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Information and Communication Technologies, Market Rigidities and Growth: Implications for EU Policies

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

There is a growing consensus in the public debate and among policy makers in particular, in support of the idea that market rigidities in the EU may explain why Information and Communication Technologies (ICT) still do not have any visible impact on growth performance in most EU countries. The objective of this paper is to check whether this view is backed by empirical evidence in a sample of EU countries, Japan and the US during the period 1980-2004. In order to do so, we examine two separate, albeit necessarily linked, questions – first, what is the influence of market rigidities on ICT investment and second, how do market rigidities influence the contribution of ICT investment to GDP? These issues are especially relevant from a policy perspective as ICT has been shown to be at the core of the growing economic divergence between the US and the EU since the mid 1990s. The evidence provided here indeed shows that the EU economy badly needs more reforms, along the lines of those proposed by the renewed Lisbon strategy, in order to make ICT investments effective and, by the same token, to increase the EU's growth potential.

The macroeconomic evidence on the role played by market rigidities in the diffusion of new technologies is still scant. On the one hand, macroeconomic studies have essentially considered the growth and productivity impact of ICT diffusion, devoting much (needed) effort to estimating ICT-capital stock and its impact on productivity and growth, see the papers by van Ark and Inklaar (2005) and Jorgenson et al. (2005). On the other hand, this literature has left practically untouched the issue of the role played by structural features of the economy and framework conditions (including institutions) which could possibly influence the adoption and expected impact of ICT on economic performance. Important exceptions to general trend in the literature are the recent papers by Gust and Marquez (2004) and Conway et al. (2006). These authors do, indeed, find conclusive evidence regarding the negative influence of labour and product market regulations on ICT investment using a similar approach to the one used here. In this paper, we move a step further, by also considering the link between market rigidities and the contribution of ICT to GDP growth. We investigate these issues by testing econometrically the determinants of ICT investment and ICT contribution to growth. The latter is derived from a growth accounting exercise using results taken from the EU KLEMS database.

Our research provides a number of important results. First we show that the persisting lower ICT investment intensity in the EU economy as compared to the US since the early 1980s cannot be attributed to lower dynamism in overall capital investment in the EU. The US economy, in particular, seems to have benefited from a first-mover advantage, given that it started to invest in ICT much earlier and has continued to do so to a greater extent (as measured in percentage of its GDP) than the EU and Japan. Consequently, the US economy was also able to reap greater benefits faster from ICT investment than EU countries. Second, while the EU also experienced a rise in the contribution of ICT to value-added growth after the mid-1990s, this contribution seems to have been much more limited. Also, the rise in the ICT contribution to growth has been broadly limited to relatively small EU economies such as Denmark, Luxembourg, Finland or Sweden. Third, the different experiences of the US and the EU in terms of ICT contribution to growth do not appear to be fully explained by differences in specialization in ICT-producing and ICT-using industries.

This evidence tends to suggest that the US economy was able to reap the benefits from ICT investment faster and to a greater extent than EU countries with similar specialization in ICT-

producing and ICT-using industries. Therefore, other structural factors must explain why ICT diffusion is still slow and its relative economic benefits are still hardly perceptible in the EU economy, at least by US standards. Our results show that greater market rigidities in the EU constitute one of the main culprits for this state of affairs. Countries where market regulations, in particular market regulations, were particularly burdensome, have also invested less in ICT and benefited less from ICT investment in terms of GDP growth.

We have also considered the manufacturing and service sectors separately, given that existing evidence suggests that the US service sectors have largely contributed to the US growth resurgence since the mid 1990s, and that ICT investment in these sectors has also influenced these evolutions. A distinctive feature of the US service sectors as compared to those of the EU is its much lighter regulatory burden and its high level of integration. In the EU, we find that market regulation has tended to deter the positive impact of ICT on growth rather significantly in the service sectors and more so than in the manufacturing industry.

A number of policy implications can be derived from these results. First, they provide evidence for the central role played by labour market rigidities in influencing ICT investment and ICT contribution to growth. This suggests that labour markets reform may play a key role in the modernization of the EU economy and in boosting EU economic growth. These reforms should be seen as part of the essential conditions for increasing EU growth potential via technology diffusion. Second, our results suggest that the re-organization of production and the skills-improvement called for by ICT diffusion could help to explain why the EU economy is still slow to invest in ICT. The explanation put forward in this paper is that market rigidities, and labour market rigidities in particular, make these changes too costly. It follows that, market-oriented reforms, like those proposed by the renewed Lisbon strategy, cannot be considered as stand-alone policies and that radical changes at the firm/business level and reforms to improve labour skills are called for in order to promote technological change in the EU economy. Third, our results concerning the influence of past ICT investment suggest that the EU possibly lags behind in terms of ICT benefits because it started to invest later than the US. However, we show that even in those EU countries where ICT investment has caught up with US levels since the mid-1990s, the contribution of ICT investment to growth has taken time to materialize. It is therefore important to bear in mind that, even if greater product and factors market flexibility in Europe is a pre-condition for increased growth potential, in particular via ICT investment, these benefits may take time to bear fruit. Fourth, we find that lower market regulation, especially in the case of the service sector, promotes a larger contribution of ICT to GDP growth. The latter suggests that lower overall regulation in services can act as an important lever for increasing ICT contribution to growth, given the size of the service sector in total EU economic activity.

INTRODUCTION

"Conventional Wisdom has it that Europe and Japan have been slow to invest in IT, partly thanks to rigidities in labour and products markets that reduce the return on such investment." *The Economist, 23 October 2003*

"The structural characteristics of the US economy – a more flexible labour market, a higher degree of competition in product markets and lower barriers to entry for new firms - were more conducive to exploiting the opportunities provided by new Technologies, than the more rigid and less competitive structures of Europe." *Jean-Claude Trichet, President of the European Central Bank, speech given for the Jean Monnet Lecture of the Lisbon Council's Board of Economists, Brussels, 4 June 2007.*

As suggested by the quotes above, there is a growing consensus in public debate and among policy makers in particular, in support of the idea that market rigidities in the EU may explain why Information and Communication Technologies (ICT) still have no visible impact on growth performance in most EU countries. The objective of this paper is to check whether this view is backed by empirical evidence in a sample of EU countries, Japan and the US during the period 1980-2004. In order to do so, we examined two separate, albeit necessarily linked, questions. First, what is the influence of market rigidities on ICT investment? Second, how do market rigidities influence the contribution of ICT investment to GDP? In both cases, we find that market rigidities have a negative and significant influence. These rigidities are represented by a number of indicators reflecting barriers to business creation and the degree of market regulation in product, service, labour and capital markets, mainly taken from the Fraser database on economic freedom.[1] The data used is taken from the recently released EUKLEMS database provided by the Groningen Growth and Development Centre (GGDC).[2]

More specifically, in the European case, our results provide new evidence regarding the potential benefits of structural reforms undertaken under the Lisbon strategy. Indeed, this strategy puts special emphasis on the potential role of ICT can play in meeting the challenges of boosting growth, competitiveness and cohesion throughout the EU. In particular, the i2010 Communication states that *"in launching the partnership for growth and jobs as a new start for the Lisbon strategy, the 2005 Spring European Council called knowledge and innovation the engines of sustainable growth (…). Information and communication technologies are seen*

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1 See http://www.fraserinstitute.ca/. Alternatively, OECD and World Bank indicators on market regulation are also used which tend to support the results obtained in the paper.

2 This database is available at the EU KLEMS website, March 2007 release, **http://www.euklems.net"**.

a powerful driver of growth and employment." - see EC(2005). Indeed, the differential between the US and EU productivity (and overall economic) growth rate has been widening markedly since the mid 1990s. Among other elements, the still low impact of ICT on EU growth and productivity has been recognized as one of the key elements of this state of affairs, see, for instance, Carone et al. (2006). The data on ICT investment and ICT contribution to GDP growth recently released by the Groningen Growth & Development Centre (GGDC) suggest that the combined contribution of ICT to the total output growth of the EU economy was 0.55 percentage points between 1995 and 2004. This contribution was approximately double in the US during the same period, with a 1.1 percentage point contribution, explaining to a large extent the differing growth performance since 1995 between the two areas.[3] The recent assessment made by the European Commission of the i2010 objectives acknowledges that Europe is making sustained progress in ICT diffusion. However, this diffusion is far from fulfilling its potential in terms of productivity and growth performance, see EC (2007). Although ICT adoption and productivity impact has been especially vigorous in certain Member States (e.g. Ireland, and Finland), this effect has still not materialized in most EU countries, see also van Ark and Inklaar (2005).

There is a great need, especially for EU policy making, to better understand how macroeconomic framework conditions and, in particular product and factor market settings, influence technology diffusion and economic growth. This is especially true when considering the potential economic benefits of the EU structural-reform process in the context of the Lisbon strategy. The main argument of the present paper is that structural reforms, technological change through ICT diffusion, and economic growth are strongly linked. Structural reforms must therefore be implemented both to increase EU growth potential *and, in addition*, to favor greater diffusion of ICT in the EU economy. Our starting point is that ICT, being a general purpose technology with widespread impact on economic structures and production processes, call for structural changes favoring both labour and capital market flexibility in order to have a visible economic impact. All in all, *creative destruction* must be facilitated in order to favor the emergence of innovative forms of economic activities and to

[3] Figures based on EU KLEMS database and authors' computations, EU figure is a weighted average value of the contribution of ICT capital services to total output using GDP in purchasing power standards as weight. The EU countries considered are France, Italy, Germany, Luxembourg, Belgium, the Netherlands, Spain, Sweden, Finland, the UK and Denmark.

facilitate the diffusion of new technologies.[4] These changes are at least as important as ICT investments themselves and condition their related economic benefits. Consequently, the structural nature of ICT's low impact on EU growth and productivity has direct consequences in terms of competitiveness of the EU economy *vis à vis* the rest of the world, in particular the US economy. Our results show that the structural problem of the EU economy tends to slow-down the capacity of the EU to adapt to fast changing technologies and a more (globally) competitive environment.

From a research perspective, the macroeconomic evidence on the role played by market rigidities for new technologies diffusion is still scant. On the one hand, macroeconomic studies have essentially considered the growth and productivity impact of ICT diffusion, devoting much (needed) effort to estimating ICT-capital stock and its impact on productivity and growth (see, in particular, the papers by Jorgenson (2005) and Jorgenson et al. (2005)). On the other hand, this literature has left practically untouched the issue of the role played by structural features of the economy and framework conditions (including institutions) which could possibly influence the adoption and expected impact of ICT on economic development. However, recent papers by Gust and Marquez (2004) and Conway et al. (2006) represent an important exception to the general trend in the literature. These authors do, indeed, find conclusive evidence regarding the negative influence of market regulations on ICT investment using a similar approach to the one used here. However, what really matters from an economic viewpoint is to analyse to what extent market rigidities do have a cost in terms of economic growth via lower ICT investment. In the present paper, we move a step further than the aforementioned authors, by also considering the link between market rigidities and the contribution of ICT to GDP growth.

The rest of the paper is organized as follows. Section 1 provides some theoretical arguments and briefly reviews the existing theoretical literature on new technology diffusion and growth. Section 2 provides a number of stylized facts, while Section 3 provides econometric evidence based on a sample of EU countries, and the US and Japan, on the link between ICT

[4] The concept of *Creative destruction* was introduced by Joseph Schumpeter who described the process of transformation that accompanies radical innovation and call for radical changes, and thus re-allocation of resources from old to emerging economic activities that call for new businesses' organisation, new product and services, new production organization processes, new markets, etc.

investment, ICT-growth impact and market rigidities. Section 4 provides a summary of our results and policy implications.

1. THE LINK BETWEEN MARKET RIGIDITIES, ICT ADOPTION AND ICT-GROWTH IMPACT: MAIN THEORETICAL ARGUMENTS.

The idea that market rigidities hamper GDP growth has been well documented in the macroeconomic literature, see Babetskii and Campos (2007) for a recent review. Much less is known, however, regarding the link between market rigidities and new technologies adoption. The existence of such link has been pervasive in the theoretical literature on growth and General Purpose Technologies (GPTs), however, although much less documented empirically.[5] As a consequence, still little is known at the empirical level regarding the influence of market rigidities on new technologies diffusion in general and on ICT diffusion in particular.

The central idea in literature on GPT follows the traditional Schumpeterian arguments: markets need to be more flexible, especially during periods of rapid technological changes where firms and sectors of activities must adopt and adapt new technologies to their specific requirements with potentially substantial, although not necessarily immediate, efficiency gains, see Aghion and Howitt (1992). All in all *creative destruction* could be made easier if markets are flexible enough in order to re-allocate productive resources from traditional to new sectors of activities and from the use of old to the use of new technologies. The re-allocation of resources is particularly important in the case of GPTs such as ICT given that the widespread use of ICT is likely to give rise to a growing and self-reinforcing number of applications with direct incidence on economic activity both in terms of overall economic growth but also in terms of economic efficiency. Although these characteristics were shared by previous technological revolutions, they are often considered as strongly exacerbated in the case of ICT, see Varian et al. (2004). At the same time, ICT diffusion also involves changes in the production process and the organization of firms that do not necessarily translate into visible sectoral changes but, nonetheless, may have a direct impact on economic growth, see, in particular, Cohen et al. (2004).[6]

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5 See, in particular, Helpman (1998) for a review of the theoretical literature on General Purpose Technologies.

6 The arguments exposed above have been illustrated empirically in a number of studies in the organization/business literature. For instance, there is a wide array of existing studies showing in particular that aspects such as skills, changes in business organization and innovative-friendly environment are all important components for promoting an effective impact of ICT adoption on economic efficiency, see for instance, Bresnahanm et al. (2002), Bertschek and Kaiser (2004) and Aubert et al. (2006).

The process of creative destruction via technological change has been investigated in particular in the case of labour market. Accordingly, new technologies may especially affect the low-skilled workers and the low-skilled intensive industries. The crucial issue here is to translate new technology diffusion into jobs creation. However, these changes are likely to be impaired by deficiencies in labour market, see OECD (1998). A high level of labour market regulations tend to slows down changes in managerial practice while business needs to adapt to ICT-led technological changes. The example mentioned by Bloom et al. (2007) illustrates this point quite well. These authors put forward the case of the US banking industry which has rapidly adopted ICT through ATMs and the use of computers and software helping to improve services to customers. At the same time, traditional functions like tellers and bank managers have been replaced by personal bankers able to gather information and to sell directly to clients. Old banking functions were therefore quickly replaced by new ones and this required different skills. By contrast, ICT diffusion seems to have started later and to have been much slower in Europe according to Bloom et al. (2007). An argument put forward by these authors is that labour market regulations in Europe made the cost of re-organising businesses and replacing old workers functions (and skills) by new ones much more costly compared to the US.

The negative impact of labour market regulation on new technologies adoption can also be magnified via specialization effects and international trade. This idea is developed theoretically by Saint-Paul (1997 and 2002) who posits that countries with a rigid labour market will tend to produce low or medium-tech goods. The reasoning behind is that, in order to avoid paying the firing cost, the country with a rigid labour market will tend to produce goods at a late stage of their product life cycle. Innovation patterns will thus tend to differ between countries with high and low firing costs. Saint-Paul uses this argument to explain why the US spending a lot in R&D in ICT sectors and Europe does so in more traditional sectors such as the car industry. Saint-Paul's arguments are also valid to the case of ICT adoption where the US are more likely to innovate and build up strong competitive advantage because of its higher capacity to re-organize its productive activity and then to build up a competitive advantage in emerging high-tech sectors such as ICT.

Following a similar reasoning, Alesina and Zeira (2006) argue that in order to explain differences in new technology adoption in relation to labour market regulation (between the US and the EU) one must look at the impact of employment regulation on wages (and

therefore, labour cost). These authors assume that technological progress is represented by the replacement of labour by machines. In their view, with rigid labour market regulations, Europe does penalize low-skill labour employment and reduce wages' disparities. On the contrary, with low labour market regulation (and low-labour costs for the unskilled) the US economy promotes employment at the lower end of the wages scale. By the same token, the most skilled workers do gain relatively higher wages. This latter group of workers is also the most productive one and provides the main input for the development of hi-tech sectors. The influence of labour market regulation in Europe, according to these authors, therefore penalizes the employment of the low-skilled and also the development of hi-tech/new sectors of activity such as ICT and biotechnologies.

More generally, two possible scenarios can be envisaged theoretically when considering the link between ICT and labour market regulation. First, following the above arguments, labour market rigidities could promote the substitution of labour by capital in the production process. One could therefore observe that countries with more binding labour regulations tend to invest more in ICT in order to lower the burden related to this high regulation. This scenario in particular assumes that ICT technologies are labour-saving technologies. The second scenario one could imagine is that, because ICT diffusion requires the re-organization of production process, firms located in highly regulated countries would refrain from investing more in ICT if these rigidities make the aforementioned changes too costly. Considering empirically the link between labour market regulation and ICT investment should then allow us to say something about the importance of business-level restructuring for ICT diffusion and on the degree of substitution between ICT and labour.

Access to capital appears also prominently in terms of potential barriers to fast technology diffusion. Generally speaking, rigidities in capital markets, represented, for instance, by strong financial regulations, may tend to hamper risk-taking behaviour by companies. On the contrary, less rigid and well-functioning financial markets may allow to (re-)allocate capital resources to fast-growing sectors of activities more easily. Those sectors, in turn, are also likely to be sectors where technological change manifests itself most prominently, see, for instance, Lööf (2004). One direct implication of capital market rigidities is that they may limit access to capital to undertake ICT investment, especially for those firms which require external financing to realize those investments such as SMEs. A number of authors have indeed suggested that one of the reasons for the European lag in ICT investment compared to

the US lies in the role played by the stock market and the higher capacity of the US financial markets to attract investors ready to invest in high-return investment projects, see Singh et al. (2001). These arguments have been largely tempered by the 2000s IT bubble burst, however.Pástor and Veronesi (2006), in particular, have linked the collapse of many dot.com share values to the uncertainty about the return from new technologies and new-technologies related companies. In the long run though, well-developed and flexible capital markets tend to be positively associated with ICT development, see in particular, Amo (2006), for recent evidence on this topic.

Finally the link between competition in markets for product and services and ICT diffusion has been put forward in order to explain the widening productivity gap between the US and the EU, see Denis et al. (2005). Generally speaking, by favoring greater competition and greater integration of EU markets, the EU may favor faster adoption of new technologies via economies of scale such that the benefit related to ICT adoption spill over to consumers. These arguments are especially relevant in the case of service sector which is lagging behind and where there exist great potentialities in relation to ICT use, especially when comparing the EU with the US case. ICT use in the service sector has contributed to substantial productivity gains in the US, in the banking sector as mentioned before, but also in the retail sectors. These sectors are also ICT-intensive sectors and have been shown to play a key role in the US growth experience since the mid-1990s, see for instance, van Ark and Inklaar (2005). One possible explanation for the growing gap between ICT-related productivity gains between the US and the EU could then be the still high segmentation of EU markets as compared with those of the US, and also the level of regulation in service activities in the EU.

All in all, the elements discussed above refer to the need to make markets, including production factors, product and service markets, more flexible, in order to facilitate new technology adoption and, by the same token, economic growth. The next Section shows indeed a number of stylized facts that tend to support these views, especially when comparing the EU and US economies.

2. MARKET RIGIDITIES, ICT INVESTMENT AND GROWTH: SOME STYLIZED FACTS.

This section provides descriptive statistics on the importance of ICT investment in a sample of EU countries, US and Japan and its relation to differences in economic structures, including industrial specialization and market rigidities. We first start by describing the ICT investment pattern of these countries and its relation to differences in economic structures. We then turn to the link between ICT investment and GDP growth. In the sequel, we will consider whether market rigidities allow one to explain differences in ICT investment and ICT contribution to growth.

2.1. ICT investment and economic structures

The data used here covers the period 1980-2004 for the EU15 countries, the US and Japan. We first consider the evidence regarding ICT investment, employment and ICT impact on value-added growth. For ICT investment, no data was available for Japan. For more details about the data, see Appendix 1.

Table 1 and Figures 1a-1b provide a first idea regarding differences in the relative importance of ICT investment in the aforementioned countries.

Table 1: Investment in ICT, specialization in ICT industries and specialization in ICT-intensive industries[§]

	EU15*			***US***			***Japan***		
	1980	**1995**	**2004**	**1980**	**1995**	**2004**	**1980**	**1995**	**2004**
ICT investment % of GDP	2.5%	3.4%	3.4%	4.3%	5.8%	5.8%	n/a	n/a	n/a
*Non-ICT investment in % of GDP***	24.0%	28.7%	29.8%	24.0%	24.3%	25.0%	n/a	n/a	n/a
ICT-producing industries as % of total employment	3.8%	3.8%	4.0%	4.8%	4.3%	3.6%	4.0%	5.0%	5.4%
ICT-intensive use industries as % of total employment	24.60%	28.01%	28.86%	27.49%	29.85%	30.49%	16.55%	18.42%	18.48%

** Weighted average (weight given by countries' GDP in PPP). Excludes Greece, Portugal and Ireland.*
Source: EU KLEMS and authors' computations
*** concerns non-ICT Equipment investment, excluding*
[&] ICT-intensive industries refer to sectors of activity with a relatively high use of ICT. See Appendix 2 for a definition and sources of this sectors classification.

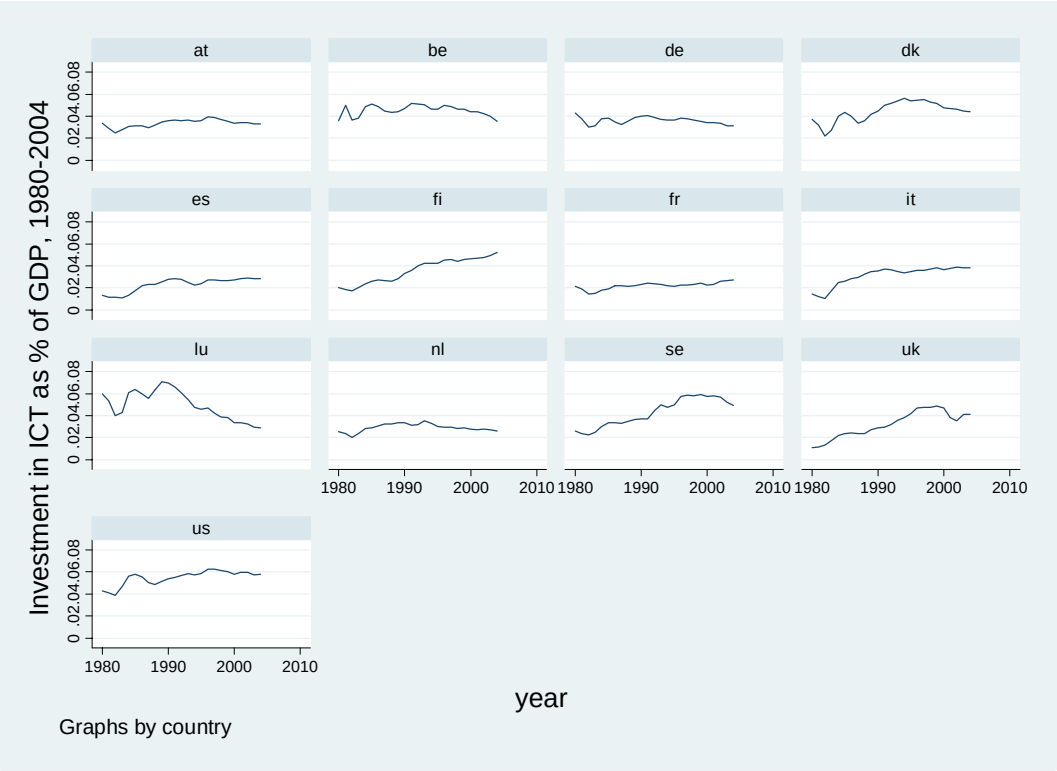
Figures 1a-b in turn plot the share (in percentage) of ICT in GDP.

Overall, investment in ICT has tended to increase steadily in the US since the early 1980s going from 4.3% of GDP to 5.8% between 1995 and 2004. Detailed annual figures plotted in Figures 1a-1b show, however, a slightly decreasing ICT investment after 2000 in the US.[7] This latter decrease, in particular, can be related to the economic downturn following the year 2001 and the burst of the IT bubble mentioned earlier. In the EU, the evolution has been rather similar to that in the US but with a persistent gap in the percentage of GDP invested in ICT as shown by Figure 1b. ICT investment measured in percentage of GDP has risen from 2.5% in 1980 to 3.4% in 1995 and stabilized around that level thereafter. Detailed figures reported in Figure 1a shows that, in many EU countries, while the period 1995-2000 has, like in the US, witnessed a peak in ICT investment in the EU, the subsequent downturn has been also relatively less marked than in the US. Overall, however, the striking feature in the EU evolution described in both Table1 and Figure 1b, is clearly the persistent gap in ICT investment in percentage of GDP, independently of the year considered.

[7] The Appendix provides more details about the composition of ICT investment following the definition provided by EU KLEMS, see EU KLEMS (2007).

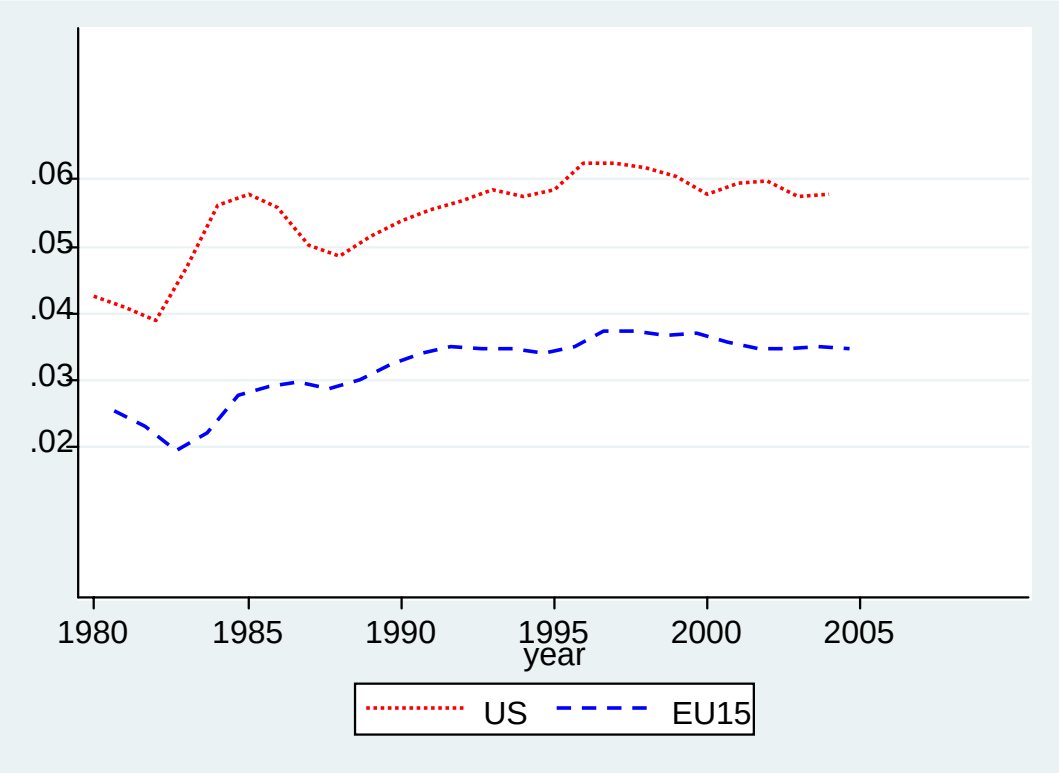
Figure 1a shows that the percentage of ICT investment measured in terms of GDP for the US has been consistently higher than that of most EU countries. In some countries, including Denmark, the Netherlands, the United Kingdom, Sweden, Finland and, to some extent, Spain, the percentage of ICT investment in total GDP has tended to follow an upward trend. Overall, however, the only countries that display percentage of ICT investment comparable to the US are relatively small countries such as Belgium, Denmark and Luxembourg. In addition, these countries have also started to invest in ICT at US levels rather later. It follows, therefore, that the experience of these countries does not have great influence of the overall EU evolutions depicted in Figure 1b.

Figure 1a: Investment in ICT as % of GDP, 1980-2004 by country



Sources: EU KLEMS and authors' computations

Figure 1b: Investment in ICT as % of GDP, 1980-2004: US vs EU15



Sources: EU KLEMS and authors' computations. Note that the EU15 countries are those considered in Figure 1a.

What could reasonably explain such persistent differences in ICT investment between the US, the EU and Japan? A first possibility could be that, the evolution of ICT investment would have just followed the overall evolution of capital good investment, including ICT. In that case, then, one should observe also different patterns in non-ICT good investment between the different countries considered here. The second row of Table 1 tends to invalidate the previous hypothesis since, over the whole the period considered here, the EU has consistently experienced higher percentages of non-ICT investment. The higher investment rate of the EU has even been growing over the whole period so that the gap in non-ICT investment has tended to widen at the end of the period, with the US investing around 24% of their GDP in non-ICT equipment while the EU has invested around 29% in 2004.

In fact, the differences in ICT and non-ICT investment patterns between the US and the EU observed previously could be linked to differences in industrial specialization between the US and the EU economies. These differences could, in turn, explain why ICT investment has followed different paths in the US and the EU. In order to investigate this possibility, the third row of Table 1 displays the percentage of employment in ICT-producing industries following

the definition provided by the OECD.[8] The descriptive evidence tends to show that the US specialization in ICT-producing sectors has been decreasing. Interestingly, the US share of employment in ICT-producing sectors has converged towards EU levels, i.e., around 4% of total employment. On the other hand, Japan, which was starting from a share of employment in ICT sectors well below the US level in the early 1980s, has experienced a steady rise in the percentage employment in ICT-producing sectors, largely outpacing both the EU and the US between 1995 and 2004. These evolutions suggest that specialization in ICT-producing is unlikely to be a sufficient explanation for the differing share in ICT investment in percentage of GDP between the US, the UE and Japan. In fact, the opposite is rather true given that the US has tended to lose its initial lead in the early 1980s in terms of specialization in ICT-producing industries.

Rather than looking at ICT-producing sectors, one would also expect that countries more specialized in ICT-intensive use industries would also tend to invest more in ICT capital.[9] The last row of Table 1 shows that this is to some extent the case, especially when comparing Japan with the US and the EU. The EU tends to be less specialized in ICT-intensive use sectors compared to the US, although at the end of the period considered here, the EU percentage of employment in ICT-using industries has tended to converge to the US percentage. It follows that, while the higher specialization of the US economy in ICT-intensive industries can explain part of differences in patterns of ICT investment compared to the EU, it remains to be seen whether this difference is large enough in order to explain it fully.

Overall, these first descriptive results tend to show that during the period 1980-2004, the US has consistently invested more in ICT in proportion to their GDP compared to the EU and Japan. This higher proportion could be due to differences in specialization in ICT-intensive use industries, although this difference is not so pronounced when comparing the US and the EU. Some EU countries seem to be experiencing a catching-up process in ICT investment. However, their relative small size explains why the EU overall ICT investment pattern is largely dominated by large EU countries, which have also tended to investment markedly less in ICT than the US.

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8 See in particular, Mas and Quesada (2005) and Appendix 2.

9 For a taxonomy of ICT-intensive industries, see also Mas and Quesada (2005).

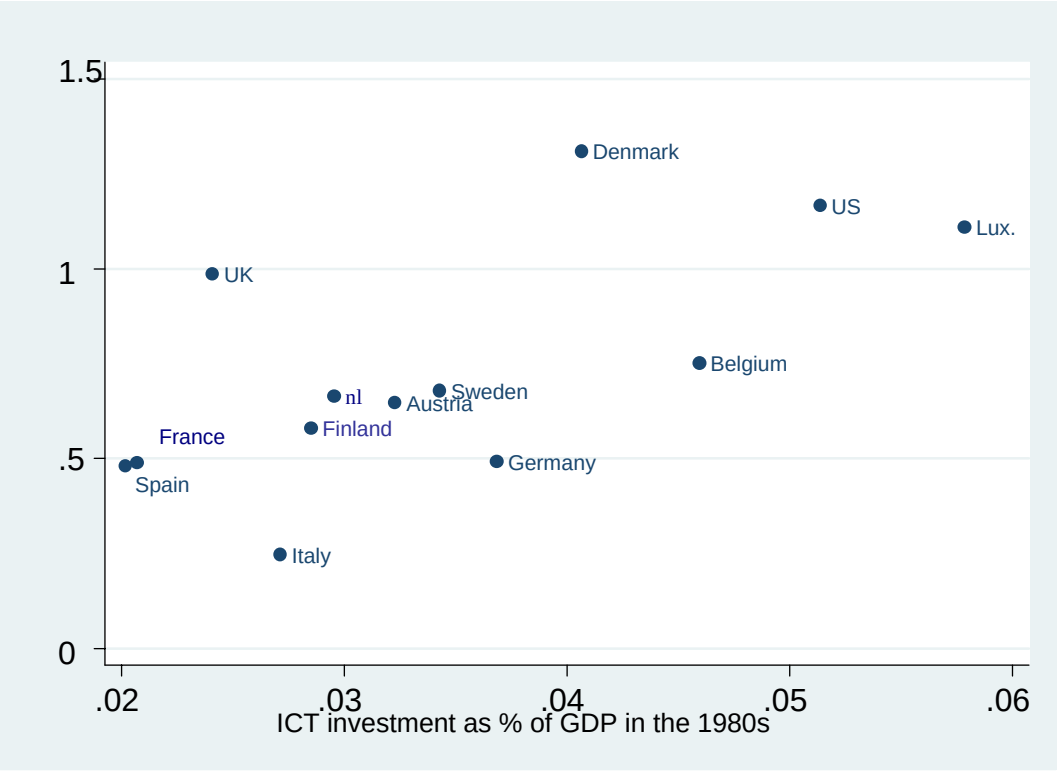
2.2 ICT investment and growth

We now turn to the issue concerning the influence of differing ICT investment patterns between the EU, the US and Japan in terms of economic growth. We draw, as before, on the results of the growth accounting analysis undertaken by the EU KLEMS project (see EU KELMS (2007) for details) for the US, Japan and a number of EU countries. Table 2 provide the results of the decomposition of the value added growth (which can be thought as a close approximation of GDP growth) in the overall economy into its main components including labour, ICT capital and non-ICT capital and the residual term which is the Total Factor Productivity component. Appendix 1 provides more details on the methodology used.

Before commenting on the results shown in Table 1, it is important to say a word on the potential long-term consequences of low ICT investment. In particular, a number of authors have already put forward the higher impact of ICT on both productivity and GDP growth in the US compared to most of the developed economies, see in particular van Ark and Inklaar (2005) and Jorgenson and Wu (2005). One possible explanation of the higher contribution of ICT investment in the US could be that ICT-related innovations become first applied to economic activities in this country. By analogy to the idea developed by Arrow (1962), in presence of learning by doing related to ICT-use, then the country that has started first to invest in ICT will tend to draw more economic returns from these investments and be able to build up a competitive advantage in both ICT-producing and ICT-using industries.[10] These arguments suggest the possible existence of a time lag for ICT to deliver its economic benefit but also the existence of a *first-mover* advantage related to the use of ICT in economic activities. Accordingly, countries that have invested more and earlier in item in ICT could benefit from higher economic returns from these investments. Figure 2 provides evidence that tend to support the previous argument. This figure plots the contribution of ICT investment to value added growth versus the share of ICT investment as percentage of GDP in the 1980s.

[10] These ideas were also further developed in the context of trade specialization, see for instance, Brander (1995) for a review of these arguments.

Figure 2: ICT Growth impact during the period 1990-2004, vs ICT investment in the 1980s: contribution of ICT to GDP growth in percentage points from 1990-2004



Sources: EU KLEMS and authors' calculations

Countries such as the US and also some (small) EU countries such as Luxembourg, Belgium and Denmark appear to have invested a relatively high share of their GDP in ICT capital during the 1980s and to have benefited more (in terms of GDP growth) from these investments in the 1990s and early 2000s. Overall though, excepting the case of Luxembourg, the first-mover advantage seem to lie on the side of the US economy which has started much earlier and also in greater proportion (in percentage of its GDP) to invest in ICT than the vast majority of EU countries, and was also able to reap the benefits from ICT investment faster and to a greater extent than countries with a similar ICT investment pattern.

Table 2: Growth accounting results for the EU15, Japan and the US

variables are expressed in growth rates

	1980-1995					1995-2004				
	Value Added	Labour	ICT capital	Non-ICT capital	MFP**	Value Added	Labour	ICT capital	Non-ICT capital	MFP**
US	3	1.2	0.5	0.6	0.7	3.7	0.7	0.8	0.6	1.6
Japan	3.6	0.5	0.4	1.5	1.2	0.7	-0.4	0.3	0.3	0.4
EU15*	1.9	0	0.4	0.7	0.7	2.2	0.7	0.6	0.6	0.3
Austria	2.3	0.1	0.4	0.5	1.4	2.6	0.5	0.6	0.3	1.2
Belgium	2.3	0.8	0.6	1	0	2.4	0.7	0.8	0.6	0.3
Denmark	2.8	-0.1	1	0.4	1.5	2.3	0.9	1.3	0.5	-0.5
Finland	1.8	-0.5	0.3	0.5	1.5	4.4	1	0.6	0.2	2.6
France	1.7	-0.2	0.3	0.6	1	2.5	0.8	0.5	0.5	0.7
Germany	1.9	-0.2	0.2	0.7	1.1	1	-0.3	0.5	0.5	0.4
Italy	1.9	0.4	0.2	0.7	0.5	1.4	1	0.2	0.9	-0.7
Luxembourg	6.1	1.2	0.5	1.1	3.2	4.3	2.3	0.9	1.5	-0.4
Netherlands	2.1	0.8	0.4	0.6	0.3	2.8	0.8	0.7	0.3	1
Spain	2.4	0.3	0.4	1	0.7	3.6	2.6	0.5	1.4	-0.9
UK	2.5	-0.3	0.5	0.7	1.6	3.3	0.9	1	0.5	0.9

* sources: EU KLEMS (2007). EU15 figures exclude Greece, Ireland, Portugal and Sweden.
** MFP =Multi-Factor Productivity

We now go back to the results of the growth accounting exercise displayed in Table2, Appendix 1 provides a description of the methodology used. A first observation needs to be made concerning the persisting lower value added growth of the EU economy as a whole compared to its main partners. During the whole period 1980-1995, all EU economies, excepting Luxembourg, have experienced on average lower value added growth rates than the US and Japan. The same can be said during the second period considered in Table 2, i.e., 1995-2004, although in that period some EU countries such as Finland and Luxembourg have experienced higher (than the US) value added growth rates. In some other countries such as the UK and Spain, the value added growth rate during this latter period has also been rather close to the US figures.

Now looking more closely at differences existing in the contribution of ICT investment to value added growth, a number of interesting features do emerge. On the one hand the gap in this contribution between the US and the EU is mainly for large EU economies such as France, Italy and Germany. In some relatively smaller EU economies such as Belgium, Denmark or the Netherlands, the contribution of ICT to value added growth has even exceeded that of the US during the period 1995-2004. The same can be said also for the UK. Overall, though, the experience of the large EU economies is driving the whole EU evolution, resulting in a smaller contribution of ICT to value added growth as compared to the US. The Japanese economy has had a similar experience to the EU in terms of contribution of ICT to value added growth with a much lower contribution during the years 1995-2004.[11]

[11] Interestingly, the larger part of the gap in value added growth between the US and the EU and Japan during the period 1995-2004 appears to be due differences in contribution of the multi-factor productivity term. In fact, the apparent low-contribution of ICT as compared to TFP is due to the variable that is being decomposed here. If, as done in Van Ark and Inklaar (2005) one considers labour productivity growth, instead of overall value added growth with the same data, the role played by ICT in explaining the gap in productivity dynamics between the US and the EU appears to be largely explained by the contributing of ICT and ICT-producing sectors' TFP, the latter being captured by the TFP term displayed in Table 2.

Figure 3 provides an overview of the evolution of the contribution of ICT to value added growth for the US, Japan and the EU during the period 1980-2004.

Figure 3: Contribution of ICT to VA growth 1980-2004

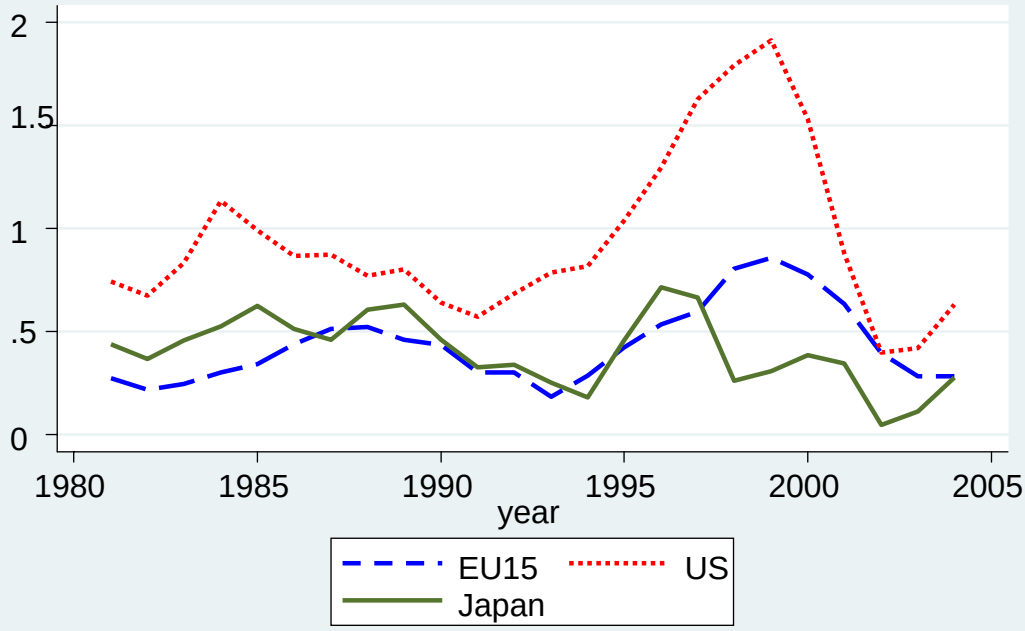


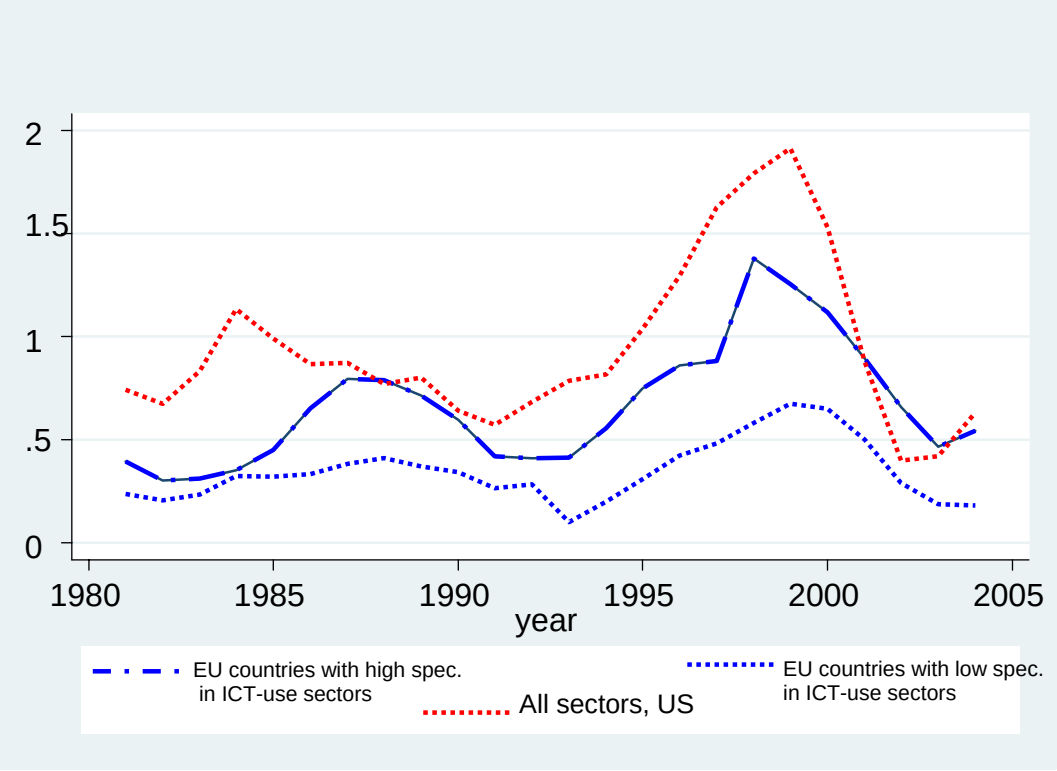
Figure 3 shows that, during the whole period, the contribution of ICT to total value added growth in the US economy has been superior to that in the EU15 and Japan. Interestingly, this figure shows that the US growth resurgence since the mid-1990s evidenced earlier in Table 2 is concomitant to the substantial rise in the contribution of ICT. While the EU15 has also experienced a rise in the contribution of ICT to value added growth during the same period, this rise has been far much limited. The same can also be said, to some extent, for Japan. However, the contribution of ICT to growth in Japan has been much lower than in both the EU and the US during the second half of the 1990s.

Given the evidence presented here, the key question is to know which factors could help us understand why the contribution of ICT to value-added growth has been much smaller in the EU and Japan. Indeed, while the last two economies also seem to have benefited from growing ICT investment and productivity impact, it is quite striking that the economic benefits linked to ICT investment seem to have failed to materialize in the EU and Japanese economies, at least when the US experience is taken as a benchmark. More specifically, in

what follow we try to understand whether there could be structural differences in these three economies that could help explaining this state of affairs.

As shown earlier, differences in specialization in ICT-intensive use industries could help understanding the relatively poor EU and Japanese performances in relation to ICT and growth. Let us consider the EU more closely. In order to do so, we draw the same figure as Figure 2 above by distinguishing within the EU, those countries with a specialization in ICT-using industries comparable or superior to that of the US economy and those with a specialization in ICT-using industries lower than that of the US. Figure 4 makes this distinction.[12]

Figure 4: Contribution of ICT to VA growth in the US and the EU: highly specialised vs low-specialised in ICT-use sectors



* Note: Countries are classified according to the share of employment in ICT-intensive sectors using the US average of ICT-intensive sectors in total employment as benchmark. Given that the average percentage of employment in ICT-intensive sector for the US during the period 1980-2004 is 29.4%, high ICT-use share EU countries include countries with percentage above the US value such as the UK (30.1%), Sweden (37.8%), the Netherlands (30.6%), Finland (34%) and Denmark (35.2%). Low ICT-use share EU countries include Austria (24.9%), Belgium (28.4%), Germany (28.4%), Spain (18.5%), Italy (21.8%) and Luxembourg (28.9%). Country-groups averages are weighted (the weights are determined by the GDP in PPP) average of the contribution in percentage points of ICT to value added growth.

[12] In order to make the interpretation of Figure 3 easier the corresponding curve for Japan has been omitted. Plotting the Japanese curve in this figure would indicate that even the low-intensive EU country-group have experienced a higher impact of ICT on valued added growth.

Figure 4 shows that the EU countries with a relatively high (as compared to the US) specialization in ICT-intensive use sectors have indeed benefited more from ICT investment in terms value added growth impact than those EU countries with a relatively low specialization in ICT-intensive use sectors. This result tends to confirm the evidence put forward earlier concerning the influence of the differences in economic structures on the contribution of ICT to economic growth. Importantly, however, Figure 3 shows that even the EU countries that were relatively more specialized in ICT intensive-use industries have benefited less than the US in terms of ICT impact on value added growth although during the latter part of the period considered here (i.e. since 2001) the US and EU experience in terms of ICT contribution to value added growth have tended to converge.

2.3 ICT investment, market rigidities and growth

The evidence described above shows that the higher presence of ICT-intensive use sectors does explain only part of the higher contribution of ICT to value added growth in the US compared to the EU. The rest of the paper is mainly concerned with the role played by market rigidities in explaining the differing EU and US experience in ICT contribution to GDP growth. In order to measure differences in market rigidities, we make use of a number of indices, coming mainly from the Fraser Institute Economic Freedom database. Box 1 below provides more information on this database of relevance for the present paper.

Box1: The use of the Fraser database to measure Market rigidities

The Fraser database provides indicators rating most world economies from 1 to 10 (1 being the worst notation in terms of market flexibility and 10 being the best mark) on a number of items. These items concern the Size of Government (including information on expenditures, taxes, and public enterprises), the legal structure and security of property rights, access to money and capital, international trade regulation and international capital controls and the regulation of credit as well as labour and product markets.[13] Here we focus on the credit, labour and product markets regulation. While the other items could possibly have an influence on ICT diffusion and its growth impact, these links are much less direct than the one between market flexibility and regulation following the arguments developed in Section 1.

The Fraser database provides annual information at country level. This index is only available on year to year basis since 2000 such that, when considering the period 2000-2004, we avail of complete series for the countries considered here, i.e., most of the EU15 countries, Japan and the US. Before 2000, however, the Fraser data is only available every 5 years, such that, for the period under consideration we only avail of information concerning the years 1980, 1985, 1990 and 1995. This discontinuity in the data availability is problematic when using the data for econometric estimation. The resulting panel of countries is therefore rather unbalanced. From an econometric viewpoint this should not represent any particular problem and simply correspond to an unbalanced panel data. However, from an economic viewpoint, using the Fraser data in its unbalanced form would mean that the very recent years are over-represented compared to the early years of the period considered here. This is especially problematic when linking recent ICT contributions to GDP growth to past ICT investment levels as done in Section 3. In order to circumvent this issue, we have therefore also used extrapolated series in order to obtain continuous time series for the Fraser indices used here. Appendix 3 provides more information on the extrapolated series as well as econometric results obtained using the original figures. The results obtained are qualitatively very similar to the ones reported in the main text.

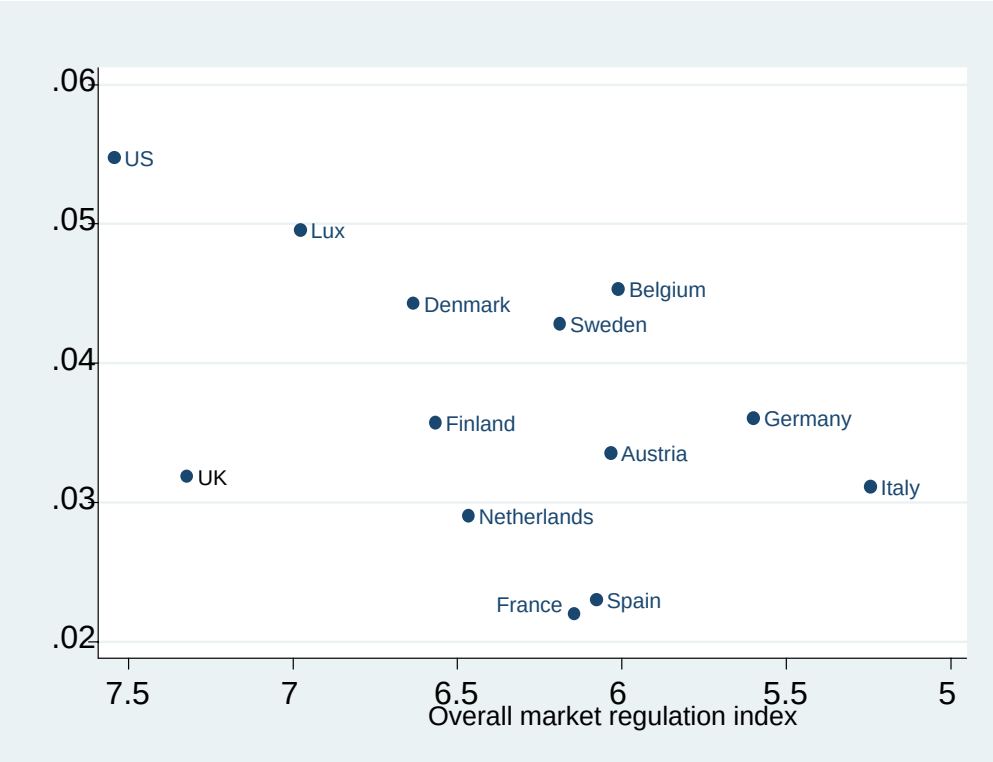
In addition to the Fraser database we will also make use of indicators on market rigidities provided by the World Bank and the OECD in order to check the robustness of our results. It must be said, however, that these latter sources provide indicators for only a few years such that their use is limited to the descriptive evidence while Section 3 will make use of the Fraser database only.

For more information, see Appendix 1 and http://www.fraserinstitute.ca

[13] Appendix 1 provides a more detailed description of the variables taken from the Fraser database.

Figure 5 provides a first set of descriptive results by plotting the overall market regulation indicator taken from the Fraser database and ICT investment as percentage of GDP in the EU countries considered individually together with the US and Japan.

Figure 5: ICT investment and overall market regulation: 1980-2004
% of ICT investment in GDP



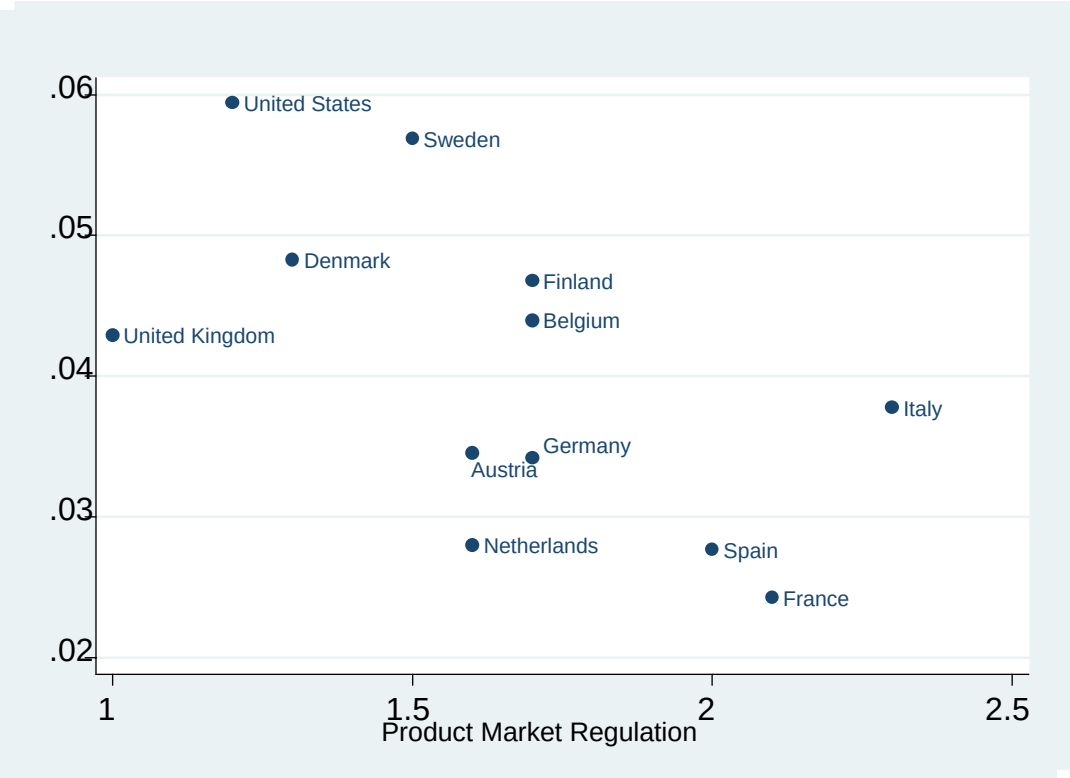
Sources: Fraser Institute, GGDC-EU KLEMS database and authors' computations

In order to illustrate the importance of market rigidities, the values of the Fraser index have been reversed in the x-axis with, as mentioned earlier, the highest possible mark on the extreme left on the x-axis being 10 (corresponding to a fully deregulated market) while the lowest mark is 1 (on the extreme right on the x-axis). The results displayed in Figure 5 show that there is, overall, a negative relationship between the extent of market rigidities and the share of ICT investment as percentage of GD in the countries considered here. When considering countries individually, Italy appears to have the lowest mark in terms of market rigidities while its share of ICT investment as percentage of GDP has been one of the lowest, although not the lowest. Countries such as France and Spain, for instance, had lower investment in ICT as percentage of their GDP than Italy. These countries also display low marks in terms of overall market regulation. The UK also stands relatively outside the overall negative relationship between the market regulation indicator and ICT/GDP ratio as it has had relatively good performance in terms of market flexibility but relatively low ICT investment

ratio. The other countries tend to be in line with our starting hypothesis, in particular the US and to some extent Luxembourg and Denmark do have a relatively high ICT/GDP ratio and low market regulation burden.

Figure 6 provides additional evidence on the relationship between market regulation and ICT investment using an alternative database for the market regulation indicator. Here we use the OECD database on product market regulation which is only available for a shorter time span, i.e., the 1998-2003 period. The ICT/GDP ratio has therefore also been considered for this period of time as well.

Figure 6: ICT investment (% GDP) and product market regulation, 1998-2003
% of ICT investment in GDP



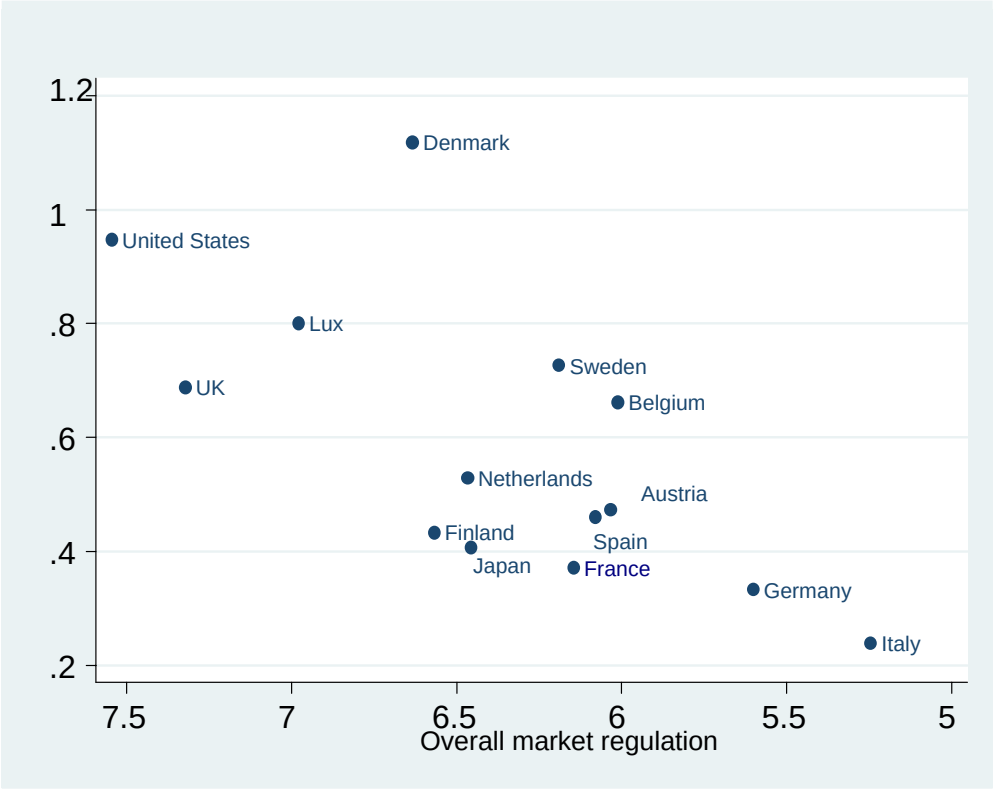
Sources: EU KLEMS, OECD (product market regulation database) and authors' calculations

Figure 6 provides a picture very similar to Figure 5. The same observation indeed holds here regarding the relative disadvantage of countries such as France and Spain and the lead of countries such as Denmark and the US. Italy appears here in a somewhat better position in terms of ICT investment than when considering the whole period 1980-2004. Here again also, the UK appears, to some extent, to be an outlier with rather good mark in terms of product market regulation but a low ICT investment to GDP ratio. Overall, the evidence provided by

Figure 6 tends to confirm the negative relationship between market regulation and ICT investment put forward earlier.

In what follows we investigate the relationship between market regulation and the return to ICT investment as measured by the contribution, in percentage points, of ICT to value added growth in the same country-group as considered before. Figure 7 below plots the contribution of ICT investment to value added growth against the degree of market regulation taken from the Fraser database.

Figure 7: ICT growth impact and overall market regulation, 1980-2004
ICT contribution to growth



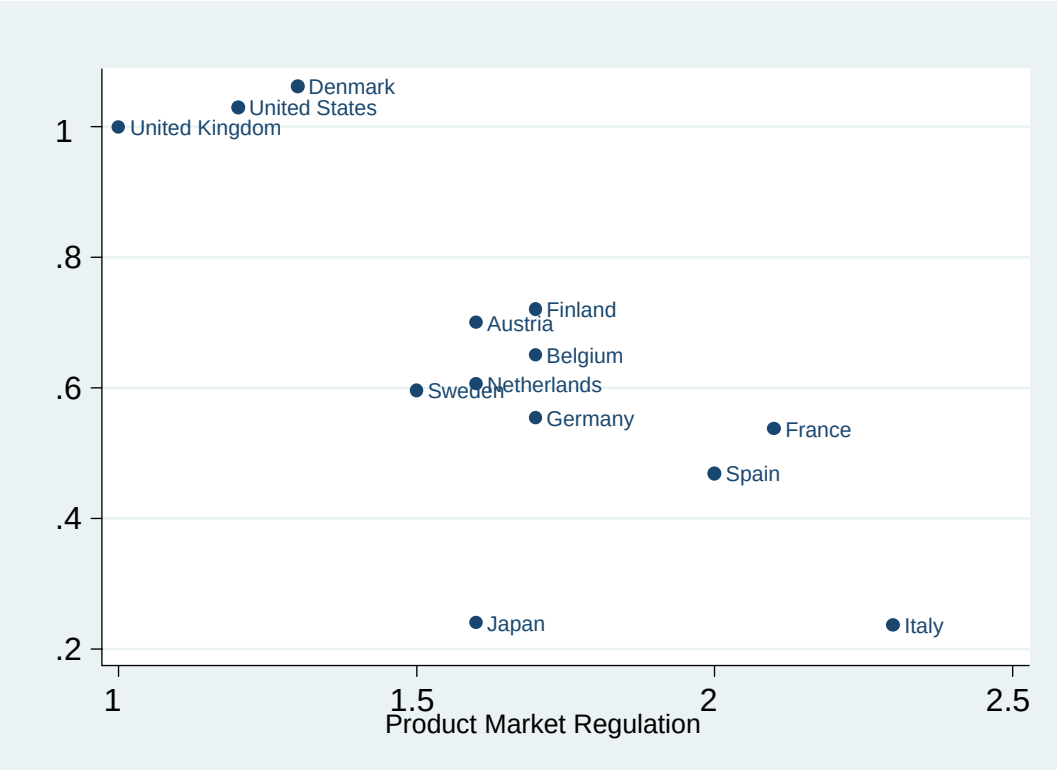
Sources: Fraser Institute, GGDC-EU KLEMS database and authors' computations

Figure 7 shows that there is a negative relationship between the degree of overall market regulation and the economic benefits related to ICT investment. Unsurprisingly, the picture depicted by Figure 7 is broadly similar to Figures 5 and 6 since the countries that have tended to invest relatively little in ICT have also tended to have a lower impact of ICT on their value added growth. Italy and Germany appear to have benefited relatively little from their ICT investment and, at the same time, were among the two most regulated economies during the period considered here. On the other hand, the US, the UK and Luxembourg, which are also

the least regulated market economies in the sample of countries considered here, have also benefited most from ICT investment. Interestingly, the UK experience in terms of ICT contribution to growth appears to be much more in line with its mark in terms of market rigidities. Indeed, we have shown earlier that the UK appears to have invested relatively less in ICT than its EU counterparts. The result concerning the contribution of ICT to GDP growth may thus appears rather puzzling at first glance. Other factors (than market structures) may also be at play, however. In particular, recent papers have shown that the UK may have benefited from ICT-related innovation and productivity gains through its trade (and foreign investment) relationships with the US. Generally speaking, therefore, one could consider that international trade and investment openness could act as a transmitter for ICT-related economic benefits. This issue will be investigated later on in Section 3.

The Figure 8 below provides supplementary evidence using the OECD product market regulation as an alternative indicator for market regulation for the period 1998-2003.

Figure 8: ICT growth impact and product market regulation: 1998-2003
ICT contribution to growth, %-points

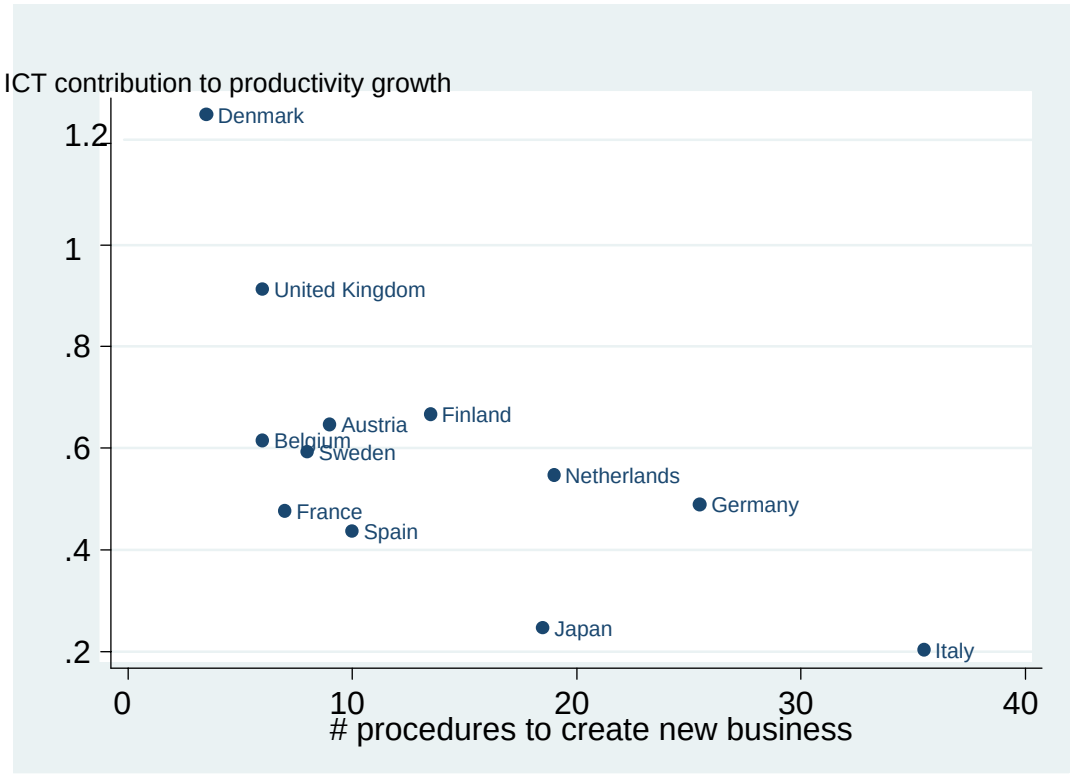


Sources: OECD, EU KLEMS and authors' calculations

Generally speaking, excepting few differences in terms of positioning of countries regarding the degree of product market regulation, the relationship between market regulation and ICT impact on value-added growth seems to hold here also. In particular, the US, Denmark and the UK appear to have performed outstandingly in terms of both market flexibility and ICT contribution to growth during the period considered here.

Figure 9 and 10 below provide similar evidence. They use data on the number of procedures to create new businesses as measures for market rigidities during the period 1999-2004 using data taken from Ciccone and Papaioannou (2006) and from the World Bank Doing Business database.[14] Figure 9 depicts the relationship between the number of procedures to start a new business and the contribution ICT to value added growth for the same sample of countries considered above. Figure 10 uses instead the estimated cost of the procedures to start a new business in terms of percentage of GDP per head.

Figure 9: ICT growth impact and barriers to business creation*: 1999-2004
**** # of procedures to start a new business***

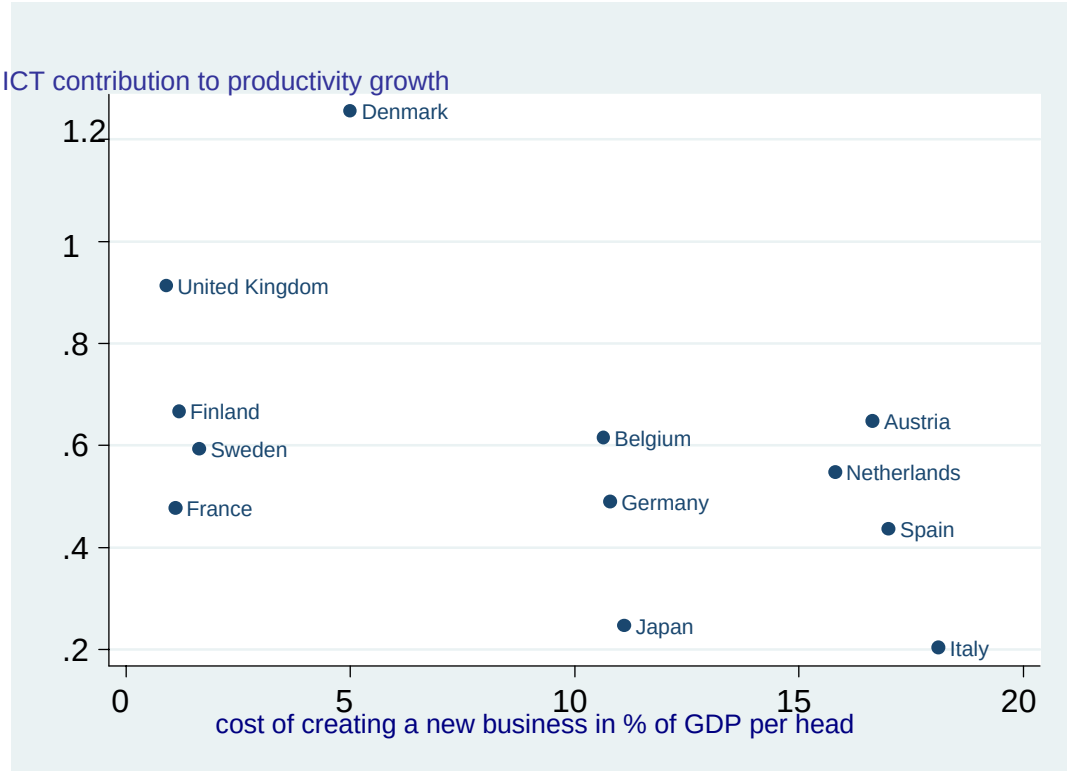


Sources: World Bank,, EU KLEMS and authors' calculations. US data not available.

[14] See http://www.doingbusiness.org/

According to Figure 9 the relationship between the degree of market regulation and the benefit of ICT investment appears to be negatively correlated, as before.

Figure 10: ICT growth impact and barriers to business creation*: 1999-2004
(* start-up costs of obtaining legal status to create a new business in % of GDP per head



Sources: World Bank, EU KLEMS and authors' calculations. US data not available.

However, the results depicted by the use of an alternative indicator such as the estimated cost of creating a new business as percentage of GDP does not appear to be as clear-cut as in the case considered earlier although the negative relationship between this indicator of market regulation and the contribution of ICT to GDP growth seems to hold here also.

2.4 Summary of descriptive results

This Section has provided a number of stylized facts that tend to support the view according to which ICT investment and its related growth impact are strongly tied to market rigidities, especially so when comparing the EU and US economies. Our first descriptive results can be formulated as follows:

- First the EU economy (and, to some extent, Japan) has been slow to invest in ICT capital compared to the US and, when this investment has significantly increased, it has done so at lower rate than the US.
- Second, the impact of ICT on GDP growth has also been much less pronounced than in the US during the past ten years or so. While some EU countries seem to have caught up to the US' productivity and growth pace, these countries have, in general, a relatively small size such that their overall influence on EU evolution has been modest so far.
- Third, there seems to be clear indication both from the short literature review provided above and also from simple descriptive statistics, that the persistence of market rigidities, essentially rigidities on the labour, capital and product markets, have gone hand in hand with the persisting EU economy deficit in terms of ICT investment and ICT contribution to economic growth. This result seems to hold independently of the source used for measuring market rigidities.
- Fourth, we find that, while the positive impact of market flexibility was larger for ICT investment in the 1980s up to 1995, this positive impact of ICT investment on GDP growth has been larger after 1995. Put simply this means that, while market rigidities have tended to deter ICT investment during the 1980s up to 1995, the negative influence of market regulation on productivity through ICT investment deterrence has only become more apparent during the recent years.
- Fifth, the result above would suggest the existence of a time lag for structural reforms aimed at making product and factor market more flexible in order to increase growth potential via ICT investment. While less rigid markets allow for ICT to be adopted faster, the economic gain related to ICT investment require more time to bear their fruits. Market rigidities thus appear to explain both the low diffusion of ICT throughout the EU economy and, at a latter stage, the low contribution of ICT to economic growth in the EU.

The following section considers the different elements likely to influence ICT investment and its growth impact together in the same analytical framework. In order to do so we undertake an econometric analysis to see whether the relationship between ICT and market rigidities holds even when controlling for other elements such as differences in specialization, past investment in ICT and business cycles elements.

3. MARKET RIGIDITIES, INVESTMENT IN ICT AND ICT GROWTH IMPACT: ECONOMETRIC RESULTS

In this section we move to the econometric analysis of the determinants of ICT investment and ICT contribution to value added growth using the EU KLEMS data. In order to measure the influence of market rigidities we make use of the Fraser data given that it is the longest time series available on this topic for the sample of countries considered here.

3.1 Equation tested and summary statistics

We estimate two empirical models as depicted by the equation (1) and (2) below:

$$ICT_{it} = \beta_0 + \beta_1 MR_{it} + \beta_2 SHARE_{it} + \beta_3 X_t + \varepsilon_{it} \quad (1)$$

$$ICT\_CONT_{it} = \beta_0 + \beta_1 MR_{it} + \beta_2 SHARE_{it} + \beta_3 X_t + \varepsilon_{it} \quad (2)$$

These two equations consider together with market rigidities, the influence of other possible determinants of ICT investment and ICT contribution to GDP growth of country *i* and year *t*. The definition of variables is as follows:

ICT_{it} represents the ratio of ICT investment relative to GDP of a country *i* in a year t.

MR_{it} represents a set of variables capturing the influence of market rigidities. These variables are represented by the Fraser indicators of market regulation and measure the degree of overall market regulation of the labour market, capital market and business. We will also use separate variables for each of these indicators.

$SHARE_{it}$ represents a set of variables capturing the economic structure of a country *i* represented by two variables: on the one hand the percentage of a country *i* employment in ICT-producing sectors and the percentage of employment of a country *i* employment in ICT-using sectors as defined in Appendix 2.

X_{it} represents a set of control variables including a measure of the influence of country-*i* specific business cycle, represented by the OECD leading indicator; X_{it} also includes a set of

year-specific dummy variables which aim to capture the influence of shocks common to all countries while ε_{it} represents a country-specific error term. Further discussion on the modeling of ε_{it} is made in Appendix 1. Appendix 1 also provides more detailed information on the construction of the variables and their sources.

We use the same empirical model as above in order to study the determinants of the contribution of ICT to value added growth using equation (2). Here the dependent variable becomes *ICT_CONT* which stands for the contribution of ICT investment to value added growth as obtained from the growth accounting exercise described in Appendix 1. In addition, we also include as control variable a measure of the degree of trade-openness of a country *i* represented by the ratio of export *plus* import to GDP in order to investigate the possibility that trade acts as channel for transmitting ICT-economic benefits as suggested in Section 2.

It is worth noting that the values of the Fraser indicator of market regulation have been assigned a negative sign for the econometric estimations. It follows that the econometric results presented here should be read as indication of the influence of market regulation, i.e., a higher mark in terms of economic freedom as originally indicated by the Fraser data therefore corresponds to a lower mark in terms of market regulation. By assigning a negative coefficient to the Fraser index we, therefore, interpret the coefficient obtained as an indication of the influence of the degree of market rigidities on ICT investment and, in the sequel, on the impact of ICT investment on value added growth. It is also worth pointing out in addition that, given that the Fraser index values are in fact marks ranging from 0 to 10, the interpretation of the coefficient obtained cannot be read in the usual way, that is, in terms of elasticity. We will, therefore, mainly consider the sign and significance level of the coefficients obtained, and pay little attention to the absolute value of those coefficient which, from an economic viewpoint, can hardly be interpreted.

The method used for the estimation is the panel Panel Corrected Standard Errors estimations, see Beck and Katz (1995). This method is preferred to other alternatives such as the fixed-effect panel, panel-GLS or dynamic panel system estimator (system-GMM) for a number of

reasons related to the nature of the data used here, these reasons are explained in more details in Appendix 3.[15]

Before undertaking the econometric analysis of equations (1) and (2), it is important to check the degree of variation of the variables used for the estimation and, in particular, of the main variables of interest, namely, the share of ICT investment in GDP, the contribution of ICT investment to GDP growth and the market regulation variables. Table 3 provides summary statistics as well as an indication of the country displaying, on average, the highest and lowest value of each of the variables of interest.

Table 3: Descriptive statistics of variables used for the econometric estimations

	Mean	Std. Dev.	Std. Dev./ Mean	Min*	Max*	country Min*	country Max*
ICT/GDP	0.037	0.013	0.351	0.022	0.055	France	US
ICT contribution to GDP growth	0.577	0.395	0.685	0.24	1.12	Italy	Denmark
Overall Market Regulation **	6.23	0.795	0.128	5.1	7.4	Italy	US
Labour Market Regulation **	4.85	1.584	0.327	3.28	7.6	Germany	US
Business Regulation**	6.84	1.075	0.157	5.27	8.43	Italy	Finland
Credit Market Regulation**	8.42	0.961	0.114	6.4	9.4	Italy	Luxembourg
Share of ICT-using sector	0.283	0.058	0.205	0.182	0.378	Japan	Sweden
Share of ICT-producing sector	0.04	0.009	0.225	0.021	0.05	Spain	Sweden
Openness	0.733	0.505	0.689	0.211	2.1	Japan	Luxembourg

Notes: * Values refer to the minimum and maximum values of the mean of each variable.** *Country min* and *Country max* in the last two columns indicate the best performing and worst performing countries respectively.

The table above illustrates a number of interesting features. First of all, among all the variables considered in equations (1) and (2), the two dependent variables relating to ICT investment are the ones displaying the highest variability compared to their mean value. This suggests that great variations have been experienced by the countries considered here both in

[15] It is important to note that, in the sequel, we have also estimated equations (1) and (2) using, respectively, fixed effect estimators using the Driscoll and Kraay (1998) calculation of the standard errors and the Arellano and bond (1991) dynamic panel estimator. Results for the general specification of equations (1) and (2) were rather close to the one reported here. Results are available from the authors upon request.

terms of their ICT investment pattern and in term of the contribution of this investment to GDP growth. Also, concerning the market regulation and ICT variables, the US appears to display the highest values meaning that market regulation was especially low. At the same time ICT investment and ICT contribution to GDP growth was especially high in this country. For this latter variable the US are only second though, behind Denmark. Interestingly, when considering more closely the values concerning the regulation variables, the Labour Market Regulation variable appears to display the highest variability. The variability of the Labour Market regulation indicator is even comparable to the mean/Standard deviation ratio of the ICT-to-GDP investment ratio. More generally, Table 3 shows that the countries with the highest ICT investment and ICT contribution to growth are also the best-performing ones in terms of (low) market regulation, the highest specialization in both ICT-producing and ICT-using industries and, to some extent, the highest Openness indices, although for this latter variable the index for the US is rather low.

3.2 The macroeconomic determinants of ICT investment

The first set of econometric estimations concerns the determinants of ICT investment as depicted by equation (1) that we test across a sample of EU15 countries and the US. as indicated earlier, data for ICT investment in Japan were not available to us although later on Japan will be included in the estimations concerning the contribution of ICT investment on value added growth.

Table 4 provides the results concerning the estimation of equation (1). Column (1) of Table 4 provides the basic results. First of all, the Rho value of the Ar(1) suggests the presence of serial correlation in the series which tends to validate the method used here. Regarding the values of the coefficient obtained, the degree of market regulation appears to influence negatively and in a highly significant way (at 1%-level) the ICT to GDP investment ratio. Regarding the other variables, the country-specific business cycle does not appear to influence ICT investment while the share of ICT-producing industries in total employment exerts a positive and significant influence of ICT investment. In column (2) we replace the share of ICT-producing sectors in total employment by the share if ICT-intensive use sectors in total employment. These results indicate that the share of ICT-intensive use sectors in total employment has also a positive and significant influence on ICT investment. The influence of the overall market regulation indicator remains negative and significant.

Table 4: The macroeconomic determinants of ICT investment
Panel Corrected Standard Errors estimations (PCSE)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Overall Market Regulation	-0.003**	-0.002*			
	(0.001)	(0.001)			
Labour market regulations			-0.002*		
			(0.001)		
Credit market regulations				-0.001	
				(0.001)	
Business regulations					-0.001
					(0.001)
Share of ICT-using Sectors in total employment		0.085**	0.102**	0.090**	0.086**
		(0.016)	(0.016)	(0.016)	(0.016)
Share of ICT-producing sectors in total employment	0.391**				
	(0.113)				
OECD Business indicator	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	143	143	143	143	130
Number of countries	13	13	13	13	13
R-squared	0.79	0.79	0.79	0.79	0.80
rho(AR1)	0.87	0.89	0.90	0.88	0.88

Notes:
Dependent variable: share of ICT investment in GDP, source: GGDC-EU KLEMS database, updated March 2007. see Appendix 1 for the definition and sources of the variables. Estimation method used: PCSE with AR(1) process in the error term following Beck and Katz(1995). Differences in number of observations are due to differences in variables availability. ** means coefficient significant at 1% confidence interval, * means 5% significance. Estimated (robust) standard errors in parentheses. All estimations include non-reported year-specific dummy variables and a constant term.

The results obtained in columns (1) and (2) therefore suggest that the influence of market regulation on the ICT to GDP investment ratio does not vanishes when the structure of the economy considered (here the relative importance of ICT-intensive use sectors) is accounted for. In Columns (3) to (5), we have decomposed the overall regulation index into each of its components, namely, the labour market regulation indicator, the business regulation indicator and the credit market regulation indicator, while controlling for the relative importance of ICT-intensive using industries in total employment. These results show that only the labour market regulation index does affect both negatively and significantly ICT investment. Although the influence of the credit market and business market regulation appears to be negative, their coefficients are statistically insignificant.

3.3 The macroeconomic determinants of the impact of ICT on value-added growth

Table 5 provides the results of our estimation of equation (2) concerning the macroeconomic determinant of the contribution of ICT investment to value added growth. Here again, we find evidence of high serial correlation which justifies the use of panel corrected standard errors estimation technique. Column (1) provides the baseline results. In addition to the explanatory variables considered in Table 4, here we consider also the average value of the ICT investment to GDP ratio between 1980 and 1989 in order to check whether countries that have started earlier to invest in ICT have also benefited from higher economic return during the latter period, i.e., 1990-2004. This should also allow to us to check the first-mover hypothesis formulated in Section 2 is validated by our econometric analysis.

Column (1) shows that the ICT investment to GDP ratio in the 1980s appears to exert a positive and significant influence on the economic return to ICT in the 1990s. Beside, the degree of market regulation appears to have a negative and significant influence on the economic return to ICT investment. The share of ICT-producing industries does not appear to have any significant influence, however, contrary to the result obtained for the determinants of ICT investment. In Column (2) of Table 5 we have dropped the ICT to GDP investment ratio in the 1980s in order for our estimation to cover the whole time span 1980-2004. The result concerning the regulation indicator still holds here as well. In Column (3) of Table 5 we have substituted the ICT-producing share of employment variable by the ICT-intensive use sectors' share of employment variable and find, as before, that a high specialization in ICT-intensive use sectors in a given country exerts a positive and significant influence on the economic return from ICT investment. We also find that, as before, even when controlling for the presence of ICT-intensive sectors, the degree of market regulation does exert a significant and negative influence on the contribution of ICT investment to value added growth.

Table 4a: The determinants of ICT contribution to GDP growth: original Fraser Series
Panel Corrected Standard Errors (PCSE) estimations

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
ICT/GDP 1980s	10.306*								
	(5.189)								
OECD business indicator	0.004	0.002	0.006	0.006	0.010	0.008	0.008	0.009	-0.004
	(0.012)	(0.012)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)	(0.011)	(0.008)
Share of ICT-producing sectors in total empl.	5.253	0.650							
	(3.885)	(4.452)							
Overall Market regulation	-0.188**	-0.236**	-0.166**	-0.187**				-0.079*	-0.177**
	(0.048)	(0.064)	(0.056)	(0.052)				(0.034)	(0.037)
Share of ICT-using sectors in total empl.			2.286**	1.849**	3.712**	1.310	2.906*	1.445**	1.780**
			(0.500)	(0.702)	(0.828)	(0.712)	(1.296)	(0.455)	(0.297)
Openness services									0.207
									(0.191)
Openness manufacturing								0.009	
								(0.018)	
Openness				0.106	0.013	0.048	-0.014		
				(0.146)	(0.207)	(0.168)	(0.249)		
Business regulation							-0.019		
							(0.063)		
Credit market regulation						-0.165**			
						(0.042)			
Labor market regulations					-0.105**				
					(0.030)				
Observations	78	84	84	84	82	84	82	84	84
Number of countries	13	14	14	14	14	14	14	14	14
R-squared	0.47	0.42	0.46	0.47	0.45	0.45	0.40	0.24	0.63
rho(AR1)	0.46	0.54	0.56	0.44	0.55	0.54	0.62	0.38	0.35

Notes:
Dependent variable: share of ICT investment in GDP, source: GGDC-EU KLEMS database, updated March 2007. see Appendix 1 for the definition and sources of the variables. Estimation method used: PCSE with AR(1) process in the error term following Beck and Katz(1995). Differences in number of observations are due to differences in variables availability. ** means coefficient significant at 1% confidence interval, * means 5% significance. Estimated (robust) standard errors in parentheses. All estimations include non-reported year-specific dummy variables and a constant term.

As mentioned in Section 2, another possible determinant of the economic return to ICT investment not considered up to now could be represented by the degree of external openness. Indeed, recent microeconomic evidence has provided support to the idea that international trade and foreign direct investment may be considered as vehicle for transmitting ICT-productivity economic benefits, see, in particular, Bloom et al. (2007). More generally the literature on international knowledge flows has now provided a large amount of empirical evidence regarding the positive influence exerted by international trade and investment on knowledge flows, see for instance, Keller (2002) for a review of the literature. In order to control for the influence of trade openness here we included an indicator of trade openness represented by the sum of import and export divided by the GDP level of each country. The results are indicated in Column (4) of Table 5. These results show that the degree of trade openness does not exert a significant influence, however. In addition, the result concerning the market regulation variable still holds even after including the trade openness variable, however.

In Column (5) to (7) we, as in Table 4, estimate the influence of each of the market regulation indicators separately. We find, as before, that the degree of labour market regulation has a strong and significant negative influence on the economic return to ICT investment given that the coefficient of this variable is significant at 1% level. In addition, we find that the degree of regulation in the credit market has also a negative and significant influence, also at 1% level. The degree of business market regulation, however, does not appear to exert any significant influence on the contribution of ICT to value added growth.

Finally, in order to investigate possible differences across sectors of the economy, we have run the same estimation as before, but now considering the manufacturing industry and the service industry separately. In doing so, we have also used appropriately redefined trade openness indicators. As before, we find that the degree of market regulation exerts a negative and significant influence on the impact of ICT investment to value added growth both sectors of activity. Interestingly, we find also that the degree of trade openness does not influence significantly the contribution of ICT to value added growth in either the manufacturing or service sectors.

An interesting difference between the manufacturing and service sectors can be observed for the influence of market rigidities. In particular, while in both sectors we find a negative and

significant influence of the overall Market Regulation indicator, the coefficient obtained is nearly double and has higher significance in the case of the services sector. This latter result, in particular, tends to suggest that the economic gains of lower overall regulations are especially important when coming to new technology diffusion in the service sectors.[16] This result also fits rather well with the evidence provided by previous studies regarding the primary role played by the service sector, including possibly the banking and retail trade sectors, in promoting ICT diffusion and growth in the US economy.

[16] Ideally one would need to use a service-specific indicator for market regulation such as in Conway et al. (2006). However, in order to keep our results by sector comparable to the ones concerning the whole economy, we have opted to use the Fraser database instead.

4. SUMMARY AND POLICY IMPLICATIONS

This paper considers two separate, but necessarily linked questions: first how do market rigidities influence ICT investment? - and second, what is the influence of market rigidities on the contribution of ICT investment to GDP growth? The paper uses data covering the period 1980-2004 for a sample of EU countries, the US and Japan. Our findings can be summarized as follows:

- The persisting lower investment intensity in ICT in the EU economy compared to the US since the early 1980s cannot be attributed to lower dynamism in overall capital investment in the EU. The US economy, in particular, seems to have benefited from a first-mover advantage as it started to invest in ICT much earlier and to a greater extent (as measured in percentage of its GDP) than the EU. Consequently, the US economy was also able to reap greater benefits faster from ICT investment than EU countries with a similar ICT investment pattern and similar specialization in ICT-producing and ICT-intensive use sectors. Overall, while the EU has also experienced a rise in the contribution of ICT to value-added growth after the mid 1990s, this rise seems to have been much more limited.

- One possible explanation for the differing experience in the US and the EU concerning ICT may relate to structural differences between the two areas in specialization of ICT-producing and ICT-intensive user sectors of activity. However, the relatively similar specialization in ICT producing and ICT-intensive use industries between the US and the EU suggests that other structural factors are at play in explaining why ICT diffusion is still slow and its relative economic benefits still hardly perceptible in the EU economy, at least by US standards. Our results show that larger market rigidities in the EU constitute one of the main culprits for this state of affairs.

- We show that countries where market regulations were particularly burdensome such as Italy, France and Spain, among others, have also invested less in ICT and benefited less from ICT investment in terms of GDP growth. More generally, our econometric results indicate that it is only labour market regulation that influences ICT investment negatively and significantly. However, the influence of market regulation and, in particular, labour and capital market regulation, on ICT contribution to GDP growth also appears to be negative and statistically significant. When considering the

manufacturing and service sectors separately, we find that market regulation tends to deter the positive impact of ICT on growth in both cases, although this effect seems to be more pronounced in the service sectors. This latter result, in particular, suggests that the economic gains of lower service market regulation are especially important when it comes to ICT diffusion. This result tends to go in the same direction as the examples of the banking and retail sectors mentioned in this paper, as well as earlier evidence provided by Alesina et al. (2005) and Conway et al. (2006). These authors, in particular, use indicators specific to the service sectors, which tends to corroborate our results.

A number of policy implications can be derived from our results:

- First our results provide evidence for the central role played by labour market rigidities in influencing ICT investment and ICT contribution to growth. This suggests that labour market reform may play a key role in the modernization of the EU economy and in boosting EU economic growth through ICT diffusion. Furthermore, these results, together with previous theoretical insights, suggest that the lowering of rigidities in the labour market, should be seen one of the essential conditions for boosting EU growth potential. While Europe's labour market reforms may, in the short-term, deter the positive impact of ICT investment on growth by lifting low-skilled workers from unemployment, they can also raise the return of skilled workers and promote ICT-intensive types of activities. Importantly however, although the index of market labour regulation used here is designed for cross-country comparisons, it must also be acknowledged that labour market conditions are very different across EU countries. This implies that similar measures cannot be expected to have comparable impact or even the same relevance in different countries.

- Second, the available literature based on microeconomic case-studies has provided a large body of evidence showing that, in order to promote ICT investment and its related economic benefits, profound change in the organization of production as well as measures which increase labour skills, are called for. As stated in this paper, two possible scenarios in relation to this point can be envisaged. First, labour market rigidities could promote the substitution of labour by capital in the production process. Accordingly, the EU could tend to invest more in ICT in order to lower the

burden related to high labour market regulation. This scenario assumes that ICT technologies are labour-saving, however. The second scenario also mentioned in this paper is that, because ICT diffusion requires the re-organization of production process, EU firms would refrain from investing more in ICT if these rigidities make the aforementioned changes in the organization of production too costly. Our results suggest that the second scenario better explains the EU case, given that the EU economy has been characterized by high labour market rigidities *and* low ICT investment. Accordingly, the necessary re-organization of production at firm-level and the skills-improvement called for by ICT diffusion seem to explain why the EU economy is still slow to invest in ICT. The explanation put forward in this paper, as mentioned in the first point above, is that market rigidities, and labour market rigidities in particular, make these changes too costly. It also follows that market-oriented reforms, of the type proposed by the renewed Lisbon strategy, cannot be considered as stand-alone policies and that radical changes at the firm/business level, as well as reforms improving labour skills, are called for in order to promote technological change in the EU economy.

- Third, our results concerning the influence of past ICT investment suggest that the EU possibly lags behind in terms of ICT benefits because it started to invest later than the US. However, even in those EU countries where ICT investment has caught up to US levels since the mid-1990s, the contribution of ICT investment to growth has taken time to materialize. It is therefore important to bear in mind that, even if greater market flexibility in Europe is a pre-condition to increase growth potential, in particular via ICT investment, these benefits may take time to bear their fruits.
- Fourth, we find that lower market regulation, especially in the case of the service sector, promotes a larger contribution of ICT to GDP growth. Two features of the US economy compared to the EU are particularly useful to interpret this result. Firstly, service sectors, such as the banking and retail trades, have played a key role in promoting ICT diffusion and ICT contribution to overall US GDP growth. Secondly, our results show that lower overall regulation in services can act as a lever for increasing ICT contribution to growth, and this effect appears to be less pronounced in the manufacturing industry. It follows that, the modernization of the EU service sectors via ICT diffusion should benefit from a lower regulatory burden. Given the

size of the service sectors in the EU economy, the growth impact of these reforms is potentially sizeable.

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APPENDIX 1: NOTE ON THE DATA USED AND CONSTRUCTION OF VARIABLES

1.ICT investment and the measurement of ICT contribution to GDP growth

The contribution of ICT investment to output growth is measured using a growth accounting approach. Some of the ingredients of this approach are described here, more details about the methods and data construction and country-sources being available in EU KLEMS (2007).

In such framework, ICT investment is included in a Cobb-Douglas production function together with other production factors including materials, labour and non-ICT capital items. Importantly, ICT investment includes three types of assets, namely, computing equipment, communication equipment and software. The production function can be represented by the following expression (country and time subscripts are omitted for convenience):

$$Y = f\left(K_{ICT}, K_{N}, X, L, T\right) \qquad (A1)$$

Where Y stands for output of a given country, K_{ICT} is an index of ICT capital services, K_N is an index of non-ICT capital services, X is an index of intermediate inputs and L is an index of labour services while T stands for time. Under the assumption of constant returns to scale and perfect competition, the value of the

$$P^{Y}Y = P^{ICT}K_{ICT} + P^{N}K_{N} + P^{X}X + P^{L}L \qquad (A2)$$

total output can be written as:

After some manipulation and using the share of each production factor i in total output value given by υ_i, one can derive the standard accounting decomposition of total output growth into the contribution of each input and the multi-factor productivity term, yielding the following expression:

$$\Delta \ln Y = \upsilon_{ICT}\Delta \ln K_{ICT} + \upsilon_{N\_ICT}\Delta \ln K_{N\_ICT} + \upsilon_{X}\Delta \ln X + \upsilon_{L}\Delta \ln L + \Delta \ln A \qquad (A3)$$

where Δ stands for the annual change in the value of a given variable and *ln* denotes the natural logarithm. The last term *ΔlnA* represent the Solow residual or multifactor productivity term. Each capital stock is determined using the perpetual inventory method where the capital stock is a weighted sum of past investments with the weights being given by the relative efficiencies of each capital type at different ages.

The price of each capital component is particularly important in order to derive their corresponding output shares. Concerning ICT more specifically, the market price of a given asset is function of a real rate of return defined as the nominal rate of return adjusted for asset-specific capital gains and a rate of depreciation taken as given. Importantly, not all countries have developed such prices indices for ICT components such that in some cases, common price indices are used instead. The latter feature, in particular may be problematic when using these figures for econometric estimations, see Appendix 3 below.

According to the above, one can derive the contribution of ICT investment to output using equation (A3). This contribution corresponds to the term $v_{ICT} \Delta \ln K_{ICT}$ in this equation.

2 .Market Rigidities variables

Credit Market Regulations including Ownership of banks: percentage of deposits held in privately owned banks, Competition: domestic banks face competition from foreign banks, Extension of credit: percentage of credit extended to private sector, Avoidance of interest rate controls and regulations that lead to negative real interest rates, Interest rate controls: interest rate controls on bank deposits and/or loans are freely determined by the market, Source: Fraser database,

Labour Market Regulations, Impact of minimum wages, Hiring and firing practices: hiring and firing practices of companies are determined by private contract, Share of labour force whose wages are set by centralized collective bargaining, Unemployment Benefits: the unemployment benefits system preserves the incentive to work, Use of conscripts to obtain military personnel.

Business Regulations, Price controls: extent to which businesses are free to set their own prices, Burden of regulation, Time with government bureaucracy: senior management spends a substantial amount of time dealing with government bureaucracy, Starting a new business: starting a new business is generally easy, Irregular payments: irregular, additional payments connected with import and export permits, business licenses, exchange controls, tax assessments, police protection, or loan applications are very rare.

The overall regulation variable used in the paper is the arithmetic mean of the Credit Market, labour market and business regulation variables described above.

3. Other control variables

Share of ICT-producing industries in total employment of the economy is represented by the percentage in total employment of employment performed in ICT-producing sectors, see Appendix 2 for a taxonomy of sector. Source: EU KLEMS database, Groningen Growth & Development Centre

Share of ICT-using industries in total employment of the economy is represented by the percentage in total employment of employment performed in ICT-intensive user sectors, see Appendix 2 for a taxanomy of sector. Source: EU KLEMS database, Groningen Growth & Development Centre

Openness index is given by the ratio (exporti,t+importi,t)/GDPi,t) Source: Ameco database, European Commission, Directorate General for Economic and Financial Affairs

Real openness index is given by the ratio (exporti,t+importi,t)/GDPpi,t where GDPpi,t is the GDP expressed in purchasing power standard. Source: Ameco database, European Commission, Directorate General for Economic and Financial Affairs

Tradable openness index is given by the ratio (exporti,t+importi,t)/GDPti,t where GDPti,t is the GDP of the tradable sectors Ameco database, European Commission, Directorate General for Economic and Financial Affairs

The OECD composite leading indicator (CLI) is designed to provide early signals of turning points in business cycles (peaks and troughs) between expansions and slowdowns of economic activity. This indicator is available at the OECD website, see http://www.oecd.org/.

APPENDIX 2: TAXONOMY OF ICT-PRODUCING AND ICT-INTENSIVE USER SECTORS

ICT-intensive users sectors	Isic rev.3 code
Pulp, paper & paper products	21
Printing & publishing	22
Office machinery	30
Insulated wire	313
Other electrical machinery and apparatus nec	31-313
Electronic valves and tubes	321
Telecommunication equipment	322
Radio and television receivers	323
Scientific instruments	331
Other instruments	33-331
Electricity, gas and water supply	40-41
Inland transport	60
Water transport	61
Air transport	62
Supporting and auxiliary transport activities; activities of travel agencies	63
Communications	64
Financial intermediation, except insurance and pension funding	65
Insurance and pension funding, except compulsory social security	66
Activities auxiliary to financial intermediation	67
Computer and related activities	72
Health and social work	85
ICT-producing	
Office machinery	30
Insulated wire	313
Electronic valves and tubes	31-313
Telecommunication equipment	322
Radio and television receivers	323
Scientific instruments	331
Computer and related activities	72
Communications	64

Source: Mas and Quesada (2005)

APPENDIX 3: NOTES ON THE ECONOMETRIC ESTIMATIONS AND THE DATA USED

3.1 Econometric estimations

The econometric estimations reported in the paper are strongly influenced by the nature of the data used. Following Stimson (1985) taxonomy, also reported by Beck and Katz (1995), we avail of time-series-cross-section (TSCS) data, that is, where a limited number of individuals, here countries, are observed for a relatively long period of time. By contrast, panel data are often referred to in the literature in cases where large numbers of individuals are observed over a short period of time. While, in principle, both types of data have the same structure, the differences in the time/cross sectional length do have important implications in terms of the estimator used. In particular, a fixed-effect within panel data model is well known to be asymptotic in the number of panels, i.e., it becomes more efficient when the number of individuals is relatively large as compared to the time dimension, see Beck and Katz (1995). This is clearly not the case here as our sample concerns 14 countries observed over a 25-year period. There is no reason also to assume that, over the period considered here, country-specific effect are fixed and properly captured by subtracting from each observation the country-mean average. These characteristics therefore suggest that the use of a panel-within estimator is not appropriate in the present case.

Importantly, the descriptive evidence provided earlier suggests that the two variables of interest, i.e., ICT investment share in GDP and ICT contribution to value added growth, are likely to be dependent on their past values such that one may also suspect the presence of autocorrelation across time. One may also expect the existence of correlation across countries given, in particular, that in many cases common ICT prices indices are used. A more general structure of the country-specific effect is thus called for accounting for correcting estimated standard errors in presence of cross-sectional and time correlation in the error *term* ε_{it} of equations (1) and (2).

One possibility would be to assume a more general/flexible error term structure using for instance Generalized least Squares (GLS). However, while GLS has optimal properties for TSCS models, one problem, however, is that it implicitly assumes that the researcher has some knowledge about the error process which is rarely the case. In the present case considered here, we face the same limitation. The problem with TSCS models, in particular, is that the error process has potentially a large number of parameters. The estimations obtained using GLS are thus likely to result in exaggeratedly low standard errors, see in particular Beck and Katz (1995).

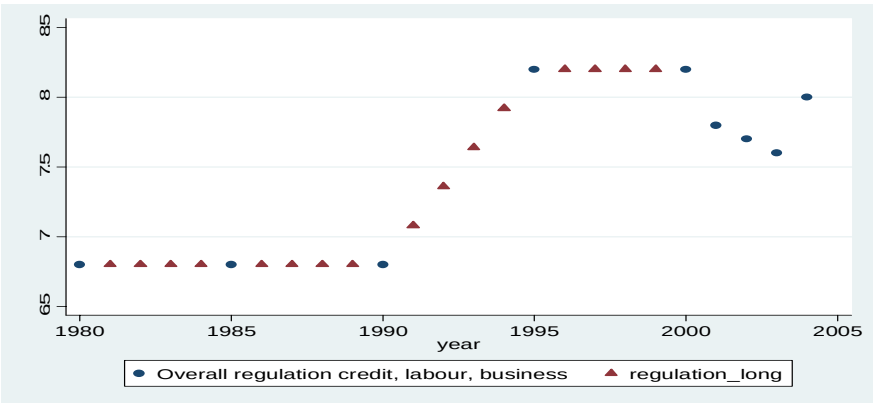
There are two alternative ways to correct for serial correlation in the dependent variable: the first one is to use lagged dependent variable; the second one by transforming the variables to get rid of the serial correlation. The first solution would call for using a dynamic panel data model (DPD) as the one described by Arellano and Bond (1991). One important reason not to use a GMM estimator is that we avail of a short panel of countries observed over a relatively long time period as noted above. If the time span considered is relatively large compared to the number of countries available, dynamic panel bias becomes insignificant. Furthermore, the number of instruments in system-GMM tends to explode with T and the Arellano-Bond autocorrelation test may become unreliable. Another reason

to disregard the system-GMM estimator is that the main variables of interest, i.e., the regulation indicators, are unlikely to be affected by endogeneity.

The second solution proposed by Beck and Katz (19995) is to use a panel corrected standard errors (PCSE) or Prais-Winsten model with panel-corrected standard errors which is proposed as an alternative TSCS models where the disturbances are not assumed to be *i.i.d.* With this model at hand, one can specifically correct for (and measure the degree of) serial correlation of the error. The advantage of the PCSE model is that one can assume the disturbances to be autocorrelated within panel, which likely to be the case here as ICT investment at a date *t* is likely to be correlated with investment at (t-1). Indeed, simple OLS estimates with lagged dependent variables suggest that indeed ICT investment at a date (t-1) is good predictor of ICT investment at date t. The PCSE estimator also allows one to consider that the disturbance term is potentially correlated across countries. In the sequel, therefore we will make use of the PCSE model to estimate equations (1) and (2).

3.2 Data used: The Fraser index on Market rigidities

One problem with the the Fraser database used to measure market rigidities is that it is only available at 5-years lags before 2000. This reduces considerably the length of the time series for each country considered in the econometric study. The Figure 4 below provides an example of the extrapolated series for the Regulation index concerning the US where circle dots correspond to the actual series and the triangles correspond to the extrapolated series.



As can be seen from this example, the resulting extrapolated series is just a linear approximation of the missing observations for the years 1981 to 1984, 1986 to 1989, 1991 to 1994 and 1996 to 1999. Given the slow change in the Fraser index on year to year basis, one may reasonably think that the resulting extrapolation fits rather closely the true series. In order to check the robustness of our results however, in the table below we re-estimate Table 4 and 5 with the original Fraser series, i.e., without using extrapolation. Overall, the results obtained with the original Fraser series are very close to the ones with the extrapolated series in the case of the macroeconomic determinants of ICT investments. As shown by the Table 3A above. The same can be said for Table 4a below.

Table 3A: The macroeconomic determinants of ICT investment: original Fraser series

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
OECD Business indicator	-0.000*	-0.000	-0.000	-0.000	-0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Labour market regulations			-0.002**		
			(0.000)		
Credit market regulations				-0.001	
				(0.001)	
Business regulations					-0.002**
					(0.001)
Share of ICT-producing sectors in total employment	0.517**				
	(0.084)				
Share of ICT-using Sectors in total employment		0.079**	0.108**	0.091**	0.073**
		(0.011)	(0.008)	(0.014)	(0.015)
Overall Market Regulation	-0.004**	-0.004**			
	(0.001)	(0.001)			
Observations	78	78	76	78	76
Number of countries	13	13	13	13	13
R-squared	0.79	0.83	0.82	0.81	0.77
rho(AR1)	0.64	0.77	0.72	0.73	0.64

Notes:
Dependent variable: share of ICT investment in GDP, source: GGDC-EU KLEMS database, updated March 2007. see Appendix 1 for the definition and sources of the variables. Estimation method used: PCSE with AR(1) process in the error term following Beck and Katz(1995). Differences in number of observations are due to differences in variables availability. ** means coefficient significant at 1% confidence interval, * means 5% significance. Estimated (robust) standard errors in parentheses. All estimations include non-reported year-specific dummy variables and a constant term.

Table 4a: The determinants of ICT contribution to GDP growth: original Fraser Series
Panel Corrected Standard Errors (PCSE) estimations

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
ICT/GDP 1980s	10.306*								
	(5.189)								
OECD business indicator	0.004	0.002	0.006	0.006	0.010	0.008	0.008	0.009	-0.004
	(0.012)	(0.012)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)	(0.011)	(0.008)
Share of ICT-producing	5.253	0.650							
sectors in total empl.	(3.885)	(4.452)							
Overall Market regulation	-0.188**	-0.236**	-0.166**	-0.187**				-0.079*	-0.177**
	(0.048)	(0.064)	(0.056)	(0.052)				(0.034)	(0.037)
Share of ICT-using			2.286**	1.849**	3.712**	1.310	2.906*	1.445**	1.780**
sectors in total empl.			(0.500)	(0.702)	(0.828)	(0.712)	(1.296)	(0.455)	(0.297)
Openness services									0.207
									(0.191)
Openness manufacturing								0.009	
								(0.018)	
Openness				0.106	0.013	0.048	-0.014		
				(0.146)	(0.207)	(0.168)	(0.249)		
Business regulation							-0.019		
							(0.063)		
Credit market regulation						-0.165**			
						(0.042)			
Labor market regulations					-0.105**				
					(0.030)				
Observations	78	84	84	84	82	84	82	84	84
Number of countries	13	14	14	14	14	14	14	14	14
R-squared	0.47	0.42	0.46	0.47	0.45	0.45	0.40	0.24	0.63
rho(AR1)	0.46	0.54	0.56	0.44	0.55	0.54	0.62	0.38	0.35

Notes:
Dependent variable: share of ICT investment in GDP, source: GGDC-EU KLEMS database, updated March 2007. see Appendix 1 for the definition and sources of the variables. Estimation method used: PCSE with AR(1) process in the error term following Beck and Katz(1995). Differences in number of observations are due to differences in variables availability. ** means coefficient significant at 1% confidence interval, * means 5% significance. Estimated (robust) standard errors in parentheses. All estimations include non-reported year-specific dummy variables and a constant term.

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Abstract

The renewed Lisbon strategy puts special emphasis on the potential role that Information and Communication Technologies can play in meeting the challenges of boosting growth, competitiveness and cohesion throughout the EU. There is also a general understanding among policy makers that investment of this kind and its related economic benefits can only materialize if labour, capital, product and service markets are flexible enough to facilitate ICT investment and the re-organisation of economic activities. This paper provides evidence of the influence of market rigidities on the propensity to invest in ICT and on the economic return of ICT investment in a number of EU countries, and in the US and Japan. We provide evidence that indicates that market rigidities deter ICT investment and lower the impact of ICT on GDP growth by considering a number of indicators reflecting barriers to business creation and the degree of market regulation in labour and capital markets. These results are invariant, even when other potential determinants of ICT investments and ICT contribution to GDP growth such as the degree of specialisation in ICT-producing industries, past ICT investment, business cycles conditions and a measure of trade openness are controlled for. The paper provides a number of policy implications, most notably, regarding the role played by structural reforms in promoting both ICT adoption and setting the best framework conditions for ICT impact on GDP growth. While the renewed EU Lisbon strategy of economic reforms is badly needed to increase EU growth potential, we show here that this strategy is also needed to promote technological change in the EU economy.

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