.

Europe has repeatedly proved to have a remarkably old geography, with patterns of innovation that date back to the 1930s at least. In the first variant, policy has focused on recreating the dense networks of linkages - in terms of labour (shared pools of skilled workers), capital (venture capital and cross holdings) and knowledge and information - that have been observed in many of the successful centres of innovation elsewhere (see the Cambridge case study in Box 1) through the creation of various forms of institutional structure (associations, clubs, networks) and the spatial context for such interaction (science parks and incubators). Such policies have sought to build on local indigenous entrepreneurial activity in the "new economy" and, where key elements have been lacking (such as venture capital activity, a skilled workforce or advanced research capacity) to attract in, or create substitutes for, these missing elements.

Box 1. The Cambridge "high tech" cluster

The growth of a number of distinct but often inter-linked "high tech" clusters in and around Cambridge, in the East Anglian region of England, has been termed the "Cambridge Phenomenon", and, more recently, "Silicon Fen". With its proximity to London and its prestigious university, Cambridge has long been a centre of research and development; indeed, the origins of the Cambridge Phenomenon can be traced back to the formation in 1881, by two Cambridge graduates, of the company which later became Cambridge Instruments, which developed the first seismograph. However, it was not until the establishment of Cambridge Science Park in 1970, coinciding with the advent of the microelectronics revolution, that a high tech cluster of economic activities came into being. Early growth was rapid, such that by 1986, 16 500 workers were employed in high tech industries in Cambridge. In 1997, there were approximately 26 000 high tech jobs in Cambridge, with a further 11 000 in the surrounding areas of Cambridgeshire. In computer software alone, there were 4 900 jobs in Cambridgeshire in 1997, with the cluster comprising some 315 firms, many of them small.

There are a number of factors which have underpinned the formation of the software cluster in Cambridge, or which have contributed to its continuing success. The most significant such factors are:

- The University although few software firms use the university for research purposes, it was a dominant factor in the initiation of the cluster. Further, the prestige of the university, in international terms, has helped in marketing firms operating within the cluster. Although the cluster was initiated by graduates from the university, this is no longer the predominant source of labour supply; indeed, many skilled people have moved to the area to be part of the cluster. It is now only the most technically-oriented companies, having strong links with the university's engineering and computing departments, that rely on the recruitment of Cambridge graduates. For these companies, however, this is a major attraction of the area.
- Proximity to market the importance of this factor varies according to the nature of a company's business. For Internet-based companies, a significant proportion of their work is generated, by means of contacts and informal networks, through the cluster, and many companies consider that a location in the heart of Cambridge is important to maintain these contacts. More generally, the proximity of companies involved in related activities has been a major factor in the development of the cluster. Indeed, several companies have come to Cambridge to be part of the "scene" or "phenomenon".
- Infrastructure for business Cambridge offers advantages to small businesses in the form of serviced accommodation sites, and business parks, such as the St. John's Innovation Centre, which offers business advice and acts as an incubation unit for small but rapidly expanding businesses. The plethora of experienced business people around Cambridge is also an attraction. There are also well established formal and informal networks, such as the Cambridge Network, established in 1998 to link the business community in Cambridge to the global high tech community.

The Cambridge Phenomenon illustrates the continuing need for direct physical presence within dynamic knowledge-based clusters, even in industries based upon the most advanced ICTs. Further, it highlights the importance of factors - notably the prestige and research excellence of Cambridge University - which would be very difficult to replicate in other locations.

In terms of the vision of an innovative milieu of indigenous firms, anything like Silicon Valley has proved almost impossible to recreate in Europe (in large part because Silicon Valley already exists, enjoying some unique first mover advantages). Further, the indigenous "new economy" in Europe has repeatedly proved to have a remarkably old geography, with patterns of innovative activity that date back to the 1930s at least (the dominance of regions such the south of England in the UK, the lle de France, south and south western Germany, Catalonia in Spain, and the northern regions of Italy). This pattern of "innovative", "high tech" or "creative" milieux that exists across Europe - the so called "archipelago" of high tech Europe - appears highly stable. Neither the "greenfield" (generally peripheral) regions that escaped industrialisation in the 19th and early 20th centuries, nor the "brownfield, older industrial, regions with their legacy of earlier rounds of investment in heavy industry, mining and textiles have seen the development of significant indigenous clusters of high tech, software or multimedia-based development.

Recreating the conditions for the development of innovate milieux in less favoured regions has proved exceptionally difficult. Recreating the conditions for the development of such innovative milieux in less favoured regions has proved exceptionally difficult, in part because those conditions were both difficult to specify and, where they were identified, have tended to have a long historical gestation and/or require the co-ordination of policy in a wide range of areas (from university-based research through land and property, training, venture capital and banking, to the establishment of inter-firm networks for information exchange). The lack of much indigenous entrepreneurship, or knowledge base, to build around has often hampered these initiatives, blunting their "high tech" edge, with science parks ending up filled with a much more diverse set of clients. There are, nevertheless, possible exceptions, for example in the Scandinavian countries, in particular Sweden and Finland, although these appear to be highly reliant on individual national champions (Ericsson and Nokia respectively) and their strategic position in the cellular telecoms boom. In general, research has tended to confirm that an indigenous approach to establishing clusters of leading-edge technology-based businesses, where these do not already exist, has failed.

If less favoured regions lack many of the preconditions of establishing an indigenous "new economy" sector, an alternative has been to import some of the most important elements - above all capital and knowledge - from the core regions in the form of inward investment. With large national or multinational corporations providing these key ingredients, the region's contribution has generally been to provide suitable land (usually in the form of the ubiquitous greenfield business or science park), suitable lower cost/turnover labour (through the training system) and a lower cost of capital (though grants and other financial inducements).

This inward investment-oriented route has recorded some successes, at least in terms of IT manufacturing, in particular in central Scotland ("Silicon Glen") and perhaps also Ireland, where (generally US) "high tech" multinationals have located a large number of branch plants. It is not yet clear, however, to what extent these branch plants are any different to (or more sustainable than) earlier rounds of branch plant investment, or the degree to which a more sustainable growth pattern with supporting indigenous activity has been established. There is often a lack of linkage between these branch plants and local suppliers, limiting the capacity for knowledge transfer as well as simple multipliers, and such branch plants have only slowly gained any local autonomy in terms of higher value adding activities (such as research and development). While these branch plants might be seen to have got their regions on the "first rungs of the high tech ladder", enabling them to move slowly up the value chain, there is little conclusive evidence that any region - with Ireland perhaps being the exception - has successfully managed to achieve this upward trajectory.

What are the lessons that can be drawn from this account? Three points appear to be critical. The first concerns the remarkable stability of the geography of innovation within Europe and scale of the task that one is attempting in seeking to radically change that geography. The second point is that it appears impossible to conjure up advanced industrial activity in less favoured regions where there is no substantial knowledge-base or appropriate competencies to build on. Third, in the early stages of development at least, external involvement (in the form of major state and/or multinational investment) is vital to establish the basic competencies and knowledge base on which development can take place.

3.2 Regional development and the "death of distance"

The second "new economy" perspective is concerned with the regional development opportunities associated with the distance-transcending capabilities of telecommunications networks. These opportunities can be taken to include:

- Access to markets: through ICT innovations, notably the Internet, enterprises in peripheral regions and rural areas could gain access to markets in core regions and metropolitan areas;
- Access to business services: electronic delivery mechanisms could help such peripherally-located enterprises to gain access to higher quality and/or lower cost business services;
- Access to public services: citizens in remote and rural areas could gain improved access to the public services - such as health and education services - available in metropolitan areas, through telematics innovations such as distance-learning or tele-medicine.

Understandably, regional disparities in levels of telecommunications infrastructure provision have been assumed to impose significant limitations on these regional development opportunities being realised. The "gap" in telecommunications infrastructure provision between core regions and peripheral and/or low density regions has long been of concern to regional policy-makers, and has been the subject of policy intervention (see the Highlands and Islands of Scotland case study in Box 2).

Within the context of increasingly liberalised telecommunications environments, the European Union's strategy with respect to closing the regional telecommunications infrastructure gap has three main elements (European Commission 1997):

- · Using regulation, and in particular the Universal Service Obligation to promote cohesion;
- · Completing the basic telecommunications network, and,
- Stimulating demands for telecommunications services to pull through supply.

The emphasis in the last point on demand stimulation reflects a broader understanding that *"infrastructural difficulties are no longer a major obstacle"* to the use of ICTs (Mitchell and Clark, 1999, p. 447). Although policy-makers initially believed that telecommunications infrastructure investment alone would be sufficient for peripheral and less favoured regions to overcome their (assumed) distance-related developmental constraints, all the evidence suggests that such regions make less *use* of ICTs than their core region counterparts, and that although telecommunications infrastructure is undoubtedly *necessary* to regional development, it is not *sufficient*.

Box 2. The Highlands and Islands of Scotland

Addressing the "infrastructure gap"

The economic development of the Highlands and Islands of Scotland has always been handicapped by the geographical realities of distance and terrain. It is remote from the urban centres of the UK, is one of the most sparsely populated parts of the European Union (on a par with the northern parts of Sweden and Finland), and has 30% of its population living on islands. In the mid-1980s, the organisation charged with the economic development of the region, the Highlands and Islands Development Board (which became subsequently Highlands and Islands Enterprise, HIE), decided that telecommunications could help overcome the physical barriers that were perceived as obstructing the region's development.

It became apparent that British Telecom (BT), the newly privatised monopoly provider of telecommunications services in the region, had no plans to up-grade the network in the area, seeing little prospect of an adequate commercial return (Richardson and Gillespie, 1996). Following negotiations between HIE and BT it was agreed that HIE would contribute GBP 5 million towards the cost of a GBP 16 million upgrade of the region's infrastructure, with the rest provided by BT. The infrastructure investment programme initially covered three areas of work:

- Improving data transfer services with the area, and making them available at local call rates rather than at trunk call rates;
- Upgrading 43 exchanges to support ISDN services, later amended to 70;
- Establishing a "network services agency" in Inverness, to provide value-added services (such as computer conferencing, e-mail, and bureau facilities) and access to national databases.

Although this meant that around 80% of business lines were connected to Digital Local Exchanges (DLEs), areas outside the main centres of population remained reliant on older exchanges, providing a more limited range of digital services. Research suggested that this left a number of businesses which, taken together, were significant to the region's growth, being without access to advanced services (Richardson and Gillespie, 1996). In addition distances between some customers and their closest exchange prevented full service provision; for example, basic rate ISDN becomes unavailable once the "line loss" is too great, typically beyond 4.5 km of a DLE.

It became clear that further intervention would be required to secure the upgrading of infrastructure in the more rural parts of the region. BT had no intention of upgrading these areas and no competitor provider was emerging. In 1997, therefore, HIE negotiated a joint programme with BT to upgrade coverage to the 20% of the population which had not been upgraded in the original programme. This upgrade cost GBP 4.8 million, with GBP 1.7 million coming as public subsidy.

A further intervention was made in order to secure the infrastructural investment to secure wide coverage in the field of mobile telephony. HIE, together with Cellnet and Vodaphone undertook a GBP 46 million project, with GBP 4 million of public money, to install cells to enlarge mobile coverage, with the aim of bringing coverage to 95% of the population. By autumn 2000 the process was almost complete. Take up of mobile has been rapid in the region, and new cells are being installed or upgraded because of the scale of demand.

This case study demonstrates that on-going constraints exist on market-led telecommunications being able to deliver high quality telecommunications services in remote and low population density regions. Public intervention has been necessary on a repeated basis in the Highlands and Islands of Scotland to ensure that particular network up-grades take place within the region, and this situation is unlikely to ease over time. Each new technology will be first deployed in metropolitan and core region markets, and remote and rural regions will be a long way down the "roll-out" queue, and perhaps unable to justify the investment at all. Public intervention - in the form of direct subsidy - can prove successful in modifying these investment decisions such that remote areas benefit from new services earlier than they could justify on commercial grounds alone.

Raising awareness of the potential of infrastructure

It was clear from the beginning that infrastructure, though crucial, would not of itself lead to economic development and a programme to raise awareness of the technology and to accelerate its take-up was established. A central element of this programme was a series of road shows aimed at closing the awareness gap amongst SMEs. Since then a range of awareness measures have been taken. Examples of support initiatives in which HIE have been involved during the 1990s include:

- · Financial support to micro and small businesses engaged in tele-activities;
- A strategy to encourage food and drink manufacturers to adopt electronic data interchange (EDI) applications;
- A Business Information Source providing a one-stop shop business information service to firms throughout the region;
- Establishing a number of Community Telecottage Centres to provide training, shared access to ICTs and a site for teleworking;
- Establishing websites such as those on the Islands of Islay and Jura, which allow businesses to promote themselves worldwide.

Investments in digitalisation and other new telecommunications infrastructures generally presupposed a ready and willing source of demand for the new services available. In many cases, the intended uses and users of these infrastructures have simply failed to materialise, at least as quickly as was hoped. The much forecast explosions in teleworking, tele-medicine, tele-education and so forth have not happened (or not as expected and not in the less favoured regions). Indigenous firms in the less favoured regions, and in particular the SMEs sectors, have proved particularly slow adopters of the new communications technologies (Ilbery *et al.*, 1995; Richardson and Gillespie, 1996). And in instances when they have adopted such technologies, the translation from adoption into effective use and competitive advantage does not automatically follow (Capello, 1994; Grimes, 2000).

In part, the disappointment with the outcomes of policy intervention is due to the nature of regional development problems being mis-specified in the first place. In particular, the problems ascribed to "peripherality" or "remoteness" have been misinterpreted as being amenable to solution by

technologies, which can eradicate the effects of distance. A good example is provided by the Internet, which appears to offer SMEs in peripheral regions and rural areas the possibility of "breaking free" of the market-access limitations imposed by remoteness. However, although the Internet will undoubtedly become a widely-used business tool, it is not likely, in any generalisable sense, to transform the market access opportunities of SMEs, most of whom are selling to local markets and do not have the managerial or market-serving capacity to efficiently serve remote markets.

The two mis-specifications here are firstly that the main barrier to peripheral SMEs gaining access to core markets is geographical distance, and secondly that this distance barrier can be overcome by ICTs. We would contend that geographical distance per se is not the main barrier facing peripherally-located SMEs wishing to gain access to core markets, rather it is their inability to compete in these markets, due either to problems of price (by definition, small firms will often not be able to reap the economies of scale which larger firms can exploit) or to problems of product/service quality or design; evidence suggests that high rates of innovation and achieving high quality are likely to be associated with having particularly demanding customers, which most peripheral and non-metropolitan areas are unlikely to have the benefit of.

For the relatively few rural SMEs which *do* have competitive products or services in metropolitan or even global terms, the problem of access to geographically distant markets is not likely to be overcome by technological solutions, such as the Internet, alone. The ability to serve a remote market will usually require both distribution networks and direct market presence, due to the requirements for negotiation in the selling process and for after-sales support. ICTs can usefully supplement the type of direct market presence that is usually required; only in a limited range of products/services can it substitute entirely for such presence. It follows that policies to stimulate the up-take of such ICT applications and services by SMEs located in peripheral regions with the specific aim of helping them to gain access to remote markets will often have disappointing or limited results; many of the firms concerned will have products or services which are not competitive outside the local market, and others will need to put in place mechanisms for providing them with direct presence in remote markets if they wish to compete effectively in such markets.

3.3 The attraction of information-intensive inward investment

As was illustrated in Section 2.3, the growth of ICTs, taken together with a number of other interrelated factors including globalisation, liberalisation of trade and markets, and the growing importance of services is increasing the number of footloose economic activities. These range from fairly basic, low-skilled activities, to relatively skilled functions, and include data processing, call centres and multi-media customer service centres, software production, shared service centres, and regional head offices (continental-wide or sub-continental hubs). However, they rarely include strategic activities.

A relatively common approach to attracting information intensive inward investment has emerged throughout the advanced industrialised world and competition is now intense. It includes the following policy levers:

Geographical distance is not the main barrier facing peripherally located SMEs wishing to gain access to core markets, rather it is their inability to compete in these markets.

Telecommunications infrastructure as an inward investment strategy

As economic activities become more and more dependent upon high-grade telecommunications networks, and as the focus of inward investment attention shifts towards information-intensive services, so the quality of telecommunications infrastructure becomes an increasingly influential location factor. This is well illustrated by the Irish example (see Box 3).

A number of lessons regarding the telecommunications infrastructure and services emerge with regard to attracting inward investors. Firstly, investment in ICTs cannot be a one off. Unlike other forms of infrastructure investment, which regional agencies have traditionally used as development levers, such as roads and real estate, the "shelf life" of particular information and communications technologies is short. Continuous updating is required in order to retain competitive advantage.

Secondly, for most urban regions at least a liberalised market is likely to be the best mechanism for ensuring investment in advanced technologies. Increasingly short ICT product cycles and the increasing variety of services on offer makes it unlikely that public agencies will have the finances or expertise to make large-scale public investment sustainable in the long-term. The Irish experience in accelerating telecommunications liberalisation in response to the demands of US companies is instructive in this regard.

Thirdly, the market will not automatically provide a high-grade infrastructure in all areas; in lowdensity rural regions such as the Highlands and Islands of Scotland, the liberalisation process has not attracted competitor telecommunication supplier to the dominant (former state) monopoly provider. Where new entrants do emerge, either in fixed or mobile services, they tend to require public subsidy (see Box 2 above). Rural regions thus face a vicious circle. They are unable to secure telecommunications investment ahead of demand in order to attract inward investors and by failing to attract inward investors they are unable to create the critical mass of information intensive firms required in order to make it commercially viable for telecommunications providers to invest in infrastructure.

Labour markets, education and training

A crucial factor in attracting or limiting the attraction of inward investment is, of course, the availability of a suitable pool of labour that is sufficiently skilled to enable firms to obtain the staff that they require at a reasonable price. The attributes of a particular region's labour force will, of course, be a function of a range of factors, not least of which is its historical industrial structure. Many of those regions that are currently attempting to attract information intensive inward investment tend to have been reliant on heavy manufacturing industries. In such circumstances, a change to the skill base and to cultural attitudes is likely to be required. Education and training are thus key elements for such regions.

Box 3. Telecommunications in Ireland

The role of telecoms infrastructure in attracting inward investment

The Republic of Ireland has been seen by many as a European success story over the past few years and has been termed the "Celtic Tiger" in recognition of the way its growth has mirrored that of the rapidly growing economies of South-East Asia. This success has largely been based on the sustained attraction of foreign direct investment in a number of industries. Over the past 15 or so years emphasis has been placed on the attraction of IT firms and on "knowledge-based" firms in areas such as financial services, particularly from the Unites States.

As Ireland sought to attract more sophisticated and knowledge intensive businesses the need for more advanced information and telecommunications services became apparent. As early as the late 1970s, it had become apparent that the existing electro-mechanical telecommunications system was unsuited to the demands of the electronics and software companies and the poor state of the telephone system was cited as the greatest single complaint from foreign industrialists (MacSharry and White, 2000). In response the government established a new state agency, Telecom Eireann, and committed to build a digital-based network. This investment came on stream in the 1980s and by the early 1990s it was claimed that USD 4 billion had been spent on modernisation (IDA Ireland, 1995). The availability of advanced infrastructure and services became a central plank in the Irish Development Agency's marketing efforts (Grimes, 2000; MacSharry and White, 2000). Additionally, services and tariffs appear to have been designed by the state-owned Telecom Eireann to benefit large internationally oriented firms. The cost of digital circuits between Ireland and the US were reduced to make Ireland a cost effective location for branches, which had heavy traffic with their parent organisations. In order to attract telemarketing firms volume discounts were introduced, as were low incoming toll free and international dial direct tariffs.

A number of reports suggest that this strategy presented Ireland with a competitive advantage over other countries, particularly in the area of pan-European telemarketing (ACT, 1999; Richardson and Marshall, 1999; Breathnach, 2000a). The same is likely to be true of other information activities such as software production and financial services.

Liberalisation as a means of meeting the needs of inward investors

Despite the undoubted success of the Irish strategy, it also underscores the lesson that investment in telecommunications infrastructure is a continuous process. Despite large-scale modernisation of the infrastructure throughout the 1980s, by the mid-1990s inward investors were expressing frustration about the lack of competition in the Irish telecommunications market, and the effect of this on investment in that market. Partial liberalisation commenced in Ireland in 1992, but was not due to be completed until the year 2000. The Advisory Committee for Telecommunications (ACT, 1999), a committee composed of representatives of US firms (and thus unsurprisingly favouring a US rather than a European model) and Irish representatives concluded that there were a number of deficiencies, namely:

 an absence of competitive, high capacity, Internet-capable international connectivity linking Ireland to the US and key European centres at prices that were less than or, at worst, no more than best international practice;

- a lack of competition in the provision of high speed Internet services and the absence of both a recognised Internet peering facility and of global Internet service providers in the Irish market;
- the availability and pricing of broadband connections to businesses throughout Ireland was deficient in comparison with the best international benchmarks (the absence of tariffed ATM and xDSL services and the high prices for primary rate ISDN and leased lines were seen as particular shortcomings in this regard);
- Internet charges were significantly higher than the best global benchmark (i.e., US).
- the high interconnection costs in Ireland and the absence of a standard of service agreement between the incumbent and new telecommunications operators.

The response to these criticisms was two-fold. First, the timetable for full liberalisation of telecommunications services was brought forward to the end of 1998. Second, a further round of public investment in advanced infrastructure was announced in the National Development Plan for 2000 - 2006 "to promote investment in advanced communications and e-commerce infrastructure where it is clear that the market will not deliver sufficient investment, and to support the acceleration of the Information Society and e-commerce" (SFD, p2). Thus, although the need for a more liberalised market environment to attract FDI was acknowledged it was recognised that the market by itself would not promote investment in all regions of Ireland.

Many regions, at least initially, can only hope to target lower-value-added information intensive jobs such as call centres. Even these jobs, however, require new skills and cultural attitudes. The evidence suggests that many regions are rapidly adapting their training systems to take into account the demands of organisations offering these jobs. Training courses are increasingly being tailored to meet these demands. It should be noted that the main demands, which these firms make, are not for ICT literate staff. It is generally felt that ICT skills can easily be taught. Rather these firms require that workers are equipped with a set of social and interpersonal skills - what they often term "people skills" - which might be seen as socially constructed personality traits rather than skills *per se*. These generic requirements need a very different approach and put a considerable pressure on training agencies.

The North East of England provides a good example of a region in which labour availability has played an important role in attracting call centres, and in which the local training system has responded to the needs of call centre inward investors (see Box 4).

Real Estate

In spite of the rhetoric of a "weightless" information economy, the importance of traditional physical (one might even say concrete) factors such as real estate and transport infrastructures appear to remain crucially important. However, the form and location of the real estate required in the information economy is often very different from that required previously. One obvious change is the growing importance of offices as opposed to factories. Further, office provision is changing. For smaller information intensive firms the demand is now for open plan, flexible, modular, wired office space. For the more industrialised office processes (such as call centres) large single or two storey

office spaces are required. In each case access to road networks and plentiful car parking are also required, such access allows firms to draw upon a wider pool of office workers and also facilitates ease of access for and to external clients. In all our case study regions, the provision of space, often ahead of demand was crucial to attracting information intensive firms. The ability to respond rapidly in providing built space also seems to be becoming more important.

Box 4. Labour market factors in the attraction of call centres to North East England

The availability of a sufficient pool of quality labour at a lower cost than other regions is a crucial factor behind the location of call centres in the North East of England. (Richardson and Marshall, 1996; Richardson and Belt, 2001). Call centre pay in the region is consistently the lowest (or amongst the lowest) in Britain. This is reflective of the generally low average earnings in the region. In addition to low wages, the region offers relatively low labour turnover rates as a result of the high levels of unemployment and lack of alternative jobs. Clearly these factors are the result of the region's poor economic position rather than the (intentional) outcome of economic development policy.

However, the economic development community has taken steps to further improve the flow of labour to the call centre sector through a series of training initiatives. Most training agencies and colleges have reconfigured their programmes to take the needs of call centres into account. Sunderland has been particularly pro-active, establishing a call centre college, an up-stream call centre course for basic training, and a course for the long-term unemployed and other socially disadvantaged groups. The latter training is located in "electronic village halls" based in housing estates in which the residents suffer from social exclusion. The inward investment community has also used the fact of low wages and low turnover as part of its place marketing strategy, albeit also emphasising the quality of labour.

Subsidies

Real estate and infrastructure subsidies remain a key weapon in the armoury of the development agencies. To take one example, in the North East of England a number of Enterprise Zones have been created which provide subsidy through grants and tax holidays. Around 60 per cent of new inward investments in call centres have located in these zones. A number of other information intensive businesses have also located here. This suggests that subsidy remains important, though it should be noted that it is difficult to disentangle the attractions of subsidy from the effects of the ready availability of customised, readily available property, with room to expand. Similar subsidies, as well as less direct subsidies associated with land reclamation were also crucial to the success of the Highlands and Islands and the Republic of Ireland in attracting inward investment.

Building institutional capacity

A further factor, which helps explain the success of certain regions in attracting ICT-intensive inward investors, is the institutional capacity that they have developed over the years. These institutions engage heavily in intelligence gathering, place marketing and company support. Ironically, of course, the success of these regions in developing inward investment agencies reflects to some extent their relative lack of success in developing a self-sustaining endogenous economic motor and

although efforts have been made to overcome over-dependence on inward investment, these regions remain heavily reliant on this form of investment.

Some problems with inward investment

Just as inward investment based regional development strategies in the industrial era had a number of problems associated with them, so do those in the information age. For many regions, the reality of their current position dictates that inward investment is the most viable, or perhaps the only option for economic growth. However, just as inward investment based regional development strategies in the industrial era had a number of problems associated with them, so do those in the information age. Typically these include the following:

- Many inward investments to less favoured regions, even those associated with ICT-intensive work, will tend to be stand-alone operations, with a restricted range of activities. They will thus call on a limited range of skills. They are likely to have few linkages within the host region, tending to be vertically integrated with their parent organisations in core regions.
- The limited nature of many inward investments also means that there is only a limited management capacity. There is thus little prospect of spin-off activities by managers.
- The footloose nature of the operations, which come to be located in less favoured regions, suggest that they may also easily move on to other locations. This may be particularly the case where they have been attracted by financial incentives, which run for only a limited period. Other regions may well offer the same type of incentives and may also offer lower labour costs. There is, of course, already anecdotal evidence to suggest that information intensive work is going "offshore" from Europe and US facilitated by growing global telecommunications networks.

* Finally, and perhaps most crucially, is the impact of further rounds of technological investment. For example, in the case of call centres, which were perhaps the fastest single area of employment generation in the 1990s, we are already seeing a range of technologies emerging which potentially make many of the activities which these centres host redundant. The growth of the Internet, and truly electronic real-time interaction between the consumers' PC and the firms' databanks may accelerate this process. The transition towards electronically mediated self-service, of course, is unlikely to be a smooth one and there still may activities where consumers demand a human interface. Further new activities may emerge as new services emerge. If less favoured regions can build on existing inward investments to capture these activities then they do not necessarily face a technologically imposed jobs meltdown. For those regions which become overreliant on a narrow base of lower skilled information intensive jobs, however, technological change may well lead to large scale employment losses in the future.

4. Conclusions

This paper has attempted to demonstrate that the "new economy" has a number of differing implications for the location of activities and for regional development prospects.

One aspect of the "new economy", the emergence of a new set of economic activities around the capabilities of the Internet, of which "dot.com" start-ups (and, in many cases, close-downs!) are the most dynamic expression, was observed to have a strong tendency towards agglomeration. This fits the more general pattern of knowledge-based clusters, and is unlikely to be undermined by ICTs.

In fast-moving knowledge-based activities, the advantages of agglomeration, first noted by Alfred Marshall, remain overwhelming. From a regional development point of view, it cannot be assumed that "new economy" clusters are replicable in any location; firstly because there are substantial first-mover advantages, and secondly because such clusters are invariably based upon pre-existing ensembles of knowledge activity. Silicon Valley, in other words, has proved very difficult to clone, and strategies to develop knowledge-based clusters, where these are not already established, have had disappointing results.

Much of the interest in the "new economy" from a regional development point of view has centred on the potential for ICTs to bring about the "death of distance", and, hence, to liberate peripheral regions from the (assumed) distance-related barriers from which they suffer. We attempted to demonstrate that the pronouncement of the "death of distance" was premature, and that there remain strong reasons why face-to-face or "co-present" interaction is unlikely to be systematically undermined by electronic communications, which are tending to complement, rather than substitute for, face-to-face interaction. Further, we suggested that the economic development problems of peripheral and less-favoured regions may be being wrongly ascribed to geographical distance, and that, in consequence, it is unsurprising that the results of policy initiatives to help firms overcome distance by means of electronic communications have proved disappointing.

ICT innovations are making many routine services "footloose", though the extent to which these jobs provide the basis for long-term development remains open to question. Finally, we suggested that ICT-based innovations in the organisation and delivery of service activities are having potentially radical implications for the locational dynamics of services. These innovations - notably the tele-mediation of service delivery through telephone call centres and the Internet - are making possible the "industrialisation" of services production and, at the same time, are making many routine services locationally "footloose". There is a strong, cost-based logic leading to the decentralisation of such activities, both between and within regions, in order to exploit factor-cost differentials. In one sense then the "new economy" is not that different from the old. From a regional development perspective, the footloose nature of routine services is providing opportunities for regions to attract telephone call centres (which have been termed "customer services factories"). A number of regions have benefited from the attraction of such jobs, though the extent to which these relatively routine and highly mobile service activities provide the basis for long-term regional development remains open to question.

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Computers and employment: The truth about e-skills



Luc Soete



Bas ter Weel

1. Introduction

When compared to other technological breakthroughs, information and communication technologies (ICT) appear to have at least two unique features. One is the long, unremitting technological improvement that has taken place in these technologies during the post-war period. A second unique feature is the exceptional technological spillovers that are possible throughout the economy.

This paper addresses the particular question of the impact of this "new" digital environment on the labour market. It will investigate in particular how ICT has changed and is changing the labour market and the "old", classical insights into the relationship between technology, employment and skills. We start in Section 2 with a review of the literature on technology and employment. In previous centuries, but also in recent decades, new technologies were often identified with employment "destruction". They were feared to be one of the main causes of unemployment amongst unskilled workers and at the origin of most of the new, so-called "biased" opportunities in favour for more skilled workers. Ever since the so-called Luddites smashed the power looms and spinning jennies that threatened their livelihood in the early 19th century, the popular fear that technological change would increase unemployment has existed and continued even in boom years.

We do not review the currently available evidence surrounding employment growth in Europe and its relationship with the "new" economy. We rather focus here on the skill aspects of the emerging new ICT. These remain controversial, and too often represent an area of meaningless "policy speak".

There is little doubt that most of the jobs being "displaced" as a result of the application of new ICT have been concentrated amongst the lower skilled workforce, whereas many of the new jobs have required, different, sometimes new (or higher), levels of skills. Hence, as the demand for skilled labour has risen relative to the demand for unskilled labour, wage differentials have widened in favour of the higher educated. For example, it is often cited that since 1979, the average weekly earnings of college graduates in the United States have risen by more than 30 percent relative to those of high-school graduates (e.g. Katz and Murphy, 1992). As average real wages rose relatively slowly for much of this period, the real pay of the least educated has actually fallen in the United States over the past 20 years.

Section 3 addresses the computer as the particular prominent example of this process. However, it does not appear to be computer skills *per se* that have particularly led to increasing demand for skilled labour. In this regard, Acemoglu (1998), and Goldin and Katz (1998), suggest that although ICT must have played a part in the widening of wage inequality over the past two decades, slower

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growth in the supply of more educated workers may have been a bigger factor (1). This evidence leads us to review (in Section 4) international data on skill levels to investigate further the differences across countries and the consequences for wages. Following this analysis, we conjecture that the ultimate effect of the computer is to free time for the core tasks of a particular job. This will induce employers to hire more skilled workers.

Concluding, we highlight some features of the current impact of ICT on growth and employment. So far the rapid diffusion of the information communication revolution has been accompanied at the aggregate level, with a predominance of new employment opportunities: in sectors predicted to witness significant employment displacement such as the telecom or financial services sector. But this current pattern gives no guarantees as to future sectoral employment trends. The only clear indication seems to be that demand satiation is more than ever not a factor bringing about technological unemployment.

2. New technology and employment

The relationship between technology, growth and employment has been the subject of a large literature in economics. We would distinguish four sets of economic debate on the relationship between technology and employment. The first, and most "classical" in its origins, took place during the economic depression of the 1930s. The second debate focused mainly on the post-war United States and the fear of "automation". In the 1960s, levels of unemployment were higher in the United States than in Europe, and many people blamed technological change. As a result, a National Commission on Automation was appointed and produced a massive six-volume report in 1966. The third debate, which began in the late 1970s, was particularly active in Europe. It focused on the emergence of the combination of computer-based communication, information, and automation techniques associated with microelectronics. These appeared at first glance to have great labourdisplacing implications. The fear was that these displacement effects might dominate the compensating job creation effects for quite some time. As with the classical debate, this was a reflection of the times: there was a set of "revolutionary" new technologies and persisting high unemployment. The fourth, and most recent, upsurge in this debate focuses more on the global aspects of ICT, and the possible erosion of employment and living standards in the advanced countries. Originating mainly in the United States, and linked to the political debate surrounding NAFTA, it quickly "globalised", and spread throughout the world (2).

While the subject of intense argument over the last two centuries, the relationship between technical change and employment appears straightforward today, at least from the macroeconomic perspective. Either the introduction of new technologies leads to more efficient production processes, reducing costs by saving on labour, capital, materials, energy, or any other factor of production, or it leads more directly to the development of new products that generate new demand. In either case, more welfare is created: in the first scenario through more efficient production that liberates scarce input resources; in the second case by satisfying new wants. The impact is often a mixture of both effects.

2) See Freeman and Soete (1994), and Soete (1987), for an overview of this latter fear.

As long as there are unsatisfied needs and labour and product markets are flexible, technical change does not reduce aggregate employment.

¹⁾ In the 1970s, the supply of educated workers surged in America as the baby-boom generation entered the workforce and college enrolment rose. But since then, the educational level of the workforce has improved much more slowly. A comparison made by Murphy, Riddell and Romer (1998), of the United States with Canada supports this argument. During the 1980s and 1990s the ratio between the earnings of university graduates and high-school graduates rose sharply in the United States, but fell in Canada. In both countries the demand for skilled labour rose by similar margins, but the supply of educated workers rose much more rapidly in Canada than in the United States.

The extent to which this higher welfare or increased productivity feeds back into employment growth depends on the extent to which firms translate productivity gains into lower prices and new investment, and the pace with which consumers respond to lower prices in terms of greater demand. The job losses that might follow the introduction of a new labour-saving process are compensated by the job creation associated with output growth (following the decline in prices), by additional employment creation in other sectors (and particularly in the new technology-supplying sector), and by the possible substitution of labour for capital (following a downward wage adjustment that clears the labour market). As long as there are unsatisfied needs in the economy and as long as labour and product markets are sufficiently flexible, technological change, even in the form of new labour-saving production processes, does not reduce aggregate employment.

Most of the controversies that have dominated the economics literature on this issue over the last decades have centred on the automatic nature of the various compensation effects described above. Since the functioning and flexibility of product markets depends in part on the firm's market power, the degree of economies of scale and various other factors influencing prices, many contributors have questioned the way in which cost reductions are effectively translated into lower prices and are likely to lead to more output growth. Similar questions can be raised with respect to employment growth and the functioning of labour markets; they range from downward wage inflexibility to the many mismatches typical of (heterogeneous) labour markets. In either case, it is less technology itself that is at the centre of the debate than the pace and clearing function of product and labour markets. The relevant policy issues therefore fall primarily under the heading of improving the functioning of these markets (3).

Other contributions have questioned the possibility of *ex-post* substitution between labour and other factors of production. At least in the short term, the implications of a more rigid set of production coefficients for analysing technical change and employment are relatively straightforward. Labour-saving technological change embodied in new investment could, if wages adjust slowly, lead to unemployment because of insufficient investment to maintain full-employment; this is the so-called "capital-shortage" unemployment. There was a lively debate during the 1980s on the extent to which the increase in unemployment in European countries could be due to this phenomenon.

Yet other contributions question the automatic nature of the link between input-saving new technologies and productivity gains. Most of these studies were empirically focused and attempted to find reasonable explanations for the disappointing performance of total factor productivity growth in most OECD countries during the late 1970s and 1980s, despite rapid investment in knowledge (in particular, in private sector R&D) and the emergence of the new combination of ICT.

The international "open economy" framework within which most compensation mechanisms are likely to operate, complicates, however, matters greatly. Relatively straightforward linkages between technology, productivity growth, and job creation such as those mentioned above no longer exist. Even the most simple elaboration in terms of employment compensation due to foreign demand (e.g. through export and import elasticities) leads to complex interactions (Stoneman, 1984). More

However, an international "open economy" framework complicates the matter greatly.

³⁾ The OECD Jobs Study (1994) can be said to have focused primarily on labour markets emphasising in particular the poor functioning of labour markets in Europe, compared to the US; the McKinsey Global Institute study (1994) on the functioning of product markets.

complete pictures including not only trade, but also the effects of international spillovers of technology on productivity growth or international capital mobility, make it much more difficult to identify the key links between the introduction of a new technology and the ensuing domestic employment impact.

The focus of some of the recent popular concerns about the implications of technological change for employment appear to relate to the way that gains from technological change are distributed internationally. In the gloomy vision of some popular authors, (4)

"...wages in the most advanced economies are being eroded owing to the emergence of a global market-place where low-paid workers compete for the few jobs created by footloose global corporations". (Rifkin, 1995).

In other words, the globalisation of industry and services casts a new light on the interaction between technology and employment in an open economic framework characterised by low transport and communication costs.

The impact on individual countries is difficult to predict and depends upon a broad range of macroeconomic and microeconomic adjustment mechanisms. While it is still generally agreed that in a "world" economic framework, input-saving technical change leads, through increases in productivity, to growth and new employment, the impact on individual countries is difficult to predict and depends on a broad range of macroeconomic and microeconomic adjustment mechanisms (e.g. Acemoglu and Zilibotti, 2000 and Berman, 2000). This is especially true because positive and negative effects do not coincide either in time or in space: adjustment takes time, and the industries and types of workers that will benefit from technical change are different from the ones that lose from it.

At the same time, the premium placed on the role of knowledge and on the acquisition of skills in this global environment implies that international differences in the pattern of employment and unemployment depends increasingly on the capacity of national economies to innovate, enter new, unregulated service sectors and/or absorb new technology more rapidly. The emergence of a so-called information society becomes hence crucially dependent on user demand for new information products and services. The "demand articulation" of the latter depends on the existing regulatory institutional framework as well as on the overall macroeconomic climate. Much had already been written about the former. Many studies point e.g. to the existing (over)regulation in Europe in a number of "information society" service sectors. Moreover, in typical cases of information or communication services, marginal costs are a fraction of fixed costs (one may think of movies, software, financial and insurance services, etc.). Commercial success seems to depend critically on the reaping of economies of scale, leaving Europe with its fragmented national service markets and cultural diversity at a disadvantage.

4) In many ways, such views are reminiscent of the old Prebish-Singer dependencia arguments, but applied to the advanced countries. In the old core-periphery models, "immiserising" growth in the developing countries would take place because all the benefits of increased efficiency gains in raw materials, agricultural, and labour-intensive manufacturing production were passed on to the advanced economies, e.g. through lower prices or higher repatriated profits. In the current view, the pattern is the opposite: most of the benefits of technological change are passed on to some of the rapidly industrialising countries through more rapid international diffusion of technology from the advanced countries, the reinvestment of profits and relocation of production to those industrialising countries, and the erosion of various monopoly rents in the advanced countries, including wages. In principle though, and in contrast to the Prebisch-Singer model, such a redistribution process should lead, as trade theory would predict, to the convergence of growth and income and not to the "end of work". In this regard, Hodgson (1999), provides an intriguing view on "why the learning economy is not the end of history".

It is these latter issues which brings the employment concerns about ICT back to the public policy spotlight, despite the many reassuring historical arguments, and the macroeconomic success stories of the United States and some of the smaller European countries. At the core of the current concerns are the distributional aspects of ICT. Various skills, competences and qualifications are likely to be of a much more pervasive and general nature, raising questions about the inherent "skill and competence bias" of new ICT. Hence, we focus the remainder of this paper on the skill content of recent technological change to evaluate those fears.

3. New technology and skills

In the previous section, we described how various forms of technological change could be connected to changing employment structures; here we develop a story connecting ICT to the possibly (changing) level of skill requirements (5). The idea is very straightforward. Suppose a technological revolution takes place requiring the implementation of new equipment. This can only be successful if the labour force can operate the new equipment, and so workers must acquire a set a "machine-specific" skills (6). A technological revolution is "skill-biased" if the new skills are more costly to acquire than the skills required to operate the old machine. On the other hand, it is "de-skilling" if the reverse is true.

Greenwood and Yorukoglu (1997), argue that 1974 is a turning point in the introduction of Information Technology (IT) (7). From this year on, the rate of technological change in the production of IT equipment increased. A sharp rise in the demand for skilled workers followed and so did income inequality in many OECD countries. Table 1 gives an overview of the rise in income inequality in OECD countries from the 1970s onwards.

The IT revolution is often perceived as a skill biased revolution. From this evidence, the IT-revolution is often perceived as a skill-biased revolution, favouring the labour-market position of the skilled part of the workforce at the expense of the unskilled. Several studies find a substantial positive correlation between skill upgrading and computer investments, employee computer use, and research and development efforts (8). For example, Greenwood and Yorukoglu (1997, pp. 49-50), argue that:

"the adoption of new technologies involves a significant cost in terms of learning and that skilled labour has an advantage at learning. Then the advance in technology will be associated with an increase in the demand for skill needed to implement it. Hence, the skill premium will rise and income inequality will widen."

⁵⁾ Acemoglu (2000), provides an overview of the effect of technological change on wage inequality and the demand for labour. He argues for the United States that the behaviour of wages and the returns to schooling indicate that technological change has been in favour of skilled workers since 1940. Chennells and Van Reenen (1999), and Sanders and Ter Weel (2000), provide an overview of the micro-econometric evidence of more than 100 studies investigating the effects of skill-biased technological change.

⁶⁾ Much research has suggested that long-run changes in the distribution of earnings is shaped by a race between the demand for skill, driven by industrial shifts and technological advances, and the supply of skills, altered by changes in educational investments, demographics, and immigration. See, for example, Katz and Murphy (1992), Murphy and Welch (1992), Autor, Katz and Krueger (1998), Acemoglu (1999), and Goldin and Katz (1999).

⁷⁾ We prefer to use the term IT here as distinguished from ICT, which emphasizes more strongly the importance of communication technologies, such as the Internet and broadband communication.

⁸⁾ See Berman, Bound and Griliches (1994), and Autor, Katz and Krueger (1998), Berman, Bound and Machin (1998), and Machin and Van Reenen (1998).

Country	1970s	1980s	1990s
Australia	-	+	
Austria	-	+	
Belgium		+	
Canada	0	+	+
Denmark		0/+	
Finland	-	0	
France	-	-/+	+
Germany	0	-/0	+
Italy	-	0	
Japan		+	
Netherlands	0	-/+	0
Norway		0	
Portugal		+	
Spain	/0	+	+
Sweden	0	0/+	
United Kingdom	-	++	+/-
United States	+	++	+/-

Table 1. Pattern of changes in earnings dispersion in the 1970s, 1980s and 1990s

Note: ++: strong increase in dispersion, +: increase in dispersion, 0: no clear change, -: decrease in dispersion, -: strong decrease in dispersion, +/-: increase followed by decrease, ..: no information available. Source: Sanders and Ter Weel (2000)

Similarly, Caselli (1999, pp. 79-80) argues that:

"technological progress has been predominantly incremental in the 1950s and 1960s, and predominantly revolutionary (of the skill-biased variety) in the 1970s and 1980s."

The main example of IT-investment is, of course, the computer. An eminent paper by Krueger (1993), on the impact of computer usage on wages and the demand for skilled workers, shows (for 1984 and 1989), that workers using a computer receive a wage premium of some 15 percent. Later work by Autor, Katz and Krueger (1998), shows that this computer wage premium has increased to more than 20 percent in 1993. In interpreting his findings, Krueger (p. 34) concludes that

"employees who use computers at work earn more as a result of applying their computer skills."

Based on the argument that workers who are best at using the computer are allotted to jobs, which require these skills most, other researchers also conclude that computer skills have a high pay off (9). This evidence suggest that IT would be a truly skill-biased "revolution" increasing the demand for high-level (computer) skills and leading to persistent wage inequality between workers possessing computer skills, and the rest.

⁹⁾ See for example Entorf and Kramarz (1997), and Miller and Mulvey (1997).

However, there is also evidence suggesting that IT has not changed the labour market as dramatically as sketched above. For example, the previous argumentation requires that the highest skilled workers have been allotted to the most complex jobs. Many authors therefore conclude that workers using a computer are most qualified to do so. Thus, a major part of the increase in the demand for skilled workers and wage differences can be attributed to the emergence of the computer. The policy solution seems obvious. Education should focus on teaching computer skills much more than it has done so far. This analysis reflects a view on computers that is now popular amongst businessmen and policy makers. Indeed, many people take the odd computer course to familiarise themselves with Windows or the Internet, afraid to lose touch with it all. They often buy a computer to ensure that their children become familiar with the new technology. Policy measures are based on the assumption that all youngsters need to enter the labour market with computer skills, because otherwise there might be a threat of an unbridgeable computer skill gap, the source of a digital divide in society.

These seven points question the traditional view that computer skills are highly rewarded. Recent research by Borghans and Ter Weel (2000b), however, has illustrated the major shortcomings of such a view. From various perspectives, research results are found that do not fit in this framework (10). They are:

1. The largest premium for e-mail and word processing

If one takes a close look at Krueger's results, it appears that the largest computer wage premium goes to computer tasks such as e-mailing and word processing. These are hardly the skills that are reserved for the higher educated. Surprisingly enough, tasks that are carried out by computer programmers and specialist staff, such as software design, are rewarded with lower computer wage premiums.

2. Many low and intermediately skilled workers use computers

As many low-skilled and intermediately skilled workers use computers, Bresnahan (1999), and Handel (1999), argue that it is unlikely that they are the cause of skill-biased technical change. In particular, many typists use e-mail and word-processing intensively. This does not seem to indicate that the use of new technology requires sophisticated skills.

3. Is it true that computer usage leads to higher wages?

Chennells and Van Reenen (1998), and Entorf, Gollac and Kramarz (1999), studied a data set of employees who started to use computers. They found that they did not receive significantly higher wages than the group who did not use computers.

4. Companies with a high level of computer usage also pay higher wages to employees who do not use computers

The idea that the computer wage premium should first and foremost be regarded as an appreciation of individual computer skills, implies that only those who actually use a computer will get higher wages. However, studies by Doms, Dunne and Troske (1997), and Dunne, Foster, Haltiwanger and Troske (2000), show that the computer wage premium is not an individual, but a company-related effect. They found that companies that work with advanced technology, such as computers, pay their employees more. It is irrelevant whether an employee uses a computer or not. He/she will nevertheless receive a wage premium.

¹⁰⁾ See Borghans and Ter Weel (2000c), for an elaborate overview of these arguments.

5. People who have computer skills, by no means always use computers

If computer skills are becoming more and more important in the labour market and increasing use of computers has made these skills a scarce commodity, it can be expected that employers will try to ensure that anyone who has such skills does work in areas where these are important. DiNardo and Pischke (1996), however, show that in Germany it is by no means the case that all those who have computer skills, are working in jobs in which computers are used.

6. The use of pencils also yields a premium

DiNardo and Pischke (1997), took a critical look at Krueger's results by investigating whether it was only computer usage that explained remarkable wage differences. They therefore looked at the use of other tools, such as pencils, calculators, telephones, and whether a person works standing up or sitting down, to see whether any of these aspects could also explain the wage differences. Apart from the computer wage premium, they found a similarly large premium for the use of pencils. From these results, they concluded that Krueger's computer wage premium is probably not an adequate measure for the importance of computer skills.

7. Rewards appear to be unrelated to computer skills

The six types of research results discussed above all cast doubt on the question whether the computer wage premium should be interpreted as a reward for computer skills. The questions that they raise, however, are always based on indirect evidence. One of the few studies based on direct measures of computer skills, by Borghans and Ter Weel (2000a), using evidence from a survey carried out in the United Kingdom in 1997, groups people by computer skills (from very high to very low). It turns out that everyone appears to receive approximately the same computer wage premium (see Table 2). As a matter of fact, individuals with average computer skills receive the highest computer wage premium.

The above seven points question the traditional view that IT skills - limited here to computer skills - are highly rewarded, and that simply operating computers requires special and more highly paid skills. How then can one explain the impact of computers on the composition of skills and the labour force? The most insightful contribution is by Bresnahan (1999), who offers a theory of workplace computerisation focusing on computer use in white-collar bureaucracies, the substitution of machine decision-making for human decision-making in low-skilled white-collar work, and the strategic use of computers by high-skilled workers. Autor, Levy and Murnane (2000), further develop the argument by modelling how the widespread adoption of computers in the workplace might alter skill demands. They argue that not all tasks are equally amenable to computerisation and that computers are an incomplete substitute for both unskilled *and* skilled labour. Their empirical results suggest that computerisation is associated with a declining demand for routine manual and information processing skills and a rising demand for non-routine information processing skills.

An important observation is that high wages themselves are an important factor in explaining the introduction of IT in the workplace.

An important observation is that high wages themselves are an important factor in explaining the introduction of IT at the workplace, because the savings are in this case much greater. Hence, IT use is determined by a combination of the specific tasks of a job and the wage level of a particular worker. As a consequence, when new IT-applications are developed and costs decrease, IT spreads further *both* among relatively skilled and unskilled workers.

Computer skills	Estimated computer wage premium (standard error in brackets)
Very high	.312 (.067)
High	.313 (.068)
Intermediate	.315 (.082)
Low	.298 (.089)
Very Low	.308 (.135)

Table 2. The returns to computer skills in the United Kingdom in 1997

Note: The following equation was estimated: In $W_i = X_i \mathbf{a} + C_i \mathbf{b} + \mathbf{e}_i$ where In W_i is the natural logarithm of the hourly wages of individual *i*, X_i is a vector of the observed personal characteristics of individual *i*, such as training level, age, working experience, etc. C_i is a matrix for the different levels of importance of computer skills. **a** and **b** are estimated parameters. \mathbf{e}_i is an error term with the usual assumptions. The equation was estimated using OLS.

Source: Borghans and Ter Weel (2000a)

4. The skill content of recent technological change

The above discussion suggests that the complementarity between ICT and skilled workers is one possible scenario but not the only one. It might also be the case that due to the costs of ICT it is more profitable to start implementing ICT at the highest (wage) segment of the labour market. By eliminating routine tasks, the computer gives more time to workers to use their particular skills.

But how does Europe compare in terms of education and skills, and what is the impact of skill differentials on wages?

Internationally comparable databases are scarce because of measurement problems in comparing educational levels. For example, on-the-job training traditions in some countries (notably Germany and Sweden) make education a biased estimator, the United Kingdom has a complex educational system depending upon profession, and the high-school-college system in the United States is again different. One database in which we are able to compare skills on an international level is the International Adult Literary Survey (IALS) conducted by the OECD and *Statistics Canada* in 1995 (11). The main advantage of IALS is that between 2 000 and 4 500 individuals in each of seven countries have been asked exactly the same questions (12). In this way, a relatively consistent picture of the skills of the workforce in these countries has been obtained. Besides the information on literacy, the survey also included questions on standard labour market variables such as employment status, earnings, education and demographic characteristics. In this section we only use data for males aged 18-65 years who were employed at the moment of the interview.

We distinguish five different skill measures: years of schooling, on-the-job work experience, numerical literacy, prose literacy, and document literacy. The first two skills do not need further

¹¹⁾ For more details on the data used here see the descriptive sections in Murray, Kirsch and Jenkins (1998) and Leuven, Oosterbeek and Van Ophem (2000).

¹²⁾ These countries are Canada, Germany, the Netherlands, Poland, Sweden, Switzerland and the United States. France took part initially, but subsequently withdrew its support.

elaboration, but the latter three are defined as follows: numerical literacy is the knowledge required to apply arithmetic operations to numbers embedded in printed materials, such as balancing a check book, figuring out a tip, completing an order form, or determining the interest on a loan from an advertisement. Prose literacy is the knowledge needed to understand and use information from texts including editorials, news stories, poems and fiction. Finally, document literacy is defined as the knowledge required to locate and use information contained in various formats, including job applications, payroll forms, transportation schedules, maps, tables and graphics, etc.

In Table 3 we show the mean and standard deviation of the test scores for each country (13). For ease of comparison we have put the United States' scores at 100 for each of the five skill measures. It is clear that - although the standard deviations are very large - average years of schooling is highest in the United States. Germany and Sweden are at the lower end, which might reflect the fact that they have many apprenticeships often not regarded as formal schooling. Indeed, the European countries all have relatively higher average rates of on-the-job work experience.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Country N	Ν	I Years of Schooling	On-the-job experience	Numerical literacy	Prose literacy	Document literacy
Canada 1 0	1 003	92.6	95.7	100.7	100.7	104.3
		(24.9)	(60.3)	(19.7)	(20.4)	(22.4)
Germany 470	84.2	110.2	103.1	98.6	105.3	
		(24.8)	(62.8)	(16.3)	(17.3)	(17.4)
Netherlands 940	96.5	102.0	102.4	101.1	105.3	
		(30.6)	(60.6)	(15.6)	(14.8)	(16.0)
Poland 671	83.4	105.3	84.7	83.1	84.0	
		(21.0)	(53.7)	(23.5)	(20.4)	(25.3)
Sweden 760	84.3	122.2	108.2	106.7	111.4	
		(26.7)	(63.6)	(18.7)	(18.3)	(18.9)
Switzerland 800	93.1	107.3	100.7	96.5	101.4	
		(23.4)	(65.1)	(17.3)	(17.6)	(20.3)
United States 789	789	100.0	100.0	100.0	100.0	100.0
		(23.6)	(57.1)	(22.8)	(22.5)	(24.2)

Table 3. Statistics on schooling, work experience, numerical, prose, and document literacy.

Note: For employed males aged 18-65 years. The scores are all indices relative to the United States, i.e. the United States is set at 100 in each column. The first observation in each column is the mean of the score, and the term in brackets is the standard deviation. N in column (2) is the number of observation available. See Murray, Kirsch and Jenkins (1998), for further details.

¹³⁾ The intuition behind investigating the standard deviation besides the mean is straightforward. When the distribution has "thick tails" we expect the standard deviation to be large, i.e. there are many people at both ends of the distribution and not so many close to the mean. If, on the other hand, the distribution is fairly "normal" we do not expect the standard deviation to be very large.

The scores for the three dimension of literacy are displayed in columns 5 to 7 of the Table. It turns out that Sweden has the highest relative scores in all three categories. The EU countries are above the scores of the United States for numerical and document literacy, but may perform less well for prose literacy. However, the large standard deviations prevent us from drawing strong conclusions from these three columns.

To say something about the importance of skills within countries, we look at the distribution of these skills. Table 4 computes the difference between the 90th and 10th percentile of the skill distribution. The United States is interesting in this regard in that it has the lowest differential for education (both for years of schooling and work experience), but a larger gap in terms of skills (only Poland performs worse). The question these data raise is whether wage inequalities across countries also reflect these differentials?

(2)	(3)	(4)	(5)	(6)	(7)
IN	louio oi	,			Document
	schooling	experience	literacy	literacy	literacy
1 003	64.5	166.2	49.0	46.5	52.3
470	64.1	170.0	42.5	44.4	44.8
940	71.3	161.0	36.7	35.9	37.7
671	57.8	145.5	60.2	53.2	67.6
760	71.6	171.8	44.9	46.5	45.6
800	57.0	171.4	36.7	38.7	41.6
789	49.9	150.6	55.4	52.5	59.4
	N 1 003 470 940 671 760 800	N Years of schooling 1 003 64.5 470 64.1 940 71.3 671 57.8 760 71.6 800 57.0	NYears of schoolingOn-the-job experience1 00364.5166.247064.1170.094071.3161.067157.8145.576071.6171.880057.0171.4	N Years of schooling On-the-job experience Numerical literacy 1 003 64.5 166.2 49.0 470 64.1 170.0 42.5 940 71.3 161.0 36.7 671 57.8 145.5 60.2 760 71.6 171.8 44.9 800 57.0 171.4 36.7	N Years of schooling On-the-job experience Numerical literacy Prose literacy 1 003 64.5 166.2 49.0 46.5 470 64.1 170.0 42.5 44.4 940 71.3 161.0 36.7 35.9 671 57.8 145.5 60.2 53.2 760 71.6 171.8 44.9 46.5 800 57.0 171.4 36.7 38.7

There are high returns to cognitive skills, and this applies to persons of all educational levels. The computer has not been a substitute for these skills. This issue is further explored in Box 1 with a regression of wages on education (schooling and onethe-job training) and literacy. The interesting feature is the significance that numerical, prose, and document literacy has in determining wages. High returns to these "cognitive" skills have also been underscored by Murnane, Willett and Levy (1995). It applies to persons of all educational levels, showing that a rising demand for basic cognitive skills might be part of the explanation for the rise in wage inequality in the United States since the 1980s.

Returning to the question of the consequences of the computer on labour markets, these results seem in-line with Bresnahan's (1999), observation that ICT has not been a substitute for high levels of human cognitive skills. As ICT applications take over work from human beings, the importance of various types of skills will undergo major changes in the near future. On the basis of the new production options, employers will reconsider the product range that their companies supply and the working methods used. Under certain circumstances, we expect that there will be more tailor-made work (in those occupations where skills are required) while under other conditions there will be greater standardisation of products (in less skill-intensive jobs).

BOX 1. The relationship between skill inequality and wage inequality

Since there is no direct information on wages in the published version of the IALS, we have to rely on estimates by Leuven, Oosterbeek and Van Ophem (2000), who had access to the wage information before publication, and on other sources. Table 1.1 shows the summary measures of wage inequality for the countries of the IALS.

When we look at the information available over time - and acknowledging that the data are drawn from different sources - we can see that inequality has widened in Canada and Europe. Typically the differential between the 90th and 10th percentile of the wage distribution increased by about 18 percent or so between the late 1980s and mid-1990s. In the United States this ratio is significantly larger, but it increases by only a small amount over this particular period.

Another observation from Table 1.1 is the fact that for some countries the difference between the 90th - 50th percentile of the wage distribution is larger than the 50th - 10th percentile. This indicates that there is larger dispersion towards the top of the wage distribution. These countries are Germany, the Netherlands (1987), Poland, Sweden (1980 and 1992), and Switzerland. On the other hand, there are also countries in which the difference between the 50th - 10th percentile of the wage distribution is larger than the 90th - 50th percentile. This indicates that workers at the lower end of the wage distribution earn relatively little. These countries include Canada, the Netherlands (1995), Sweden (1995), and the United States.

(1) Country	(2) Authors	(3) Year	(4) 90th - 10th	(5) 90th - 50th	(6) 50th - 10th
Canada	G&J	1991	1.337	0.532	0.805
	LO&VO	1995	1.578	0.579	0.999
Germany	B&K	1988	0.995	0.540	0.450
	LO&VO	1995	1.188	0.626	0.562
Netherlands	G&J	1987	0.900	0.549	0.351
	LO&VO	1995	1.256	0.593	0.663
Poland	LO&VO	1995	1.625	0.852	0.773
Sweden	B&K	1980	0.840	0.465	0.395
	G&J	1992	0.834	0.497	0.337
	LO&VO	1995	0.986	0.452	0.534
Switzerland	B&K	1987	1.230	0.790	0.475
	LO&VO	1995	1.171	0.625	0.546
United States	B&K	1989	1.595	0.555	1.005
	G&J	1991	1.625	0.622	1.003
	LO&VO	1995	1.662	0.706	0.956

Table 1.1 Inequality measured by percentiles of the wage distribution.

Note: Authors: B&K: Blau and Kahn (1996, Figure 1), G&J: Gottschalk and Joyce (1998, Table 1), and LO&VO: Leuven, Oosterbeek and Van Ophem (2000, Table 3).

Table 1.2 takes these comparisons further. It gives the results of the following wage regression for each of the seven countries (taken from Leuven, Oosterbeek and Van Ophem, 2000, Table 4):

$\ln W = C + \alpha SCH + \beta EXP + \chi EXP^2/100 + \delta IALS + \phi IND/OCC + \varepsilon$

where $\ln W$ is the log of the wage, *SCH* is years of schooling, *EXP* is on-the-job work experience, *IALS* is a simple arithmetic average of the scores on three measures of literacy, *IND/OCC* are industry and occupational dummies, *C* is constant and ε , is an error term with the usual properties.

The results of this simple exercise are as follows: First, there are large differences in the returns to schooling. For example, one year of additional education pays under 3 percent of additional wage in the EU, while it pays close to 5 percent in the United States, and as much as 9 percent in Poland. Many scholars have attributed the high returns to education in the United States to skill-biased technical change (see, for example, Katz and Murphy (1992). Columns (3) and (4) of the Table reflect the returns to on-the-job work experience. The coefficient is highest in Switzerland and lowest in Sweden and the United States. In all countries workers face decreasing returns to experience ($EXP^2/100$ is negative and significant in all instances). However, on-the-job work experience is probably not a very good measure for skills and these results should be interpreted with caution.

The most interesting column is column (5), the return on literacy. This is highest in the United States. Germany, the Netherlands, and Switzerland also show relatively large wage premiums. Surprisingly, the coefficient is insignificant in Poland and Sweden. This could be interpreted to mean that these skills do not give workers a wage premium in those countries.

(1) Country	(2) SCH	(3) <i>EXP</i>	(4) <i>EXP</i> ² /100	(5) IALS	(6) R_{2}
Canada	0.032 ** (0.008)	0.521 ** (0.057)	-0.073 ** (0.012)	0.169 ** (0.042)	0.39
Germany	0.022 ** (0.008)	0.491 ** (0.069)	-0.075 ** (0.015)	0.125 * (0,050)	0.41
Netherlands	0.027 ** (0.004)	0.519 ** (0.047)	-0.080 ** (0.010)	0.182 ** (0,041)	0.44
Poland	0.088 ** (0.013)	0.364 ** (0.095)	-0.063 ** (0.020)	-0.028 (0.047)	0.18
Sweden	0.026 ** (0.007)	0.449 ** (0.061)	-0.070 ** (0.012)	0.056 (0.041)	0.18
Switzerland	0.028 ** (0.007)	0.665 ** (0.056)	-0.109 ** (0.012)	0.182 ** (0.042)	0.31
United States	0.047 ** (0.008)	0.457 ** (0.062)	-0.074 ** (0.014)	0.213 ** (0.038)	0.43

Table 1.2 Ordinary Least Squares wage regression results

Note: Dependent variable log wage; standard error in brackets. ** is significant at a 1 percent level and * is significant at a 5 percent level.

Source: Leuven, Oosterbeek and Van Ophem (2000, Table 4)

The major effect of ICT is that individuals can concentrate on professional activities, as many secondary tasks can be taken over by the new technology. Thus, a major effect of greater penetration of ICT is that individuals at work are able to concentrate more on those activities that constitute the essence of their profession. Many secondary tasks will be taken over by the new technology. This means that employers will tend to increase skill requirements. After all, the costs of higher wages will be compensated by the fact that less time is lost on tasks in which these skills are not used. It is in particular this argument that gives rise to the expectation that the demand for higher educated workers will continue to grow. As a result the computerisation of the labour market may then in effect lead to "skill-biased technical change".

5. Concluding comments

The particular employment concerns associated with ICT investment relate ultimately to their likely impact on output and productivity growth and wage premium redistribution across educational and skill levels. We have in this paper focused very much on these latter aspects, highlighting some of the complexities currently involved and insufficiently captured in the simple dichotomy of "skill-biased" versus "de-skilling" revolutions. Let us conclude with some general observations with respect to the growth and productivity impacts.

In attempting to assess the overall employment creation and destruction effects of ICT it is not possible to distinguish the direct negative and positive effects from the indirect effects, if ever this was possible in the past. The direct effects represent as much the new jobs in producing and delivering new products and services, as the old jobs being replaced by new ICT equipment. The indirect effects are the amalgamation of the many positive and negative consequences elsewhere. Thus, while computer terminals are everywhere, it is not always clear whether they are displacing workers or adding additional services and employment (14). The computer industry itself has provided machines that displaced earlier types of electromechanical office equipment, while the microelectronic industry largely displaced the old valve (tube) industry.

Such arguments do not hold only for manufacturing. In services too, it is no longer possible to distinguish clearly direct from indirect employment creation of displacement effects. New digital telephone exchanges require far less labour to manufacture and to maintain than the old electromechanical exchanges and the number of people working in the telephone switch industry has fallen in most industrial countries. Competitive re-structuring of the old monopolistic networks has also resulted in a reduction of the number of employers, even though the number of firms and the number of lines and cells has increased. However, and contrary to initial expectations, the new telecommunication infrastructure provided the basis for many new information service industries, bringing about a significant employment growth rather than the predicted employment loss. Similarly, some of the main ICT-using service sectors, such as financial services and insurances witnessed overall little employment displacement. However, within these sectors a significant restructuring took place amongst different jobs. That restructuring process is far from over. It is likely to be followed in the years to come by a significant employment displacement of clerical "physical presence" jobs in many local branches of banks, insurance offices, even call centres as such jobs are further "automated" through computers and through virtual communication on the Internet. The

¹⁴⁾ See Autor, Levy and Murnane (2000) who analyse job creation and destruction in a large US bank following the introduction of an automated cheque processing system. They find it hard to distinguish whether changes took place within the job, or whether new jobs were created as a result of this particular technological change.

unexpected, positive employment trends in these sectors is hence no basis for any prediction of future trends.

To compare the sector balance of gains and losses remains therefore an impossible undertaking as numerous empirical studies of the 1980s and 1990s already confirmed (e.g. Davis, Haltiwanger and Schuh, 1996). What is for sure is that an aggregate output growth which lies - as has been the case over the last decades in a number of OECD countries such as the United States, the Netherlands, Denmark, Ireland and the United Kingdom - substantially above productivity growth will lead to significant declines in unemployment rates, employment growth being sufficient to absorb both new entrants to the labour market and reabsorb displaced workers. As a matter of fact, in the 1990s some of these countries witnessed a significant growth in labour force participation, which itself has been a source of additional growth. Many of those new entrants (women and youth) having relatively high consumption patterns in some of the new ICT areas (mobile communication, Internet use, etc.). All this makes it difficult to argue what the true domestic employment effects of technological change are.

What can be argued nevertheless is that ICT investment's impact on growth depends in the first instance on the new needs and markets the new information service sectors are capable of addressing. In Europe this has been aptly illustrated by the phenomenal rise in mobile telephony use. Whether the recently tendered frequencies for third generation mobile communication (UMTS) will lead to a similar uptake of mobile Internet use remains to be seen, but will again depend crucially on the way telecom operators succeed in identifying possible core "new" mobile needs. The information and communication technologies have undoubtedly opened a new dimension of business and consumer wants. Such new demand led growth does not seem, at least in these early stages of the information communication revolution, to be subject to intrinsic demand satiation effects, as in the case of previous manufacturing consumer needs. Nevertheless, Gordon (2000), has argued that the new information and communication technologies represent ultimately little more than increased substitution possibilities of "free time" ultimately constrained by "the fixed endowment of human time". That might well be so, but such increased substitution possibilities do open up possibilities for an infinity of alternative, individual consumption activities, unlikely to be ever subject to demand satiation. The spectre of "technological unemployment" resulting from demand satiation seems from this perspective more than ever unrealistic.

Demand for skilled labour has undoubtedly risen. But it is not computer skills that are behind the widening of wage differentials: it is the freeing of time so that more skilled workers can get on with their job. With respect to the distributional aspects of ICT, the demand for skilled labour and in particular the highly specialised IT jobs, has undoubtedly risen relative to the demand for unskilled labour. However, it does not appear to be computer skills per se are behind the widening of wage inequality over the past two decades. Rather the effect of the computer on which we focused in Sections 3 and 4 appears in essence to consist of the freeing of time so that more skilled workers can get on with the core tasks of their job. In this sense computer skills have become pervasive, truly general purpose skills widely used across all skills and all jobs. The freeing of time in the case of the more expensive, skilled work force has not only led to a more rapid diffusion of computer use amongst this particular group of the work force, it has also induced employers to hire more skilled workers.

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The diffusion of information technology in Europe



Harald Gruber

1. Introduction

Europe, as all modern economies, is shifting towards an information-based society, where Information Technology (IT) is dramatically modifying patterns of production and consumption and the modern way of life. Low-cost data processing and transmission technologies are leading the way not only in a technological revolution, but also in an economic and social revolution. The main drivers for these trends are technology and market liberalisation. Technological advances, in particular in microelectronics and optical fibres, have drastically reduced the cost of data processing and transmission. In parallel, reduction of trade barriers for IT equipment and the market liberalisation in key sectors adopting IT, such as telecommunications, mobilised huge amounts of private funding for the adoption of new products and services.

Information is the main good around which this revolution is built. Information as a good has some radically different feature compared to traditional goods produced in the economy: information is intangible; information can be shared in its use in an almost unlimited way and this makes it also very difficult to appropriate by the originator; while the production of information typically involves relatively large fixed cost, the diffusion of information is achieved at low cost. Hence traditional approaches to analysing markets for physical goods may not apply for certain sectors of the information economy (1). Because of pervasive "network effects", i.e. the action of one agent has a feedback on others and vice versa, certain extreme features may occur, such as the "winner takes all" phenomenon. As a matter of fact, IT abounds with examples of innovative companies dominating, if not monopolising, markets such as Intel for microprocessor chips, and Microsoft for personal computer software. Another particular feature of IT production relates to the geographical clustering of production activities. The most illustrating example is Silicon Valley, which houses the world's largest concentration of IT production, and generates most of the innovation in this field (Saxenian, 1994).

Because of so-called "externalities" in the production of IT, the sector has attracted the attention of policy makers. Moreover, as IT is a general purpose technology, it has pervaded all sectors of the economy, and the scope for innovation is widespread rather than restricted to a single sector of the economy. Significant productivity increases are expected as a result (Helpman, 1998).

One can distinguish the productivity increases generated within the IT producing sector from those generated by the IT using sectors. For Europe the view is forming that productivity growth has been lagging behind the US in both these dimensions (European Commission, 2000). Hence, the concern that the failure of Europe to participate in the IT revolution will doom the continent to playing a marginal role in the future of the global economy. This paper tries to unravel some of the main issues in this debate and indicate the policy options that would lead to an IT revolution. Sections 2 and 3

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¹⁾ For an excellent survey of these issues see Shapiro and Varian (1999).

briefly discuss the supply and demand aspects of IT, respectively. Section 4 indicates some broader policy options to stimulate the production and diffusion of IT within Europe. Section 5 concludes.

2. Production of IT hardware and software

Technical progress in hardware

We define the IT sector to be semiconductors, computers and related equipment, and software. This definition links IT to the information processing part of the "digital economy", where different forms of information such as text, audio and picture are processed in the same way. There is a second leg in the digital economy that is related to telecommunications. In a world of technological convergence, the two sectors are becoming fully integrated, and thus very often they are jointly referred to as the "information and communications technology" (ICT) sector. Internet is the clearest example of this. However, the reason for treating the IT and communications sectors differently is that IT expenditure is predominantly an investment whereas telecommunications is mainly a consumption or intermediary good.

The whole IT sector is relatively young, starting with the invention of semiconductor devices in the late 1940s and with the additional boost received from the invention of microprocessors and memory chips at the beginning of the 1970s. All the basic inventions have been made the US, and the worldwide industry has been shaped by firms originating in that country (2).

The IT sector has an impressive track record in terms of speed of innovation and growth The IT sector has an impressive track record in terms of speed of innovation and sector growth. Competition among producers has accelerated the pace of innovation and has shortened the life cycle of products. The technological progress in the industry is well described by "Moore's Law": because of the relentless downsizing of the chip size, performance of semiconductor chips doubles every 18 months. This prediction has proved to be remarkably accurate since it was first articulated in the late 1960s. Figure 1 shows the evolution of the information processing capacity of a microprocessor in terms of the number of transistors per chip (notice that the y-axis is logarithmic).

Table 1. The evolution of the cost of data processing (in nominal USD)

Cost of:	1970	1999	Annual growth rate
1 MHz processing power	7 600	0.17	-31%
1 M bit storage	5 260	0.17	-30%
1 trillion bits sent	150 000	0.12	-38%

Source: The Economist magazine

This strong performance has translated into dramatic declines for the price of processing information. As indicated in Table 1, the average cost of microprocessor computing power, in terms of instructions per second, has fallen by 30% annually, as has the price of data storage per bit. The performance in transmission capacity for information has increased even more impressively thanks to the invention of optical fibre cables. The cost of sending information is falling at rates close to 40% per year.

²⁾ For interesting accounts see Cortada (1987), and Scherer (1999).

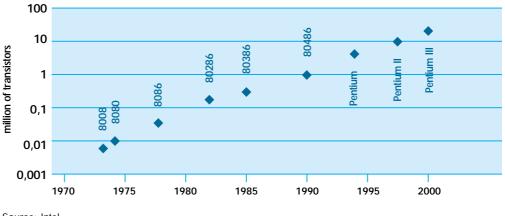


Figure 1. The evolution of processing capacity of microprocessors (logarithmic scale)

Source: Intel

The position of European companies

A comparison of IT production among the major economic regions indicates the relatively small role the EU plays in the world production of IT hardware (see Table 2). The most striking difference is with electronic components, where the EU produces only about half that of the US or Japan. A similar difference exists in the production of computers. There appears to be a strong relationship between the production of semiconductors, personal computers, and the location of invention; moreover, technological leadership tends to persist.

Table 2 also lists the value of production of telecommunications equipment. Even though this is not IT in the strict sense, the point here is that Europe scores much better with telecommunications equipment production. Moreover, Europe is particularly well placed in new and rapidly growing sub-sectors of the telecommunications equipment industry, such as mobile. The strength of production in telecommunications is concomitant with the fact that expenditure for telecommunications services accounts for a higher share of GDP in Europe than in the US.

Table 2. Value of production of selected IT products in 1997 in USD billion

	Electronic components	Computers	Telecom equipment
EU	40.1	53.5	28.3
US	79.2	82.4	36.2
Japan	84.4	67.7	21.8

Source: OECD

For many countries, IT hardware production has lost its ability to create a significant number of new jobs. Labour productivity growth in the IT hardware production sector is outpacing the growth in total production. Hence the employment level in the hardware sector is stable or even declining. New IT related jobs are typically created in the software sector and sectors using IT. The IT hardware production sector nevertheless has an important role as it supports high paying jobs. For

US and Japanese firms emerge as the main suppliers in the IT hardware market. European firms are virtually absent from the top ranks. example, in the US, the average annual salary in the IT sector was USD 46 000 in 1996, compared to an average of USD 28 000 for the private sector on average (US-DOC, 1998).

Table 3 lists the world's most important IT equipment manufacturing companies. In line with the aggregate data in Table 2, US and Japanese firms emerge as the main suppliers in the IT hardware market. Indeed, European firms are virtually absent from the top ranks, with the exception of Siemens. The technologically leading computer hardware producers such as IBM and Compaq, as well as the leading software and services producers such as Microsoft and EDS, are all based in the US.

There is also the undisputed technological and market leadership of Intel in the development and production of microprocessors, the key component of a computer (Intel has a market share of more than 15 percent of total world semiconductors sales, with a 90 percent share of the market for microprocessors). The only competitor in this field is another US firm, AMD (Gruber, 2000).

	Headquarters	Revenues (USD billion)	Employees (thousands)
IBM	US	81.7	350
Siemens	EU	66.9	416
Hitachi	Japan	64.3	331
Matsushita	Japan	60.3	276
Hewlett-Packard	US	47.0	125
Toshiba	Japan	41.7	186
Fujitsu	Japan	38.1	180
NEC	Japan	38.0	152
Compaq	US	31.2	90
Motorola	US	29.4	133

Table 3. The world's top IT companies in 1998

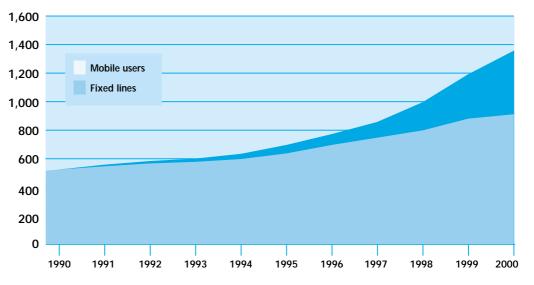
Source: OECD (1999)

Japanese firms, such as NEC and Toshiba, have specialised in memory chips. These are considered commodities, where production efficiency and economies of scale are important. The worldwide dynamic random access memory (DRAM) chip market is dominated by these firms along with the South Korean company, Samsung.

European semiconductor producers ST Microelectronics, Philips and Infineon occupy the places 8 to 10 in the world ranking of this market segment by sales (in 2000). They tend to specialise in niche markets, such as applications for telecommunications and automotive components. However, in these smaller segments they rank in leading positions on a worldwide basis.

European firms also have a strong position in telecommunications equipment. In terms of telecommunications equipment revenues in 2000, the two largest companies were Ericsson and Nokia. In third position was the US company, Lucent, followed by another European company, Alcatel. Ericsson and Nokia have their particular strengths in mobile technology. Ericsson accounts

European semiconductor producers tend to specialise in niche markets, where they sometimes rank in leading positions. for about 40% of worldwide sales of mobile telecommunications infrastructure equipment, whereas Nokia has 30% of the worldwide sales of mobile handsets (Financial Times, 13 March 2001). These companies are favoured by the fact that mobile telecommunications is the most rapidly growing sub-market in the telecommunications industry. As Figure 2 shows, the number of mobile subscribers is growing at a much larger speed than the number of fixed lines. It is expected that within two years the number of mobile subscriber will exceed the number of fixed lines.





Source: ITU

New opportunities may arise for European companies from the Internet, but here too US firms have already been able to conquer leading positions. New opportunities may arise for European companies specialising in telecommunications equipment with the convergence of information and communications technologies favoured by the emergence of the Internet. But also here, US firms such as Cisco and Oracle have already been able to conquer leading positions. Because of the strong network effects involved in these industries, early mover advantages are typically decisive for market leadership. While US companies are very successful in establishing dominant systems through market forces, European telecommunications equipment producers have proven to be more successful when there is also a regulatory element. For example, the coordinated development and introduction of GSM across Europe have been decisive in providing the momentum for making it also the most widely spread digital mobile communications technology worldwide.

Europe has developed a major position in software production (3) thanks to the growth of this sector in Ireland (see the Box). This country is the world's largest exporter of software goods, ahead even of the US (4). However, as all major EU countries are net importers, the EU net position is entirely due to Ireland.

³⁾ The software sector is divided into products and services. Software products are commercially available packaged programmes for sale or lease. Software services instead refer to consulting, implementation and operations concerning the information infrastructure of a client.

⁴⁾ In 1998 software exports were as follows: Ireland, USD 3.3 billion; United States, USD 3.0 billion; Britain, USD 0.7 billion; the Netherlands, USD 0.6 billion; Germany, USD 0.5 billion, and France, USD 0.3 billion.

Box. The Irish software industry

The software sector played a significant role in the development of the Irish economy, and was triggered off by massive foreign direct investment. Thirty years ago, when the first steps were being taken by the Industrial Development Authority (now IDA Ireland) to promote the software industry in Ireland, few could have imagined that this sector would develop as successfully as it has. Approximately 24 000 people are currently employed in the industry, which has combined annual revenues of over 6.6 billion. Nineteen of the top 25 computer companies in the world operate in Ireland (including Microsoft, Computer Associates, Oracle, Informix, Novell, SAP and Symantec) and together with the 400 indigenous companies they employ over 7 000 people. Over 40% of all packaged software and 60% of business applications software sold in Europe is produced in Ireland. Foreign owned firms accounted for 84% of total software revenue, and 88% of software exports from Ireland. This success was made possible by the combination of a favourable economic environment (low inflation, financial support schemes, tax concessions, low operating costs), a well-educated, young and English speaking labour force, and the development of a nation-wide software-oriented support infrastructure.

Sources: OECD (1999), Barry (1999), and www.jobsireland.com.

Market leadership through innovation

Firms operating in IT industries need to invest heavily in R&D to sustain the rapid pace of innovation. Along with pharmaceutical companies, IT firms are the main R&D spenders in the economy. For the world's top 20 IT companies, average R&D expenditure amounts to about 7% of total revenues (OECD, 2000a). This figure however conceals the R&D intensity of smaller companies, in particular in the semiconductor industry, where the R&D to sales ratio is typically in the 15-20 per cent range. R&D carried out in the ICT sector usually accounts for a large part of national R&D expenditure undertaken by the business sector.

EU industry is substantially less R&D intensive than US and Japanese industry. Figure 3 shows the comparative evolution of business expenditure on R&D (BERD) as a share of the domestic product of industry (DPI). This shows that EU industry is substantially less R&D intensive than US and Japanese industry, both of which have a 50% higher relative spending. A closer look at the data also shows that Europe is not only spending less for R&D because it is specialised in less R&D intensive sectors, but also because it is spending relatively less on R&D in almost each sub-sector of the economy.

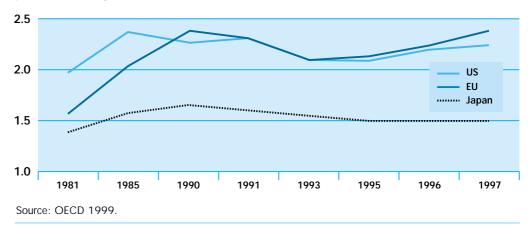
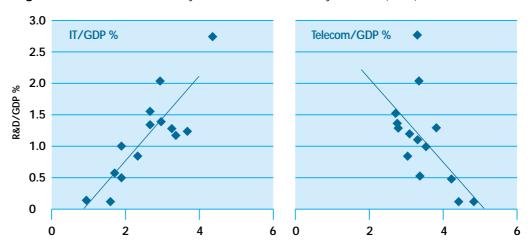
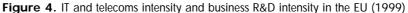


Figure 3. The evolution of business expenditure on R&D (BERD) as a percentage share of domestic product of industry

Much innovation in IT is created by new firms (CEA, 2001; European Commission, 1995). Start-up firms also play a fundamental role in the adoption of IT. These companies are a source of permanent renewal of technology, of technological breakthroughs, and of competitive pressure for large incumbent firms, which are compelled to innovate in order to keep their technological edge. Unfortunately, Europe is also weak in creating new technology-based firms. Indeed, the US venture capital market is an example of a uniquely supportive climate for technology start-ups. Venture capitalists not only provide finance, but also match entrepreneurs with other resources that are crucial for the success of the company. Kortum and Lerner (2000), show venture capital financing significantly improves the success rate for innovative activity. The relatively slower development of venture capital markets in Europe may therefore contribute to the performance gap of Europe compared to the US in the IT sector.





There could be an agglomeration pattern whereby IT adoption has cumulative effects. Figure 4 shows how within the EU the R&D intensity is fairly closely correlated with IT intensity. This suggests that there could be an agglomeration pattern whereby IT adoption has cumulative effects. Conversely, there appears to be no significant relationship between telecommunications intensity and R&D intensity. With this in mind we now turn to factors influencing the demand for IT and telecommunications.

3. The demand and diffusion of IT

Over the last decade, firms in all sectors of the US economy have invested massively in IT (Sichel, 1997). As Figure 5 shows, Europe is far behind the US in terms of IT intensity: the IT market in the EU represents 2.7% of GDP, compared with 4.5% for the US (EITO, 2000). Thus, Europe is behind in both the production and the adoption of IT. Even though in an integrated world economy with extensive trade flows, one would expect that production should be of secondary importance, there seems nevertheless to be a link between competitiveness in production of IT and the adoption of IT.

Source: Data from OECD and EITO.

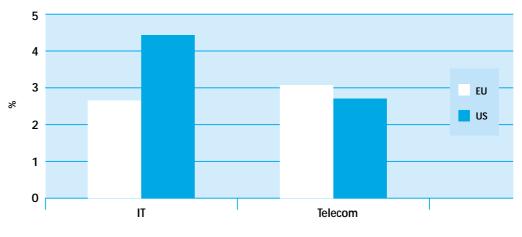


Figure 5. Share of information technology and communications expenditure as a percentage of GDP in 1999

Source: OECD

In general, prices for IT equipment in Europe are similar to those in the US. This is not surprising as it concerns internationally widely traded goods, which do not carry import duties. A significant price difference may, however, occur during the early stage of the product life cycle. The typical pattern then is as in Figure 6, which shows the evolution of the selling price of a representative PC (equipped with a Pentium-Pro processor) in Europe and the US. In the early stage US users benefit from a substantial price advantage, and this may induce US users to adopt innovations earlier than European users.

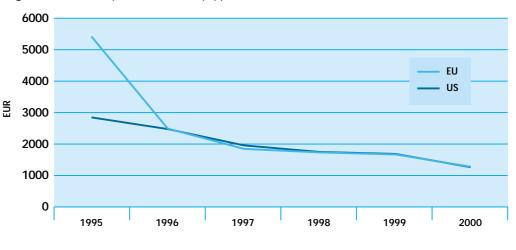


Figure 6. Price comparisons of PCs equipped with Pentium-Pro

Source: EITO

Figure 5 also showed that with respect to the telecommunications intensity of the economy Europe is ahead of the US. Table 4 shows the size market of the IT sub-sectors (5). What strikes here is the sheer size by which the European telecommunications equipment market exceeds the US market. Indeed, it is the only sub-sector where this is the case.

5) This Table refers to the market size in terms of sales of the sector. These figures should not be compared with the data on value added (Table 2) because of the different data sources which use slightly different sector definitions.

	EU	US
IT hardware	98.6	141.2
Software	43.5	68.2
IT services	77.6	141.4
Total IT	219.7	350.8
Telecom equipment	58.1	23.8
Telecom services	192.1	189.7
Total telecom	250.2	213.5

Table 4. The sub-markets for information and communication technology	ologies in 1999 (in EUR billion)
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Source: EITO (2000)

There could be structural reasons that prevent the European economy from assimilating IT. There could be structural reasons that prevent the European economy from assimilating information technology. These may reside in a lack of skilled workers to operate IT, as well as organisational rigidities that weaken the incentives for companies and public sector institutions to adopt IT. A survey of the adoption rate of equipment for accessing the information and communication infrastructure (see Figure 7) shows that Europe is also lagging behind the US in the adoption of PCs, the predominant mode of access to the Internet. Therefore it is not surprising that Internet usage is lagging in Europe too. Figure 8 also shows that there is a huge diversity in the adoption of IT equipment within Europe. The average number of 35 PCs per 100 inhabitants varies from a maximum of 66 for the Netherlands to a low of 15 for Greece. Likewise, Internet access has also a very large variation across EU countries.

Europe is also behind in the diffusion on fixed telecommunications lines (see Figure 7). However, with overall penetration rates of more than 50 lines per head, all households and firms are connected, and differences in diffusion may not have important implications. Europe is also ahead of the US in the diffusion of enhanced data rate telecommunications access, such as ISDN. Finally, Europe is definitively leading in the diffusion of mobile telecommunications. As Figure 9 shows, in this sector the variation across EU countries is also less pronounced than for PCs and Internet access. Around the EU average of 65 lines per 100 inhabitants, there is a maximum of 75 for Austria and Sweden and a minimum of 50 for France. What is also interesting is that the usual ranking of high tech industries with Scandinavian countries in the lead and Southern European countries lagging, does not apply with the diffusion of mobile telecommunications.

This raises the question on what makes Europe so much more successful in the telecommunications sector compared to IT. One answer may be related to a lack of exposure to IT equipment. Surveys (EITO, 2000; INRA, 2000) show that there are significant educational hurdles in the adoption of IT. A large share of the population, and this share increases with age, declare that they do not use IT because it is too complex. In the US there is a long-standing tradition of spreading computer literacy, starting at school. In Europe this is much less the case. For instance, Finland, which is Europe's most advanced country in the adoption of ICT, had one PC for 12 primary school pupils in 1997 (25 pupils for the EU on average). This compares with 6 for the US. A further implication of the low diffusion of computers in Europe is that teaching personnel are poorly trained to teach these new technologies. The bottom line is that the widespread adoption of IT needs a well-disposed environment of sufficiently well paid and skilled people, working within an economy prepared for innovation.

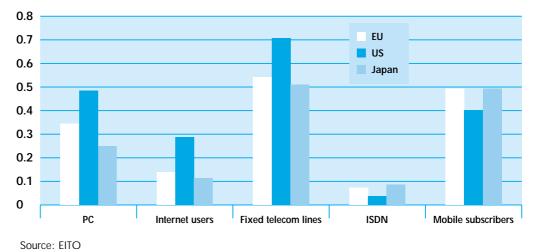


Figure 7. Adoption of ICT equipment (on a per head basis)

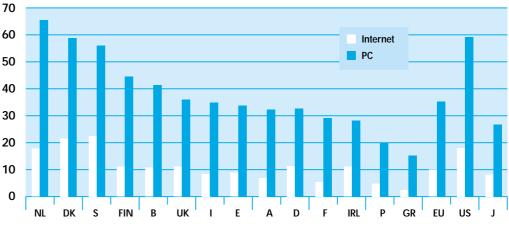


Figure 8. Computer ownership and Internet access (per 100 inhabitants) in 2000.

Source: OECD (Internet) and INRA (PC).

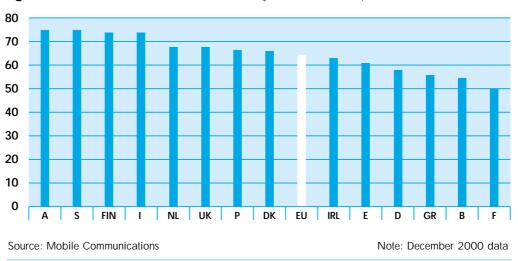


Figure 9. Mobile telecommunications subscribers (per 100 inhabitants) in 2000.

4. Policy issues

The policy environment needed for the "new economy" to thrive includes, investment in education, and liberal trade policies that induce competition and broaden the market opportunities for firms. The fact that IT pervades all sectors of economic activity puts new challenges to policy makers. First of all, the "new economy" will not emerge spontaneously: it requires an appropriate economic policy environment to thrive. The experience of the US shows that this is a policy framework based on sound fiscal policy, investment in education, and liberal trade policies that induce competition and broaden the market opportunities for firms (CEA, 2001). European policy makers are aware of the shortcomings in Europe and are undertaking action to remedy the shortfall in both the production and diffusion of IT. Indeed, the issue is permanently on the agenda of European Council meetings and most national governments have launched initiatives in this field.

Some significant steps have been taken towards the provision of a liberal market environment. The diffusion of IT was supported by the worldwide trend of trade liberalisation such as the establishment of the Information Technology Agreement (ITA), by which the EU, US and Japan engaged to eliminate tariffs on semiconductors, computers, software and communications hardware by the year 2000. This had a significant impact on Europe, as these products typically carried import duties in the range of 5 to 15%. The ITA was complemented by the liberalisation of the European telecommunications market.

Market forces and private investment have always been the engines for economic growth. However, IT is central in shifting the economy towards the production of goods embodying knowledge rather than physical capital. R&D is the principal means by which knowledge capital is created, and this is exactly where Europe is not doing very well. On the IT production side, Europe loses out by not having a vigorous sector with above average productivity growth. On the diffusion side, the lack of resources reduces the propensity of an economy to absorb IT based innovations and to create new opportunities for further growth. Hence, there is the urgency for Europe to increase the resources for innovation, through larger R&D expenditure, both public and private.

Importantly, the nature of the R&D process has changed fundamentally. Innovation traditionally was a highly vertically integrated activity, performed by large firms working independently from each other. In the IT sector today innovation is performed increasingly by small firms in collaboration with each other, with academic institutions, and with government agencies. It is clear that the financing of innovation within a network of small firms requires completely different instruments compared to the world of innovation in large companies. Hence, there is an increased role for private equity and venture capital, which is geared towards financing high risk undertakings by small firms (Gompers and Lerner, 1999). Public bodies in most countries share the awareness that their task consists in removing bottlenecks, which impede private financing of investments in this field.

European policy makers are also keen on managing the social aspects of new technologies. In other words, public organisations not only have to safeguard competition and solve market failures: policy should also smooth as much as possible the social and economic frictions from the introduction of new technology. This objective, however, may be in conflict with the promotion of diffusion. To ensure a rapid diffusion of new technology more flexibility of the economy is required. Diffusion of new technology not only involves a reallocation of workers across sectors and firms, it also leads to a complete reshuffling of hierarchies and competences within firms. For instance, increased recourse

to IT means that supplier relationships become more integrated, shifting rapidly as strategic alliances are made with supplier, customers and even competitors. The most representative example of how IT has changed this is the introduction of procurement based on the Internet.

Dealing with the labour market consequences of IT requires education and training. The introduction of IT requires different skills compared with the previous form of work organisation. If a significant gap in the technical and cognitive skills of users persists, the critical mass for certain types of IT applications may not be generated. This may also help to explain failures in reaping the benefits of investment in IT, as the applications of new technologies may not have been adequately supported by organisational changes and upgrading of individual skills.

A second issue of social concern derives from the regional inequality in the spreading of IT (6). Today, IT technology is unequally spread across European countries. There are entire countries lagging behind; even in the more advanced countries there are regions and groups of citizens that are still excluded from access to the information society. In these cases, public institutions in the educational, cultural, medical, social and economic fields of local communities should provide the services the market is not able to provide.

5. Conclusions

The dramatic decline in the cost of processing and transmitting information has led IT to pervade all sectors of economic activity, leading the way to an economy that is information intensive. The convergence of IT with telecommunications has opened up the way to a whole range of new capabilities that were previously unimagined. Through the dynamic interaction of these powerful innovations, the economy has become "lighter", in the sense that products embody more knowledge and less physical capital. Investment in IT and in creation of knowledge has become a major part of total investment activity.

Evidence from the US suggests that the benefits from the shift to the "new economy" could be sustained productivity growth. Europe is trying to unleash a similar virtuous cycle. In this attempt, however, Europe is handicapped by its lagging position in both the production of IT and the adoption of IT. This paper has discussed the causes and the effects of these lags. Though there is considerable heterogeneity across countries, clear European shortcomings emerge. Europe is devoting far too little resources to innovative activity, both in terms of investment and in terms of human resources. Europe is also doing very little to valorise its innovative capability, by, for instance, creating new technology based firms.

The remedies suggested consist of stepping up the resources for innovation, improving the access to IT, increasing the investment in education, and in adopting policies favouring greater flexibility and entrepreneurial activity. Even though Europe lags behind in the IT sector, it has a good position in the telecommunications sector. Europe, therefore, should try to leverage to the largest possible extent on this position in telecommunications in its attempt catch up. There are considerable opportunities open for Europe if the key access mode to the Internet switches from the PC to the mobile telephone. Europe is worldwide leading in the production and adoption of mobile telecommunications and the prospects of "Third Generation" mobile telecommunications should permit widespread access to the Internet.

6) For a description of the challenges see Brynjolfson and Kahin (2000), and OECD (2001).

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