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How Should Europe's ICT Ambitions look like?An Interpretative Review of the Facts

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How Should Europe's ICT Ambitions look like? An Interpretative Review of the Facts

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Abstract
In this Discussion Paper we analyse how Europe's ICT ambition can be translated into a policy agenda. To achieve this, we provide a quantitative overview of the importance of ICT and the relative position of Europe versus the US. Next we provide a discussion of potential explanations for the differences in ICT use and production. We find that Europe's position with respect to ICT use and production is not only worse compared to that of the US. In some areas Europe is ahead of the US, whereas in others Europe lags on an aggregate level. Our main conclusion is that Europe should not aim at creating an ICT-production cluster but it should aim at removing barriers to ICT use. The reasons are as follows. It is not a sensible strategy to specialise in industries where one has a comparative disadvantage. Moreover, the largest benefit from ICT is in its use not in its production.

JEL classification: H89, D2, E61

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1 Introduction

The Lisbon Council identified the “transition to the knowledge-based society ” as an important element for the European Union to reach the target of becoming the world’s most competitive economy in 2010.

The motive for the Lisbon agenda - and our analysis - is that, towards the end of the 1990s, it became clear that the macroeconomic performance of the US was remarkably better than that of other regions in the world, like Europe. With regard to the development of GDP, labour productivity and employment, the US outpaced most other countries in the recent past (see table 1.1). In fact, labour productivity growth has accelerated in the US, whereas it has decelerated in the EU.

Table 1.1 OECD Regional growth summaries, 1990-2002

	EU	US	Japan	OECD
	annual percentage changes			
GDP				
1990-1995	1.6	2.3	1.4	2
1996-2002	2.3	3.3	0.9	2.6
Labour productivity				
1990-1995	2.5	1.1	1.8	1.7
1996-2002	1.3	1.9	1.8	1.8
Employment (hours worked)				
1990-1995	-0.8	1.2	-0.4	0.3
1996-2002	1	1.4	-0.9	0.8

Source: R.H. McGuckin and B. Van Ark (2002)

To explain this remarkable divergence in productivity performance between both regions, the focus has primarily been on the impact of Information and Communication Technology (ICT). Increased productivity growth in the ICT producing sector is argued to be one of the main sources of the US productivity acceleration. Moreover, cross-region differences in productivity performance appear also to be related to the use of ICT, as investments in ICT were lower in Europe. But, does ICT really make the difference? And if so, what does this imply for growth, and most importantly, for European policy?

Against this background, this paper analyses the economic performance of Europe. We compare the European ICT producing sector - the sector that produces the ICT goods and services - with its counterpart in the US. Moreover, the paper examines the effect of ICT use on the productivity performance of Europe. To assess the role of ICT in reaching the goals agreed upon in Lisbon we address the following questions. First, what is the role of ICT in the economy and how important is ICT for the ‘Lisbon’ agenda. Second, how good (or bad) is Europe’s relative position with respect to the production and use of ICT. Third, how much potential does the ICT revolution still have for both the US and the EU economies. Finally, is there potential for policy, to improve Europe's future benefit from its current position.

We answer the last three questions as follows.[1] Europe's position is only weak when you wear one-eyed glasses; only the production of hardware is small and productivity growth in that part of the ICT producing sector is low in Europe compared to the US. The next question is answered boldly with: yes, probably there is still a lot to expect from ICT. If spillovers of ICT knowledge can be ignored, we add to this the notion that it is not so very important to produce ICT but that it is more valuable to use ICT. And finally, policy: the 'evergreen' policy advice that structural reforms are necessary again holds, mostly because of the logic that what is good for the economy in general, is good for the ICT producers and users. Also, we re-emphasise the importance of educational policy and the like. However, more specific policy options are: to re-evaluate patent and copyright policy, to monitor firms in the ICT producing sector in order to prevent abuse of a monopolistic position and to watch price-discrimination with different eyes than before.

The structure of the paper is as follows. Section 2 discusses the main characteristics of ICT by sketching the specific characteristics of ICT. This section states that ICT can be seen as a general purpose technology. The section continues by analysing the strengths and weaknesses of Europe versus the US with respect to the size and productivity of the ICT producing sector and the *use* of ICT in the economy. Section 3 interprets thee evidence from Section 2, by posing the question whether Europe's position is worrisome. Section 4 examines potential market failures related to the specific features of ICT and it provides a preliminary explanation of the observations in section 3. The final section discusses European policy options viewed from the ambition becoming the world's most competitive economy in 2010.

2 Strength and weakness of Europe's ICT production and use

2.1 ICT as a general purpose technology

How to assess the ICT revolution? The hype about the technology's new opportunities resulted in a stock-market boom. The subsequent stock-market bust brought expectations about the revolution down to earth with a bump. Is ICT nothing special or has the stock-market bust lead to an overly gloomy perspective on ICT? In this section we address this question from a theoretical perspective.

[1] The first answer is merely a theoretical exposition as a framework for the subsequent analysis or questions.

Can ICT be entitled as a general purpose technology (GPT)? Characteristics of a GPT are: (1) scope for improvement, (2) a variety of applications throughout the economy and (3) complementarity with existing or potential new technologies and (4) effort or investments are required to introduce the GPT fruitfully in applications.[2]

In our view, ICT meets all these requirements. It has already undergone a significant evolution and there are likely more opportunities. The variety of applications throughout the economy is reflected in applications such as in travel agencies, aircraft navigation, medical equipment, just-in-time inventory systems and many more. Also directly for consumers numerous applications are prevalent, think of mobile communication, Internet shops etc. Complementary technological innovations have occurred in the above-mentioned applications. The effort required to introduce ICT is easily seen when thinking about the introduction of the Internet. The Internet offers new means of communication at a distance and for firms this implies that investments in organisational changes are necessary because computers replace for example low-skilled administrative tasks. The remaining tasks become more service-oriented: advising customers on products which are becoming increasingly complex and increasingly tailored to individual preferences. This requires not only more education and training but above all more skills in dealing with people and more autonomy for staff.

Can ICT have a permanent growth effect?

As ICT can be entitled as GPT, this raises the expectation that productivity growth, at least, could accelerate temporarily for some time. Comparison with historical GPTs promises a lot (see box later in the paper). In the early twentieth century electricity was the dominant GPT; further back in time the steam engine played such a role: both innovations that revolutionised the economy.

Even more interesting is the question whether ICT can induce sustainable economic growth. For long, productivity gains of ICT appeared to have been disappointing. As Solow (1987) once wrote: “we see the computer age everywhere except in the productivity statistics”. This so-called Solow or productivity paradox is more precisely formulated as: why is productivity growth disappointing despite the ICT revolution?

If the historical analogy applies, and ICT evolution is now maturing, then does the economy stand on the eve of a period of structurally high growth? This is not self-evident, for two reasons.

First, the emergence of a GPT manifests itself in macro productivity only very gradually and in a complex way. Hence there may not necessarily be a sharp acceleration of the growth rate at the macro level. Second, over the long run a GPT seems to prevent the levelling off of productivity growth rather than actually increasing it. If no GPTs emerge, technological developments eventually (seem to) reach a saturation point and overall productivity tends to slow down.[3] A GPT rejuvenates the growth process in the economy by creating a whole new range of opportunities for further development. Thus the GPT takes the economy to a higher *level* of income. It is possible, though,

[2] Based on Bresnahan and Trajtenberg (1995) and Lipsey et al. (1998).

[3] This would also explain the emergence of new GPTs over time.

that productivity *growth* could come out higher over the long term if ICT makes the innovation process itself more productive (Romer, 1990). In that case, ICT would be different from previous GPTs.

Looking at empirics to evaluate the impact of ICT, the focus should be on the development of TFP growth. It is therefore not surprising that the role of this channel in the rebound in US TFP growth is fiercely debated among economists. There are two main positions. Either this rebound is primarily due to technological progress in the ICT-producing sector or it is (also) caused by efficiency gains or spillover effects in ICT-using sectors. The proponents of the former position emphasise that the ICT-revolution is a pure neoclassical story of the relative price decline of ICT and input substitution. More ICT-capital per worker enhances labour productivity in the ICT-using industries but not their TFP growth. Due to decreasing returns, the effect of ICT will disappear in the long run.

Proponents of the other position assume that ICT differs from other inputs because of network externalities and spillovers. Network externalities and ICT spillovers enhance the benefits of the investor. Moreover, ICT can help to invent new products and processes that induce higher productivity.

Stiroh (2002) investigates whether there are ICT spillovers across US manufacturing industries at the sectoral level. He finds little evidence that ICT capital is associated with measured TFP growth. So, he finds no compelling reason to drop the neoclassical framework relying on input substitution. Likewise, Van der Wiel (2001) does not find a significant correlation between ICT capital and TFP growth for the Netherlands at the sectoral level. In contrast, at a micro level, several researchers find evidence that contradicts with the neoclassical assumption of no spillovers of ICT.[4]

2.2 How does ICT affect productivity?

ICT can affect labour productivity growth through three channels:

- production of the (domestic) ICT-sector;
- use of ICT as an input in the production process;
- spill-over effects of ICT.

First, the domestic production of ICT can contribute directly to overall Total Factor Productivity TFP and labour productivity growth. Technological progress in the production of ICT-products can generate productivity growth in the ICT-sector itself. The contribution to the overall economy depends on the size of the ICT production sector relative to the economy.

[4] See e.g. Brynjolfsson and Hitt (2000), Van der Wiel and Van Leeuwen (2003)

Second, higher productivity in the ICT producing sector leads to lower prices of ICT (investment-) goods, of course unless suppliers can prevent prices from lowering. In practice large parts of the rents from productivity improvements accrue to users. Lower prices stimulate firms (and consumers) to invest in ICT. Increased ICT application in production means capital deepening and hence higher productivity. Note, however, that this mechanism does not require a domestic ICT-sector, since ICT-products and investment goods can mostly be imported. In this view, ICT is just one investment good among many others. Summarising: firms substitute between inputs along a given production function in response to relative price changes. More and better ICT per worker contributes to higher productivity.

The third channel is that ICT also has the potential to generate TFP-growth due to externalities or excess returns. This implies that the production function of ICT-using industries shifts outward. This effect is controversial in the literature. Potential mechanisms are the following: (1) ICT can induce higher TFP-growth because savings in transport and search costs can be made at all points along the production chain. For example, it can do so because of positive network effects among firms. An investment in communication equipment such as e-mail may have a positive impact not only for the investor but also for all the other users. These network externalities are larger as the level of standardisation rises. On the other hand, because of high switching costs, firms can get locked into certain technologies.[5] This can create negative effects. (2) ICT can also promote the creation of new goods among both producers and customers. Many ICT goods are supplied as an input to other industries. These industries can benefit from the embodied knowledge in these goods. (3) Finally, in combination with other changes in the organisation, ICT enhances a firm's efficiency.

2.3 ICT producing sector of Europe

2.3.1 Size and structure of Europe's ICT producing sector

Around the world, the ICT-producing sector accounts for a small share of the economy. Its share in GDP is no more than 10% in the main economic regions. In the US (and Finland), the ICT producing sector makes up the most (see Table 2.1).

The ranking of ICT firms underlines this outcome. The Top 50 of ICT firms in the world includes many American firms.[6] American firms like IBM and HP dominate the hardware market.

[5] High switching costs could reduce the aforementioned positive externalities. A user who switches to a new technology incurs costs. Both network externalities and switching costs can lock users into a particular product or technology and, therefore, affect (price) competition. This could induce negative externalities. For instance, producers of ICT with large market shares might have greater market power than is common in other industries.

[6] According to OECD, 2000, OECD information Technology outlook 2000; ICTs, e-commerce and the Information economy (2000b), 36 of the largest IT-firms in 1998 were US based.

Well-developed university research centres with close ties to business, defence, and the space program helped the US take the lead in the computer and semiconductor technologies.[7] Additionally, Japan is also specialized in the production of some ICT goods.

Compared to the US, Europe has a smaller ICT production industry. In Europe, like in the US, the size of the ICT manufacturing is considerably smaller than that of the ICT services. However, the size and structure of the ICT producing sector differs strongly across European countries. Except for Finland and Ireland, most European countries have lower GDP shares in the ICT producing sector than their US counterpart. Particularly, France and Italy have rather small ICT producing industries.

Table 2.1 Size of the ICT producing sector, 2000

	ICT producing manufacturing	ICT producing services	ICT producing sector
	% share in GDP		
Austria	1.7	3	4.7
Denmark	1.1	3.6	4.7
Finland	5.6	4.5	10.1
France	1.3	4	5.3
Germany	1.5	3.9	5.4
Italy	1	3.5	4.5
Netherlands	1.3	5.1	6.3
Sweden	2.2	5	7.7
UK	1.8	5.2	7
EU	1.5	4.3	5.8
US	2.3	5.7	8

Source: Van Ark et al. (2002)

Observation: On average the EU has a smaller ICT producing sector than the US; however, within the EU few countries have a larger or comparably sized ICT producing sector.

2.3.2 Effects of ICT production on European's economic performance

The pickup of labour productivity growth in the US in the second half of the 1990s has induced a heated debate among economists to what extent this is due to ICT. At least, there is a consensus that ICT producing manufacturing has contributed considerably to the resurgence in productivity growth during the course of the 1990s.

[7] See Mc Guckin, R. H. and B. van Ark (2001).

Table 2.2	Labour productivity performance ICT producing sector					
	ICT producing manufacturing		ICT producing services		ICT producing sector	
	1991-1995	1996-2000	1991-1995	1996-2000	1991-1995	1996-2000
	annual percentage changes					
US	13½	20¼	3¾	¾	7	7
Canada	7¾	11¼	1¼	3	3¼	5¼
Japan	10¼	23	4¼	4	7¾	13¾
EU	7¾	14	5¼	6	6	8½

Source: Van Ark et al. (2002)

US's productivity performance in the ICT manufacturing was spectacular in the 1990s, especially in the latter part of that decade (see table 2.2). It experienced much more rapid productivity growth than its counterpart in Europe. But European ICT producing manufacturing accomplished rapid improvements in productivity too. The debate is moving towards how much of the macro-economic productivity acceleration was cyclical[8].

Contrary to conventional wisdom, growth rates of the European ICT producing sector as a whole were faster than that of their US counterpart in the second half of the 1990s. In fact, Europe outpaced the US due to disappointing productivity growth in ICT services in the US. Particularly, the productivity growth in US' telecommunication industry is low in an international perspective.

Observation: The ICT producing sector consists of ICT services and ICT manufacturing where the latter is somewhat larger in most countries. Though the US ICT manufacturing labour productivity growth catches the eye, the growth rate of the European ICT producing sector as a whole was faster than that of their US counterpart in the second half of the 1990s.

Summarising this section:

- the US leads in ICT producing manufacturing (both in size and growth rate)
- the EU leads in ICT producing services (at least in terms of the growth rate)

[8] We return to this issue after discussing the ICT using industries

2.4 Effect of using ICT in production process

2.4.1 Analytical framework

As discussed in Section 2, ICT affects economic growth through three channels. To assess these three channels empirically, a standard growth accounting can be applied. The growth accounting framework is based on the neoclassical model of Solow (1957). It decomposes labour productivity growth into contributions of capital deepening and TFP-growth, either in the ICT-sector or in the ICT-using industries.[9] TFP-growth is a residual, and cannot be measured directly. It is a catch-all term reflecting a bunch of developments like organisational changes, scale effects, measurement problems, the effect of new products etc. Hence, the interpretation of the development in TFP is not straightforward. Higher TFP-growth could be related to ICT, but it may also come from developments in the economy that are independent of ICT.

2.4.2 Productivity effects of ICT for Europe

At present, there are only a limited number of comparative international studies regarding the international impact of ICT. Particularly, studies on the effect of ICT in European countries are scarce. Moreover, studies that go beyond the aggregate level are almost absent.[10] The most important problem is a lack of ICT-investment data at the sector level.

Table 2.3 Contribution of ICT to output growth, 1991-2000

	1991-1995	1996-2000	Acceleration[a]
	in %-points		
United States			
Oliner/Sichel	0.7	1.1	0.4
Jorgenson/Stiroh	0.4	0.8	0.4
Colecchia/Schreyer	0.5	0.9	0.4
Euro-area			
Colecchia/Schreyer	0.3	0.4	0.1
Vijselaars/Albers	0.3	0.7	0.4

[a] Period 1996/2000 versus period 1991-1995

Nonetheless, recently two studies (Collechia and Schreyer, 2001; Vijselaars and Albers, 2002) have endeavoured to assess the contribution of ICT investments to output growth for a number of European countries.[11] In this regard, Table 2.3 summarises the main results of both studies and

[9] Appendix II contains more details about this method.

[10] One of the exceptions is a study by Van der Wiel (2001).

[11] ICT investments include software, information and communication equipment.

compares them with akin studies for the US. Remarkably, the absolute contribution of ICT growth to output growth is not markedly different between the Euro-area and the US in the second half of the 1990s. Likewise, the acceleration in US output growth due to ICT investments is not unique. Vijselaars and Albers (2002) come up with comparable results for their Euro-area definition. In the second part of the 1990s, many European countries invested heavily in ICT, sometimes even more than in the US. Hence, other factors must explain the difference between the productivity performance of the US and Europe.

Table 2.4 Decomposition of labour productivity growth, 1991-1999

	Euro-area		US	
	1991-1995	1996-1999	1991-1995	1996-1999
	annual contribution in % points			
Labour productivity growth	2.4	1.3	1.5	2.6
of which ICT capital	0.3	0.4	0.5	1
other capital	0.7	0.3	0.1	0.1
TFP	1.4	0.3	0.9	1.5

Source: Euro-area Aalbers and Vijselaar (2002), US: Oliner and Sichel (2001)

Table 2.4 presents the results of growth accounting on an aggregated level for both the Euro area and the US. In Europe, labour productivity growth remained on a track of slower growth rates. The contribution of ICT capital slightly increased, the contributions of TFP-growth and other capital considerably decreased in the second part of the 1990s. The contribution of TFP growth and capital are different from the outcomes for the US. In the US productivity accelerated in second half of the 1990s due to stronger contribution of ICT capital and TFP growth as well.

Observation: US labour productivity growth was lower than the EU's in early 1990s and higher in the late 1990s. The US and European countries are experiencing positive growth effects of investments in ICT. However, TFP-growth seems to be absent in Europe in contrast to the US. In Europe, TFP-growth has been shrinking rather than growing over time.

Intermezzo: Looking at longer time perspectives

As labour productivity growth tends to be pro-cyclical, this behaviour can hamper the comparison between Europe and the US by looking at short-term figures. The cited papers compare productivity developments in Europe and the US in the 1990s, and divides the period into two parts: before and after 1995. These time periods can be criticised due to differences in the state of the business cycles between both regions and its effect on productivity growth. Ideally, productivity growth should be analysed with cyclical adjusted data. However, this correction is difficult to obtain, especially over short time periods.

Vijselaars (2003) looks at a longer time perspective. He compares the Euro area and the US over the period 1982-2001 and divides the period into two comparable business cycles (see table 2.5).

Table 2.5 Decomposition of labour productivity growth, 1982-2001

	Euro-area		US	
	1982-1993	1993-2001	1982-1991	1991-2001
	annual contribution in % points			
Labour productivity growth	2.6	1.9	1.3	1.7
of which ICT capital	0.3	0.4	0.5	0.6
other capital	0.4	0.3	-0.3	0
TFP	1.7	1.2	1.1	1.1

Source: Vijselaars (2003)

Taking this perspective, the increase of productivity growth in the US is less pronounced, as the acceleration of the contribution of ICT capital deepening is more modest. As a result, the difference in the impact of ICT between both regions is limited. Apparently, the contribution of other capital to productivity growth differs more widely in the 1990s.

An alternative indirect approach: the use of ICT in industries

At present, data availability does not allow an international comparison of growth accounting at lower levels of aggregation. To circumvent the lack of sector data for the growth accounting method, an alternative approach is to analyse the benefits of ICT from the production side. For instance, McGuckin and Van Ark (2002) followed that approach by dividing industries into ICT-intensive industries and non-ICT-intensive industries. This approach implicitly assumes that any (spillover) effects from the use of ICT should pop up in the industries that use ICT on a broad scale.

In an international context, no straightforward definition of which industries should be classified as an ICT-intensive industry is available.[12] Using US and Dutch data McGuckin and Van Ark (2002) classified industries outside the ICT-producing industries into ICT-using industries and non-ICT-using industries.[13] The shares of ICT using-industries in GDP is substantially lower in Europe than in the US (see table 3.6). This result is due to the higher shares of ICT-using services in the US. In contrast, ICT-using manufacturing is relatively smaller in the US than in Europe.

[12] It, therefore, goes without saying that any classification scheme is to some extent arbitrary.

[13] See appendix I for a detailed overview of this classification scheme.

Table 2.6 GDP shares of the ICT using and non ICT industries, 2000 (current prices)

	ICT using industries	Non-ICT industries
	% share in GDP	
Austria	27.9	67.5
Denmark	26.5	68.8
Finland	24.1	65.8
France	28.1	66.5
Germany	29.2	65.4
Italy	33	62.5
Netherlands	30.8	62.8
Sweden	24.4	68.4
UK	30.6	62.4
EU	29.9	64.3
US	34.3	57.7

Source: Van Ark et al. (2002)

Using the grouping of ICT industries, table 2.7 shows the sectoral labour productivity performance in the EU and the US in the last decade of the 20th century. The strong growth rebound in US is partly explained by fast productivity growth in ICT-intensive industries, especially in services industries like wholesale and retail trade and securities. In contrast, the productivity performance of the ICT-intensive industries deteriorated in the second half of the 1990s in Europe.

Table 2.7 Labour productivity growth in ICT using and non ICT using industries, 1991-2000

	EU		US	
	1991-1995	1996-2000	1991-1995	1996-2000
	annual percentage changes			
ICT using industries	1.9	1.3	1.3	4.2
o.w. manufacturing	3.3	2	0.5	2.1
services	1.7	1.1	1.6	4.6
Non ICT industries	2.4	1	0.4	0.4
o.w. manufacturing	3.7	1.2	3	1.3
services	1.6	0.7	-0.2	0.3
others	3.6	1.6	0.1	0.4

Source: Van Ark et al. (2002)

The contribution of the industry groups to overall labour productivity growth can be quantified using a shift-share analysis.

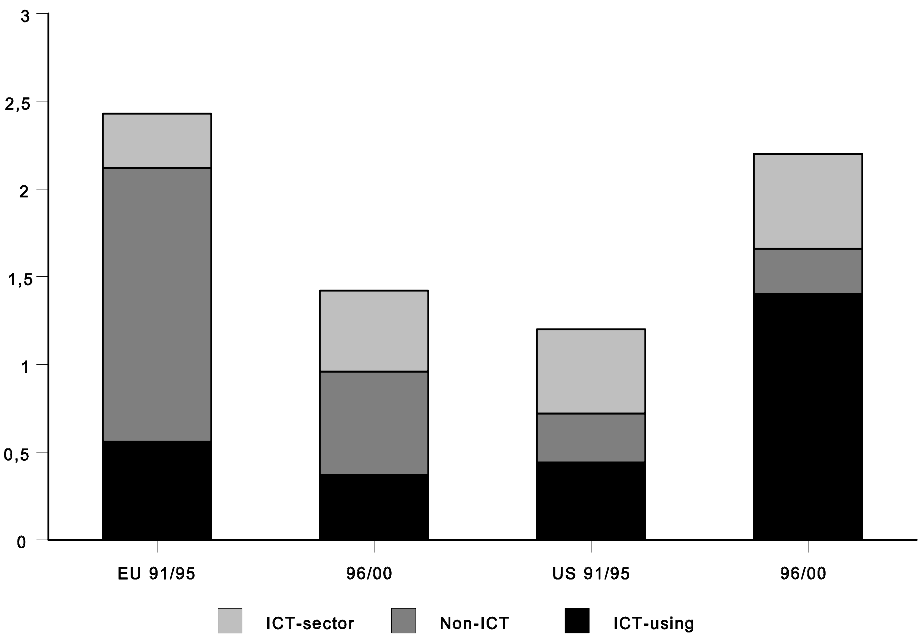

Figure 2.1 Contribution of industry groups to labour productivity growth, 1991-2000

Figure 2.1 reports the results of this exercise. It can be seen that the contribution of the ICT-using industries makes the difference in productivity growth between the US and Europe. The results suggest that the US' economy reaped more benefits of ICT than Europe did. But why? Based on detailed country econometric analysis, McGuckin and Van Ark (2002) suggest that the diffusion of ICT in Europe is proceeding at a somewhat slower pace than in the US. A sizeable number of European countries show significantly faster growth in ICT using services compared to non-ICT services since 1995. Is it, therefore, justified to conclude that it is only matter of time for Europe to fully reap the ICT potential?

Observation: Productivity growth differentials between the US and the EU are largely due to lower growth in the ICT using industries, notably ICT using services.

Some qualifications to this observation are in place. First, note that the observation only holds for the second half of the 1990s; not for the first half; this suggests again that cyclical phenomena play a role. Second, though the lag in European productivity growth in ICT using industries is suggestive, we do not have direct evidence that it is the use of ICT that causes low productivity growth (that is, a third factor might play a role).

2.4.3 Evaluation of Europe's position on ICT-use

We considered the following aspects. The size and productivity growth of the producers of ICT: ICT manufacturing and ICT service. The (sources of) growth in ICT using services and ICT using manufacturing. Doing wrong to all the details about time variation and cross-European differences we can summarise our findings as:

- the US leads in ICT-using services
- the difference in ICT-using manufacturing is less clear (though Europe had highest average growth rate in the 1990)
- the differences in non-ICT-using manufacturing as well as services are not outspoken.

2.5 What can Europe still expect from ICT?

There are two ways to look at the question posed in the title; together they provide an answer. The first way is: what can the technological leader, the US, still expect from ICT innovation? And second, how will the adoption of ICT in the EU work out in the future?

2.5.1 The future of the US productivity development

One observation about US growth is that it is unlikely to maintain at the 1995-2000 level simply because of the cyclical nature of growth. One reason why labour productivity will not rise so quickly is that the hours worked cannot increase unbounded. From 1995-2000 the hours worked in the US increased at an unsustainable rate of 2% annually (for an elaboration see de Groot, Nahuis Tang, 2003).

Will the real ICT contribution to growth keep up it's current pace? The answer is yes. The following logic illustrates this. An equation explaining productivity growth is helpful:

$$\hat{\pi} = S\left(\pi^{ICT}, \pi^{O}\right) \bullet \hat{\pi}^{ICT} + \left(1 - S\left(\pi^{ICT}, \pi^{O}\right)\right) \bullet \hat{\pi}^{O}$$

This equation says that the change productivity ($\hat{\pi}$) is determined by the share of the ICT producing sector in demand, *S*, times the productivity growth of the ICT producing sector plus the demand share of the other sectors (1-*S*) times the growth in the other sectors. Two questions ought to be answered. First, will productivity in ICT keep on rising and induce falling prices? Based on the opinion of analysts, it is expected that new ideas, software and other related ICT products will keep coming at a rapid rate. This raises productivity growth. The second question is, will the share of ICT in demand rise? This is determined by the relative price of ICT to other goods and the demand elasticity.[14] So far the relative price fall of ICT is met by larger spending shares, implying an elasticity larger than one. There is no reason to believe this will change in the near future as new applications of ICT keep on arriving (this is also in line with what one can expect from the general

[14] The income elasticity also plays a role; for now it seems that more income is associated with more ICT spending as ICT is a luxury (this is hard to establish empirically given the enormous relative price drop of ICT and the uncertainty about the elasticity). It is difficult to say something sensible about the income elasticity of ICT spending in the future.

nature of the general purpose technology).[15] This is not the case for all types of technologies; take for example the technology for heating houses that evolved from collecting wood in the forest to today's central heaters (this amounts to an enormous fall in real prices). Spending shares on heating have obviously fallen, from a half days work in the past to a minor fraction of a working person's income today. The reason that the spending share falls, is simply because heating has limited additional application possibilities. The logic above explains that the real ICT contribution to growth indeed is likely to keep up its current pace.

Two qualifications to the above analysis can be made, one valid, one not. The valid one is that our expectations about ICT are high if we compare them with past general purpose technologies (see box). The invalid qualification is that the Nasdaq crash illustrates that ICT as such is a bubble. The crash did not illustrate that the growth pace delivered by the 'new economy' was overestimated or that it will be much lower in the future. What happened was that the insight crept up that ICT is not a winner take all paradigm in most application but that ICT generates highly competitive markets. Hence, it is much harder to create entry barriers that generate a large lasting profit flow than was imagined in the early days of the stock-market boom.

It is not the case that (natural) monopolies do no arise, on the contrary, the high-fixed cost low-marginal cost production technology does tend to generate monopolies. However, in many markets competitors do seem to do well or are at least able to generate a competitive fringe (markets tend to become contestable). Even the most famous monopolist is slightly held back by competitors: think Linux 'threatening' Microsoft. Moreover, Microsoft succeeds more often than not to convince anti-thrust authorities that it faces indeed substantial (potential) competitors. The Amazon book store and the E-bay internet market face -- despite the first-mover advantages -- serious competition (at least outside the US. Only recently Amazon did make a profit. The factor that holds back the, would be, ICT monopolist is 'paradoxically' the ICT technology itself. The ICT technology makes it possible to reach a world of customers without the enormous cost of rolling out a network of local suppliers. The technology also makes the spread of information so cheap that competition is enhanced.

[15] Ohliner and Sichel (1994) used the exact analogous logic to explain the *low* contribution of ICT in the late 1980s early 1990s: the share of ICT goods was still low, so obviously the contribution to growth was moderate.

How does ICT compare to historical GPTs?

A different way of looking into the future is comparing the recent past with history of major technological breakthroughs, this is exactly what Crafts (2002) does. Comparing the GPT of these days -- ICT -- with those in the past is revealing. Comparing the contribution of ICT with the 18th century invention of the Steam engine learns that it took some 70 years before the substantial gains in productivity appear. It took long before one of the most effective applications of the steam engine was implemented: the Railway system. The contribution of this GPT to per capita growth culminated to roughly 24%. For ICT in the 1990s the comparable number is around 55%. For Electricity, the contribution to growth peaked below 50%. These numbers suggest that there is no productivity paradox (see however our earlier discussion where we argue that the main puzzle is low growth in ICT using industries). More important, the numbers suggest that ICT has paid already off at a rate that is unprecedented in history. Therefore, the expectations for even further contributions of ICT to growth imply that ICT is proving more valuable than the previous GPTs.

GPT Contribution to growth, 1760-2000 (percentage points per year)[b]

GPT			UK		US			US
Country			Steam (and Railways)		Electricity			ICT
	1760-1800	1800-1830	1830-1860[a]	1899-1929	1919-1929	1974-1990	1991-1995	1996-2000
GPT Capital Contribution	0.005	0.012	0.04+ 0.16	0.5	0.93	0.52	0.57	1.36
GPT TFP Contribution	0.003	0	0.01+ 0.05	0.06	0.05	0.17	0.24	0.50
Total GPT Contribution	0.008	0.012	0.26	0.56	0.98	0.69	0.79	1.86
(as % GDP/Capita Growth)	(3.8)	(2.4)	(23.6)	(28.2)	(47.0)	(30.4)	(54.6)	(56.3)

[a] The second number in the column is the contribution of the Railway system
[b] Source: Crafts (2002).

This table raises some second thoughts, however. A common sense historical view very much suggests that people's lives changed less the last 40 years than the 40 years before that period (Krugman makes this point convincingly). The example Krugman uses is the fridge: the last 40 years the fridge became somewhat more efficient and got a digital display etc. However, going back another 40 years; a horse cart brought ice blocks around in order to cool. Noticing these second thoughts is however far more easy than explaining them.

On a more theoretical level one can argue that ICT is a general purpose technology with a very specific characteristic, different from past GPTs. ICT is not only enhancing the productivity of existing production processes but also the innovation process. Research is ICT intensive: it depends on high-tech computer application; it depends on easy communication processes etc. Speculatively, this implies that ICT will enhance economic growth for a long period. Not all GPTs have this characteristic, think for example of the chemical and plastic revolution after world war II, such a technology creates huge benefits for producers and consumers but does not directly impact research productivity.[16]

[16] For an elaboration, see Nahuis (1998).

Observation Theoretical and empirical arguments suggest that the US growth will remain high. On a macro level the potential for further increases in hours worked is exhausted, this however is likely compensated by a more important contribution of the ICT producing sector as a whole. There is no evidence that growth in the ICT industry is going to drop drastically.

3 Why worry about ICT?

3.1 Do we need European ICT-producing industries?

The question is, does it matter if the EU is less specialised in producing ICT? A priori there is no reason why producing eatable chips is worse for welfare than producing computer chips. Economic logic rules out that everybody is specialised in producing ICT. The following qualifications should, however, be noted.

First, it is important to specialise in goods that produce now and in the future high value added. The US appears to be more specialised in ICT manufacturing than in ICT services compared to Europe. A common belief is that *if* past growth rates of productivity in ICT manufacturing are a good prediction for the future, the US allocation is beneficial. This is, however, not sound economic reasoning. It is about value added, not productivity, that one should worry. If fierce competition takes care of shifting the benefits of higher productivity to the users, having a sector with high productivity growth is not especially helpful. So, only in case the ICT production is able to generate high-value added growth in the future it is especially worth having a large sector.

Bayoumi and Haacker (2002) provide a detailed analyses of the overall welfare effect of the ICT revolution. They underline the analysis provided above, as they argue: “ The social saving benefits are not closely connected to the size of IT production in a country. Some of the major beneficiaries have small domestic IT sectors (such as Australia and New Zealand), while other countries which are major producers of IT equipment are not experiencing major social saving gains (such as Malaysia, Thailand, and the Philippines).” To understand this, it might be useful to think about the following somewhat far-fetched example. Suppose France and Spain both produce only good: red wine. Then by some new technology productivity is doubled. They need to export most of the additional production, as to benefit from the technological progress they want to import more goods. Then France and Spain compete on the world market to sell their red wine. Depending on the toughness of competition and the world demand elasticity for wine, a drop in prices will result. This means that, of the doubling of productivity, a part is passed on to other countries by a changed terms of trade. Acemoglu and Ventura (2001), find that a 1%-point faster growth (over the whole range of production) is associated with a 0.6 %-point deterioration in the terms of trade. It could be that this number would be higher in case one would focus on ICT only.[17]

Second, it could be so that producing computer chips is preferable above producing eatable chips due to local knowledge externalities. We have no evidence that ICT production is generating these effects at an aggregated level, however, at a disaggregated level these are found (van Leeuwen and van de Wiel, 2003). This inconsistency is yet to be solved.[18] One hint that the externalities related to ICT manufacturing need indeed not produce important knowledge spillovers is that the R&D intensity of ICT services and software is higher than that of equipment (read: ICT producing manufacturing). Hence, given the low R&D intensity of equipment it is likely that R&D spillovers are small too.

> **Observation**: The relative small size of Europe's ICT manufacturing sector is not an important disadvantage.

To *explain* the relatively small size of European ICT manufacturing is a different matter where we only touch upon, as a full exploration is beyond the scope of this paper. One explanation -- is it really an explanation? -- is simply luck. Somehow the US was first in producing ICT and ICT is characterised by a first-mover advantage. Second, the US has a comparative advantage in ICT production: they have ICT knowledge centres which provide fertile soil for ICT production, think of the research cluster at Stanford and MIT. The ICT research was also strongly influenced by the massive military expenditures associated with the cold war and the space program.[19] More general, the European labour market is more regulated than that in the US. Regulation leads to distorted allocation and thus might cause Europe to specialise in sectors where it has a comparative disadvantage. In the long run, Europe could end up with an economic structure baised toward lower productivity and lower welfare. For this we have no compelling evidence however.

4 Explaining differences between the US and Europe

4.1 Introduction

In the remainder of the paper we step aside of the detailed discussion of the differences between the EU and the US. Section 3 argued that the production of ICT is not a major item for policy to worry

[17] See Nahuis and Geurts (2004) for an elaboration.
[18] See e.g. Stiroh (2002) and Van der Wiel (2001).

[19] See McGuckin et al. (2001).

about as long as ICT spillovers can be ignored. Therefore, we centre our discussion around the following question:

Why is the EU's ICT diffusion relatively slow?

At the moment, literature explaining the slow diffusion is scarce. We pursue the following steps in answering three questions raised above:

- What are the different approaches to explain differences in ICT use?
- What market failures occur in the use of ICT?
- Is there an empirical link between regulation and ICT use?

4.2 An overview of potential explanations

4.2.1 Different fundamentals

The lag in ICT use in the EU compared to the US might simply be an optimal but different technology choice due to different prices.[20] The EU is more capital abundant and therefore produces more capital intensive. This can be read also as producing more 'old technology' goods. An alternative different fundamental could be that the US has a higher supply of skilled labour that is required for the implementation of 'new' technologies. This is indeed a possibility, Europe's skill supply level is very heterogeneous and on average below the US (see Nahuis and de Groot, 2003).

4.2.2 Different investment incentives

The literature has come up with several explanations for differences in the extent of dissemination of new technologies like ICT (see e.g. Thritle et al. (1987)). The main notion is that firms are confronted with differences in at least one of the crucial components of the investment decision: (expected) costs, (expected) benefits and discount rate.

Though the costs of the direct ICT investment goods are not likely to be higher in Europe than in the US, as these goods are worldwide tradeable, the other costs components, benefits and discount rate might differ. Hereafter, we focus on some of these investment components in more detail.

ICT investments: lower returns due to a labour market imperfections?

Regulated labour markets with for example high firing costs might force EU firms to be more reluctant in experimenting with new technologies (Saint-Paul, 2001). Also, the more compressed wage structure in EU induces firms to choose for different technologies. Acemoglu (1999) argues

[20] At least this is in a static sense optimal.

that a less skill-biased (read: ICT) technology choice follows from binding minimum wages in Europe and he shows that the resulting skill premium and unemployment pattern fits the facts.

According to Feldstein, Europe has failed to share in the productivity gain because its employment practices limit companies' ability to use ICT. Moreover, dismissal of redundant workers due to productivity gains is far more easier in the US than in Europe.

ICT investments: lower returns due to capital market imperfections?

The GPT nature of ICT makes it necessary to change the production processes, marketing, financing and organisation of businesses. Usually several decades elapse between the invention of the technology and its large-scale application. The principle of steam power, for instance, had been known for seven decades before steam power started to replace water power.

These delays occur for a number of reasons. Complementary innovations and structural changes in many areas take time. Uncertainties and sunk costs are another potential reason for delay. The introduction ICT involves substantial outlays, which cannot be easily reversed. Investments in new equipment or retraining staff spring to mind here. Because of the uncertainty attached to technological changes, a firm runs the risk of investing too early in the wrong technologies. The higher risk premium, related to the lower availability of venture capital in Europe, can explain waiting behaviour.

ICT investments: lower returns due to final-output-market imperfections?

Differences in functioning of markets, is an argument often heard to explain the weak European technology position. The diffusion of technological opportunities from the ICT producing sector throughout the economy depends on the way in which markets operate. In this regard, Europe is often characterized as less flexible in product markets due to more regulations and structural impediments.[21] The failures to adopt best-practice technologies derives from regulations and laws that formally prevent technological improvements.

Baily (1993) studies productivity differences in service industries in Europe, the United States and Japan.[22] He evaluates the role of certain types of regulation and the intensity of competition as an explanation for productivity differences. The general lesson to be drawn is that productivity differences in service industry's productivity is due to regulatory barriers and lack of competition. These cause slack and inhibit productivity growth. A case-study of banking stresses that innovations are not adopted without the threat of competition. Germany's overall productivity level in banking is about 68% of that in the United States. This productivity gap is due to the failure to exploit economies of scale and scope in German banks with their many small branches, and their less effective use of information technology; far fewer transactions per person pass through ATMs in

[21] See for example Alesina et al. (2003).

[22] Four major industries are examined: airlines, retail banking, telecommunications, and general merchandise retailing.

Germany than in the United States. Competition in the banking industry is limited by the regulated structure in Europe due to the consideration that financial stability is more important than efficiency. In the United States, however, the regulatory environment encourages competition.

Inefficient standardisation policy is an important product-market explanation for differences in technology diffusion. The US lags in the mobile telecom market due to a lack of standardisation in the mobile infrastructure. This forces producers to inefficiently low investment as small market sizes impede them to benefit from scale effects. Moreover, uncertainty about standards makes consumers hesitant to switch to the new technology.

4.2.3 On the advantage of backwardness?

The concept of the advantage of backwardness is familiar in the economics of technological change (see for example Brezis, Krugman and Tsiddon, 1900) and potentially helpful in understanding late adoption. Some examples: First, France is relatively low in ICT rankings -- easily attributed to inflexible markets -- but was actually a pioneer in e-commerce and e-communication: Minitel was a text-only Internet predecessor introduced successfully in the late 1970s. The success as a forerunner is the explanation for France's late adoption of ICT. Obviously not the factor and product market regulations are to blame, as the introduction of Minitel was very successful. Second, the relative penetration grade of mobile phones is much higher in countries that never got very far with rolling out a non-mobile network.

As a corollary; the US might have had an advantage of backwardness relative to the forerunner France but might France now be again in the advantageous position to be backward? This in not inconceivable as there is some evidence that US firms over invested in ICT as they overestimated the market potential.

Observation Product market regulation to boost ICT has two dimension. First, markets ought to be competitive (possibly to a limited extent; we return to this issue in the next section). Second, deregulation of product market is not the same as no regulation; standardisation can be crucial for ICT type of technology.

This observation leads us to the question whether there are more types of regulation that are important for the well-functioning of an ICT market. This is the topic of the next section.

4.3 Market failures in use of ICT: the economics of information and potential market failures

This section provides a general discussion of the potential market failures related to trade and production of information.

The economics of information is summarised in a systematic way in Table 4.1.[23] The text from here to the table explains the table. Those readers interested in market failures and possible instruments to deal with the failures are advised to jump to Failure 1 immediately.

The first column describes the characteristic of information that possibly leads to a market failure, the next column provides an example for the demand and for the supply side of the market.

The first characteristic is increasing returns. That is, the production process is characterised by falling average costs. Much information is costly to develop but cheap to reproduce. Such a cost structure leads to monopolistic market structures. Think for example of the Microsoft operating system. This might lead to monopoly pricing. Several market forces mitigate this problem. For the operating system example, Microsoft competes with older versions of its own operating system.

Increasing returns on the demand side work similar. The utility of using an information good, can increase with the number of users, something obviously relevant for communication products like fax, telephone and the like. The interdependence between users can cause a lock-in into inefficient technology. Rapid technological change or coordination (by firms or the government) might overcome the problem.

Perfect information on the supply side might lead to price discrimination. This is not a market failure, but a distributional issue. Perfect information the demand side might cause some goods to be under supplied. Consider the following made up example. One can think of background tourist or health information on travel-agent's internet sites. As comparing prices between the different agents is so simple, no firm can capture sufficient additional revenue to make up for the cost of providing such information, despite the fact it would be welfare improving to supply the information (see Motta, 2004, Chapter 6 for an elaboration).

Complementarities between different informational goods might lead to under supply of goods as the different producers of, for example, hardware and content both might wait for a sufficient market size. The discussion for the demand side is analogous to increasing returns on the demand side.

Finally, non-excludability might lead to sub optimally low supply, quality or innovation. On the demand side: it is very difficult (read: costly) to find information sides free of ads. It can also be the case there would be a market for ads-free information, but that this has a public goods character (it would be good if it existed but nobody is willing to pay).

[23] This section draws upon Shapiro and Varian (1998) and Varian (2001).

Table 4.1 The economics of information: an overview

Characteristic	supply/demand (example)	Popular name	Potential (market) failure	Market forces mitigating the failure(s) or welfare-loss	Possible policy instruments
(I)	(II)	(III)	(IV)	(V)	(VI)
Increasing returns	supply (OS software)	'natural monopoly'	monopoly pricing	(i) competition to obtain monopoly (ii) competition with own products (iii) rapid technological change	tender/auction firm break up price-regulation
	demand (e-mail, fax)	'direct network effects'	lock-in inefficient technology	rapid technological change	standard-coordination
			monopoly pricing	competition to appropriate the locked in technology	open standards
Perfect information	supply (amazon, easyjet)	'personalisation' or 'customisation'	price discrimination bundling	contesting the separate markets (compete against yourselves)	regulation
	demand	'free riding'	no commitment to pay for quality		
Complementarities (between products)[a]	supply (DVD and content)		coordination failure	mergers and integration	standard setting
	demand (software and user-skills)	'switching-costs'	lock-in inefficient technology monopoly pricing		regulation
Non-excludability	supply (music or software)	'copying'	too low innovation or quality	lead time	patents and copyright
	demand (porn pop-ups)	'free riding'	no commitment to pay for quality	appropriation of information	copyright

[a] Increasing returns is a symmetric case of complementarities.

All of the following is to be read with the notion in mind that governments might fail too and that the market might provide solutions that are preferable over imperfect government regulation. Government s might fail for specific reasons in the ICT industry. The market is very dynamic and policy making is a relatively slow process. The ICT industry is a global industry, so the hands of governments might not reach far enough. The rapid developments in the industry might worsen the information problem that governments encounter in general.

Having said this, we address the market failures that can occur in the information economy (see column IV on market failures in Table 4.1). We discuss the separate failures, sketch the trade-offs and relevant considerations and suggest possible policy measures.[24]

Failure 1: Monopoly pricing

Monopolies tend to be formed by high fixed costs and low marginal costs. This gives rise to the following trade-off.

Trade off: A large market size for a firm leads to lower costs but a pure monopoly can lead to inefficiencies.

It is important to note that a relatively efficient outcome is characterised by high concentration and prices above marginal costs. High concentration saves on fixed costs and prices should equal average costs in order to recoup the fixed cost. For full efficiency marginal prices should equal marginal costs. This implies that either price discrimination should be possible of firms should be subsidised. It is thus apparent that price discrimination can be a virtue.

Potential instruments: Unless the market is characterised as a pure natural monopoly, the distortion due to above marginal cost price need not be high given that competition might still be intense. A natural monopoly may have important implications for competition policy.

The major challenge for policy is a distributional one. Policy 'needs' to prevent ‘too’ large profits and to prevent incumbent from retarding innovation. Still it is important to stress that competition to become the natural monopolised can alleviate the distributional problem by shifting a share of the rents to the consumers. Designing legal structures and monitoring agencies that do not frustrate market dynamics but that do meet the challenges sketched is not easy. The positive effect of a large market size indicates that openness of economies is an even greater virtue than before as it creates larger markets and, possibly, more competition.

Failure 2: Lock-in

Many information technologies are characterised by switching costs and network externalities (they also lead to failure 1, so the remarks made there apply here too).

Trade off: Solve the coordination problem to benefit from the network externalities and to avoid lock-in into an inferior technology.

[24] We discuss the potential market failures separately though in some cases they are amplifying each other, think of scale effect in both demand and supply.

To solve the coordination problem standardisation is an appropriate tool. The lock-in into inferior technologies does not seem to have prevailed often in practise especially as the ICT market is developing very rapidly still.

Potential policy instruments: Standard setting is a potential instrument. Whether or not policy to solve the coordination problem is needed depends on the market's ability provide standards.[25]

Failure 3: Non-excludability

Trade-off: Avoid serving a too small market (that reduces consumer surplus) and avoid at the same time the negative consequences of non-excludability with respect to supply and innovation.

There are two dimensions to this trade-off. First, non-excludability makes it impossible for consumers to commit to pay for quality.[26] However, non-excludability combined with non-rivalness (very low marginal costs) might make it welfare enhancing not to introduce excludability, as that would prevent serving consumers with a low willingness to pay. Second, innovation involves laying out a fixed, or actually a sunk cost. This cost is to be recouped somehow, which means that for some time the price of the produced good should be above the marginal cost. This requires some degree of excludability (patents and copyrights are the things to think of). However, information revelation is necessary to allow other 'stand on the shoulders of giants' and innovate further.

Potential policy instruments: The first problem can be minimised by having competition between a limited number of firms whom is given an exclusive right. Competition policy should take care of a sufficient number of firms in the market. Also facilitating or allowing for price discrimination in combination with creating excludability can partially overcome the undersupply of quality.[27] The second, innovation related, problem can be solved by patents (or copyrights). They can take care of the intellectual property rights and give rise to a monopoly for the duration of the patent. For the designer of patent rules the question is how long and how broad the patent should be; a difficult

[25] A holder of the dominant technology still might have an incentive to introduce a shared standard, as this might raise the total market size so substantial that it is still more profitable although it has to be shared by more standards.

[26] DeLong and Froomkin (2000) discuss the example of broadcasting. In the initial days of television, with only three channels and no property rights (in the US anyone with an antenna got the products for free; in The Netherlands the government intervened by charging a price for having a receiver) producers introduced advertising to recoup their costs and lowered quality to a sub-optimal level (according to DeLong and Froomkin). The intuition for the low quality is that if only few people have a high willingness to pay for quality, but cannot commit to pay, and a lot of people watch anything that is broadcasted, the goal of selling advertisements gives a low equilibrium quality.

[27] Price discrimination runs into the problem that firms compete with themselves, such that an optimal outcome is not guaranteed. An example: think of books. Often a hard-cover and a soft-cover are produced. If firms consider producing a hard-cover they need to take into account that they can only limit price to the soft cover (price-quality ratio). It is not trivial that the high-quality good is able to survive on the market (without lowering the quality of the soft-cover for example)

issue.[28] Without pretending to be exhaustive, we point at two disadvantages of the patenting technology. First, the patent prevents others from copying the product but also prevents others from freely standing on the shoulders of the innovator by using the ideas embedded in the good. Second, the patent design is unlikely to be optimal in diffusing the use of the good (the famous example here is that of anti-HIV medicines for less-developed countries).[29] An additional argument against patents is that most time seems to be spent on nuisance patenting, in order to be able to exchange patents with other firms doing the same, or to collect licensing fees, instead of actually protecting property (Cohen, Nelson and Walsh, 2000). This is not likely efficient, as firms and patent offices spend resources for redistributing rents.

Failure 4: Price discrimination[30]

ICT allows for marketing strategies that were unthinkable in the past. The internet in principle allows for personalised offers and prices (which is close to the theoretical benchmark of first-degree price-discrimination).

Trade-off: Serving a larger part of the consumers and avoiding the monopolist to capture all rents.

Note, first of all that first degree price discrimination is efficient (under some mild conditions).[31] The whole potential surplus under the demand curve is realised. However, all rents accrue to the producers, so there might be a distributional 'problem'. This problem is severe once there is a (natural) monopoly. If you add competition (which is likely relevant in the ICT market) the distributional problem is mitigated substantially.

Potential policy instruments: In general policymakers judge price discrimination as a sign of abuse of market power. In the ICT context, however, this judgment might be too harsh as there are market forces that limit the abuse of the power and there are welfare gains due to serving a larger part of the consumers. Price regulation is a possible instrument.

[28] For an extensive discussion on patents, see Cornet (2002).

[29] Boldrin and Levine (2002) show that having no intellectual property rights is superior to property rights (patents). The intuition is that innovators can recoup some of the sunk costs simply by selling the first goods for a high price to those who highly value the good's use or those who want to copy the good to sell it etc. Without dwelling on this, a rational innovator foresees this and only undertakes potentially profitable innovation ideas. This gives a positive excess-profit to the innovator without creating a long term monopoly. Somewhat paradoxically maybe, a better copying technology raises the return for the initial innovator.

[30] Bundling is a special form of price discrimination where more than one good is concerned, see Varian (2001) for an exposition.

[31] We think of a (natural) monopolist facing a demand curve that consists of different consumers demanding a single good that they value differently.

Having said that regulation is possibly hampering the adoption of ICT and at the same time appropriate regulation might be necessary for a healthy ICT market, the question is what the empirics have to say about regulation and productivity.

4.4 Evaluating the role of regulation in productivity growth

4.4.1 What does the empirical literature tell?

Two recent studies attempt to address the question empirically why Europe is lagging behind the US in ICT usage (see Bartelsman and Hinloopen, 2002 and Bartelsman et al., 2003). Both studies emphasise that the lack of competitive pressure on the product markets and restrictive employment protection on the labour market are important causes for retarding incentives to invest in ICT by firms in the EU. In order to weed out inefficient incumbents and attract new innovative firms, the selection process among firms must not be hampered by too many product market regulations. Additionally, hiring and firing costs diminish the distribution of output growth rates of firms. The results suggest that certain institutional and regulatory procedures reduce the amount of market experimentation by firms. In this respect, although there is a similar degree of firm turnover in Europe as in the US, the number of exits and the stronger post-entry growth of entrants in the US indicate a different degree of market experimentation. This could lead to a faster process of the adoption of ICT.

5 Conclusion: designing institutions for the ‘new economy’

Before discussing the institutional design, we have to put weight on the adoption and use of ICT versus the invention and production of ICT. As discussed in section 2, ICT can basically have impact on the economy in three ways. The production of ICT itself can be a valuable activity, the use of the improved input (ICT) can bring gains though lower prices and ICT can have spillover effects and (network) externalities. The importance of the latter effect is still highly uncertain. It is however related to ICT use. So we can distinguish use and production. Empirical assessment suggest that the welfare effects are for a large part related to ICT use (Bayoumi and Haacker, 2002). Their work can be summarised as follows: “Social saving gains in many euro-area members are currently relatively small. The social saving benefits are only about 50 percent of the United States value, in terms of GDP, for Germany, Austria, and France, and about a third for Italy and Greece, compared with 70 percent or more for other Europeans countries such as Sweden, Denmark, the Netherlands, Ireland, Finland, and the United Kingdom” (Bayoumi and Haacker, 2002, p. 25-26). Thus, some countries with a small ICT-producing sector -- the Netherlands’ and Denmark’s GDP share is close to 1% only -- benefited very much from the revolution. Hence without making ‘it’, just exploiting the possibilities to use ‘it’ gives good prospects for welfare! In the remainder we discuss what this implies for policy.

Suppose Europe decides to aim at creating an ICT production cluster despite the fact that attracting ICT producers is probably not the most sensible strategy (see Section 3.1). Are Europe's institutions designed such that they create a competitive and welfare-enhancing market for ICT producers? The economics of information were summarised in a systematic way in the previous section. The right institutions to deal with this complex set of issues is not very clear but a laissez-faire setting is not always optimal. However, governments might fail too and that the market might provide solutions that are preferable over imperfect government regulation. Governments might fail for specific reasons in the ICT industry. The market is very dynamic and policy making is a relatively slow process. The ICT industry is a global industry, so the hands of governments might not reach far enough. The rapid developments in the industry might worsen the information problem that governments encounter in general.

Thus we argue that a more sensible strategy is to remove obstacles for ICT adoption. For Europe technology adoption is important. First, because European adoption still seems to lag that of the US in important areas and second, the US is the most important shifter of the technology frontier. The EU can adopt the technology in principle as long as one has worldwide access to these products. First, for technology adoption open international markets are important. Access is probably enhanced, for example, by liberalising services trade. Second, the incentive to adopt best practise technology should be healthy. If the goods are tradable European countries/companies will adopt these new technologies unless the incentives to do so are lacking. Regulatory and structural impediments on product, labour and capital markets could indeed be an obstacle. So organising competition and flexibility on these markets is an important precondition. Though this is a "catch-all" policy advice it is important (with "catch-all" we mean that you would get the same advice if you asked for lower unemployment, higher growth etc). Another important factor for technology adoption is the availability of sufficient skill (see Benhabib and Spiegel, 1994, for evidence).

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Appendix I Classification of industries

Definition of the ICT producing sector

In the traditional statistics, the ICT producing sector was not defined as a separate industry. Therefore, OECD decided to provide a set of statistics drawn from official sources that measure the output of the ICT producing sector in a consistent manner and that sticks to a common international definition.[32] The agreed definition of the ICT producing sector was based on the following principles:

- ICT producing manufacturing industries must be intended to fulfil the function of information processing and communication transmission and display. Or, it must use electronic processing to detect, measure and/or record physical phenomena or to control a physical process.
- ICT producing services industries must be intended to enable the function of information processing and communication by electronic means

The table presents the industries that the OECD classified as ICT producing industries based on the industrial classes of the International Standard Industrial Classification (ISIC).

OECD definition of the ICT producing sector

Industry	ISIC	Description
Manufacturing	3000	Office, accounting and computing machinery
	3130	Insulated wire and cable
	3210	Electronic valves and tubes and other electronic components
	3220	Television and radio transmitters

[32] OECD, 2000, Measuring the ICT Sector.

OECD definition of the ICT producing sector

	3230	Television and radio receivers, sound/video/recording apparatus
	3312	Instruments and appliances for measuring, checking, testing
	3313	Industrial process control equipment
Services	5150	Wholesaling of(ICT) machinery, equipment and supplies
	7123	Renting of office machinery and equipment
	6420	Telecommunications
	72	Computer and related activities

Although, thereafter, National Statistics attempted to base the ICT producing sector on this common definition, the international comparability has still been hindered by different classification schemes. In many countries, it is not possible to distinguish the wholesale of machinery and equipment, and the renting of office machinery and equipment from the data. Furthermore, telecommunication mostly includes postal services. Another problem of demarcation of industries is that the ICT-sector itself produces more than only ICT-products. Non-ICT-industries, in turn, can also produce ICT products. Information is lacking to adjust for these demarcation problems.

Composition of ICT using and non ICT using industries

	ICT using industries	Non-ICT using industries
Manufacturing	18 Apparel	15-16 Food products
	22 Printing & Publishing	17 Textiles
	29 Machinery	19 Leather
	31-31.3 Electrical machinery	20 Wood products
	33-33.1 Watches & instruments	21 Paper products
	35.1 Ships	23 Petroleum & coke
	35.3 Aircraft	24 Chemicals
	35.2+35.9 Railroad and other	25 Rubber and plastics
	36-37 Misc. manufacturing	26 Stone, clay & glass
		27 Basic metals
		28 Fabricated metal products
		34 Motor vehicles
Services	51 Wholesale trade	50 Repairs
	52 Retail trade	55 Hotels & restaurants
	65 Banks	60-63 Transportation
	66 Insurance	70 Real estate
	67 Securities trade	74.9 Other business services
	71 Renting of machinery	75 Government
	73 R&D	80 Education
	74.1-74.3 Professional services	85 Heath
		90-93 Personal & social services
Other sectors		01-05 Agriculture
		10-14 Mining
		40-41 Utilities

Appendix II Growth accounting

Here, we assume that at the level of industry (=*i*) there exists a (value added[33]) production function relating output to labour, ICT capital, other capital, and time:

$$Y_t = F_y(L, K_c, K_o, t)$$

where *Y* is output, *L* denotes labour input, *Kc* is capital input and *Ko* is other capital input. Taking logarithmics, the production function can be written into the following formula:

$$d \ln y_i = \alpha_i \, d \ln l_i + \beta_{o,i} \, d \ln k_{o,i} + \beta_{c,i} \, d \ln k_{c,i} + d \ln TFP_i$$

The elasticity of output with respect to labour is equal to the share of labour cost in the value of total output. Given the assumption of constant returns to scale imply that the elasticities of the input factors add up to one. So the sum of the shares of other capital and ICT capital is assumed to be equal to (1- α).

Equation (1) can be rewritten to obtain a decomposition of labour productivity growth into the contribution of capital deepening and TFP-growth, either in ICT-sector or in ICT-intensive industries

$$d \ln y_i - d \ln l_i = \beta_{o,i} [d \ln k_{o,i} - d \ln l_i] + \beta_{c,i} [d \ln k_{c,i} - d \ln l_i] + d \ln TFP_i$$

TFP-growth is residual, and cannot be measured directly. It is a catch-all term reflecting a bunch of developments like organisational changes, scale effects, measurement issues, the effect of new products etc. Hence, the interpretation of TFP is not straightforward. Higher TFP-growth could be related to ICT, but TFP growth may also come from developments in the economy that are independent of ICT.

Caveats of growth accounting

Despite its transparency and simplicity, the growth accounting framework includes some caveats that should be borne in mind. It assumes constant returns to scale, but positive and diminishing returns with respect to each input: marginal products of each input approach zero as

[33] As labour productivity growth is defined as value added per hour worked, intermediate inputs are not seen as sources for productivity growth.

each input goes to infinity. TFP can be seen as a proxy for (Hicks-neutral) technology progress, i.e. the Solow residual. Growth accounting encounters also specific difficulties related to the ICT 'revolution'.

First, the dramatic fall in registered computer prices is to be corrected for quality changes (by means of calculating so-called hedonic prices) leading to an even more rapid fall in the cost of computing power. The question is, however, whether (other or) past innovations should not have been corrected for quality changes too?

Second, related to the first caveat is that once hedonic prices are used for computers, the contribution of computers is likely overvalued unless hedonic prices are used for other types of capital too.

Third, we argued that ICT is a GPT. One characteristic is that it is applicable throughout the economy. It is not hard to imagine that the ICT revolution made existing capital stock more rapidly obsolete. If this increase in depreciation of other production factors is ignored the growth rate (and the contribution of ICT) is underestimated.[34]

Fourth, and also related to the GPT character of ICT, is the notion that to implement ICT in the organisation a lot of investment that is not registered as such is done; think of all workers learning to work with new software. This leads to a temporary underestimation of TFP and a long lag in the resurgence of growth.

There are more caveats. If the neoclassical assumptions fail to hold, TFP contains the effect of externalities, non-constant returns to scale and mark-ups. Additionally, as TFP growth is a residual variable, it also reflects the impact of omitted variables and, measurement problems.

Moreover, the growth accounting framework provides information on what happens to productivity growth immediately, but it provides no explanation why something happened. In other words, the growth accounting framework presents the proximate sources and not the ultimate sources of productivity growth. To address the latter sources one needs another sort of analyses such as firm-level studies or case studies. These qualifications hold for all growth accounting exercises.

[34] For a calibration exercise to assess the size of the obsolescence effect see Howitt (1998).