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Research Report

The importance of complementary policy for ICT in the EU

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The Importance of Complementary Policy for ICT in the EU

By Erik van der Marel *Senior Economist, ECIPE*



1 Introduction

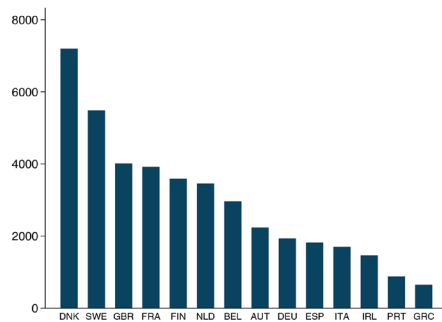
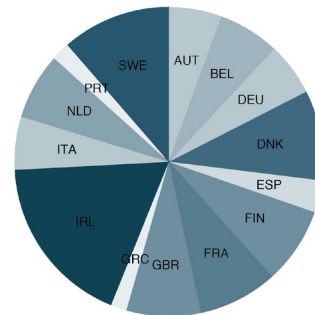
The importance of Information and Communication Technology (ICT) for European economies has been increasingly recognised over the last two decades (EC, 2014; van Ark, 2014a; EIB, 2011). The role of ICT, which includes computer, software, and data processing services activities as well as other computerised information such as databases, is significant in the economy as it acts as a vehicle to improve productivity and value-added. As the impact for boosting growth in advanced countries through increasing factor input accumulation is likely to be limited in the future, attention should be given to how efficient these factor inputs, such as labour and capital, are actually allocated. Factor inputs have a more important impact on growth in developed countries when they are used more efficiently, rather than its accumulation in quantity. An important element in this efficiency-enhancing process is precisely ICT as it improves the way in which all these input measures are effectively employed in the economy.

An additional characteristic of ICT is that it forms an important driver for innovation and knowledge-based activities, which in turn further increases economic growth. For instance, the growth of the software sector and its productive use in developed economies industries' has been a strong factor explaining overall economic growth over the last years. In large part this is because software interacts with many other types of so-called intangible assets, which are sources of growth and for which the use of software is indispensable. Examples include research and development (R&D), capital dedicated to organisational change or business process investments, which are all closely linked to innovation.¹ Hence, these activities have a more pronounced effect on growth when put in combination with ICT and software. All these intangible capital factors, of which software itself is also one of them, have recently generated much attention from both the policy and research literature as it forms new types of sources for economic growth (OECD, 2013c).

With this economic framework in mind, this paper analyses the importance of the ICT sector, and in particular the software sector, for the European economy. It does so by looking into the question of how value-added is created through the lens of improved productivity using ICT in various European economies. In analysing this channel, this paper looks specifically into how complementary policies play a crucial factor in the employment of software in order to enable a significant effect on economic growth. Examples of these complementary policies are various and vary from labour market regulations to product market regulations. As a result, this paper shows which of these additional policy measures can further benefit the European economy whilst employing software and other ICT-related services. In doing so, this work has developed and used a research methodology which is presented in the annex of the paper, and of which only the results are shown in the main part of this work.

The question of how complementary policy can play a significant role for the ICT sector in the EU is an important one as the pool of knowledge and assets in this sector is not equally spread across European countries. Figure 1 shows that although the average software stock per worker in the EU for which we have data is around 1700 USD, this figure masks important differences across European economies. For instance, Denmark retains more than four times as much accumulated software capital stock as Italy, Sweden has almost three times more software levels as Germany, and Great Britain has almost twice the amount of software capital than Spain. These differences in software are stark and are reflected in the overall economic growth performance. However, these differences cannot solely be explained by countries' economic structures or because a country like Denmark just puts more software in its economy. Explanations for why countries use more software must therefore also be found in the policies these countries apply. Hence, complementary policies have important implications for the extent to which countries can generate growth in their economies through the use of software.

¹ Other types of intangible assets that has been put forward in the economic literature are innovative property, economic competences, scientific research and development (R&D), new architectural and engineering designs, new product development costs in the financial industry, entertainment, artistic and literary originals, market research and advertising expenditure, training and finally organisational capital. See Corrado et al. (2014) for further insights on these measures. Moreover, software or ICT in general is a so-called general purpose technology that helps industries and firms to develop other innovations and reorganisations.

Figure 1: Net real software capital Stock per worker in USD, 2010**Figure 2: Domestic value-added in software and computer sector per worker, 2011**

Source: author's calculation, intan-invest, WB WDI and TiVA; investment figures are deflated using appropriate software deflators and calculated according to the perpetual inventory method with appropriate depreciation rate according to Corrado et al. (2012). Data refers to 2010, which is the latest year available.

The various additional policies are also likely to explain how competitive the ICT sector is itself in European economies. When looking at the value-added that is generated within the software and computer services sector, Figure 2 points out that although the EU holds a relatively high share of more than 33 percent of global value-added in this sector, each country's share within the EU in this sector is unequally distributed.² By way of example, Ireland holds a much larger share of ICT services compared to Belgium whilst Greece, as well as Portugal, only holds a minor stake of the value-added generated in this sector in Europe. Again, one significant factor in explaining these differences in competitiveness of the computer and software sector for each country needs to be found in the various complementary policies these countries apply. For instance, countries in Europe having strong policies to protect patents or encourage the diffusion of private credit for entrepreneurs are more likely to experience greater value-added growth in the ICT sector.

Yet, this paper is interested in how complementary policies can generate productivity in industries using software and ICT rather than in the ICT sectors itself. Therefore, the remainder of the paper is organised as follows. The next section explains briefly why complementary policies are an important vehicle for ICT, and in particular software, to have an impact on productivity and, eventually, growth. Section 3 shows some figures on productivity and software across European economies with new data that has become available in recent years. Section 4 shows the results of our study that are found from analysing which complementary policy measures in Europe have a significant effect on how industries use software services and can therefore increase productivity. We do this for software services only because of data availability and because this sub-category of the ICT sector is found to have an important effect for productivity, as previously mentioned and as discussed in Corrado et al. (2014, 2012). Finally, the conclusion of this paper will discuss the policy outcomes from our study in more detail within a European policy context.

2 Why complementary policy?

Why are policies outside the ICT sector itself important for ICT to be an enhancer for the European economy? And what policy-related factors can explain differences in productivity when using software? These questions are important as even though this sector represents a modest 2.1 percent of the EU's total domestic value-added, the ICT sector's indirect contribution to the economy is significant, as this paper shows. The reason for this important indirect effect must be found in the fact that software and other computer-related services play an intermediate "vehicle" in the so-called downstream economy in an attempt to generate higher productivity in each sector. Each industry outside the ICT sector uses software and computer services, which acts as a channel through which production processes in these using industries can be optimised. Without the use of software, organising production chains can become a lot more ineffective.

² These figures are based on 2011 which is the latest year available.

As a result, in the overall economy software acts as an indispensable means to effectively use production factors such as labour, capital or R&D and innovation in each downstream industry. Economic growth is a result of two ways in using these factor inputs: either through increased accumulation of factors or through the productive use of these factors. The role of ICT and its contribution to the economy must be found in the latter explanation of this growth trajectory in which productive resources can be unleashed in the production process. However, productivity growth in Europe has become stagnant over the recent years. In part, this stagnant productivity growth may reflect the declining technological progress or, for some countries, the low accumulated stock and use of ICT in itself. Yet, a second type of explanation lies in the so-called low “spill-over” effect in the sense that stalled reforms and policy rigidities slow down the endorsement and therefore the use of new technologies of ICT in the wider downstream economy.

Put differently, the productive use of ICT nowadays is not so much likely to stem from investments in the ICT sector itself, or ICT investments made in the ICT-using industries, but rather from the dissemination of ICT in the wider economy in which industries incorporate and interweave more software and computer services in their production processes. Van Ark (2014a) distinguishes three stages in a cycle of ICT deployment that feeds into economic growth, namely (a) that of investment in the ICT producing sector itself, (b) investment deepening in the so-called ICT using sectors in the wider economy, and finally (c) the “augmented” productivity effect from actually using ICT in the wider downstream economy. Since the current productivity levels in Europe remain weak and as the first two stages have been progressed over the last decade, it is precisely the latter part of this sequence that appears to lag progress in most European countries. This puts the focus of how ICT can be effectively used in the wider economy.

This, in turn, shifts attention to how the spread and usage of ICT in the economy can be accommodated by other policies that focus on how software and computer services can be embedded.³ These are the so-called complementary policies. For instance, lower regulations in product markets are likely to lead to resource re-allocations between firms within each industry, which can be accelerated by the use of software which before was not possible to use in more rigid markets. Similarly, more private capital to young start-up firms which are likely to use more ICT or software in their innovations could lead these firms to undertake riskier innovations that have a greater impact on growth. As one can see, these policies are, however, not always directly related to the ICT sector itself. Indeed, various works such as OECD (2007) suggest that the strong decline in productivity across Europe relates to complementary policies measures that could further enhance the employment of ICT in the wider economy.⁴

When looking at Europe, some countries in particular still have some sectors where there is a lack of competition due to higher regulations in product markets which could prevent other downstream industries, and particularly services, from effectively deploying ICT and software services. This prevents countries from increasing value-added and productivity. If markets are inflexible in Europe, industries are frustrated in their process of innovations and product development, including business reorganisations, which are all much dependent on the use of ICT and software services. In addition, complementary policies may also stifle the creation of value-added in the ICT sector itself in Europe. Labour market regulations may have a stronger adverse effect on creating value-added in the ICT sector as this sector is comprised of many young dynamic entrepreneurial firms that are better placed in a flexible environment for hiring and firing employees.

Other factors are also likely to have a similar strong effect on the effective use of ICT services. For instance, the level of expenditure of R&D that each sector uses may be strongly connected with the use of ICT and software. If that is the case, then country policies which encourages firms to use more R&D may be particularly helpful in industries that already use a lot of ICT and software. Likewise, since many innovations are done with the help of ICT, and as many innovation activities won't take place without applying for patents, industries using a lot of ICT in their innovations so as to enhance productivity could, as a consequence, be strongly dependent

³ Moreover, whilst ICT in Europe makes up a smaller share of total EU investment compared to the US, this in turn generates a lower contribution of ICT to overall productivity and eventually GDP growth when compared (Van Ark, 2014b).

⁴ Note that one study, namely Arnold, Nicoletti and Scarpetta (2008) state that also some of these complementary reform policies also hindered for countries to capitalise on the technological boom in ICT to as to effectively accumulate ICT capital.

on an efficient patent system. There are various other policy sources that are assessed as having an indirect importance on the wider usage and embedment of software and computer or ICT services in other industries, which this paper will assess.

As a result, the importance of ICT needs to be found in how productive the wider economy employs the services that the ICT sector brings forward, which can be enhanced with the implementation of complementary policies. In addition, complementary policies may also play a role in how value-added is created and enhanced within the ICT sector itself. However, this paper investigates the first channel, namely the one related to productivity in the wider economy: which complementary policies benefit industries and sectors that use ICT (and in particular software) most intensively. Hence, this paper looks into a wider set of policy measures that have been identified across the policy literature as potentially important drivers for enhanced productivity through the use of ICT (i.e. software) in other downstream industries. (OECD, 2007; van Ark, 2014).

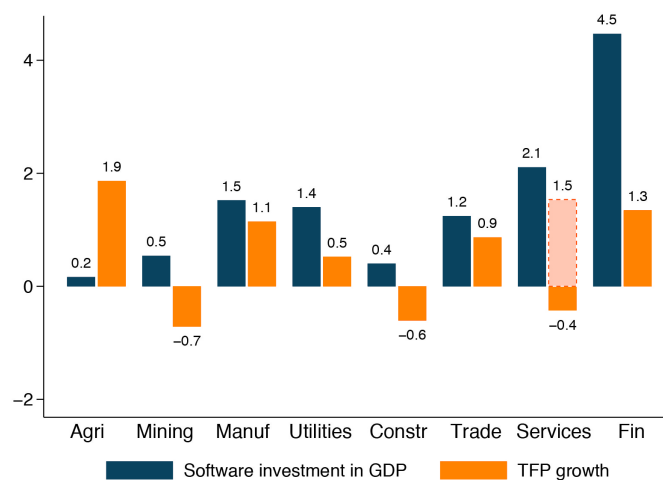
3 Productivity in the wider economy and ICT

The extent to which the economy uses capital in the production of output is highly correlated with a country's level of development. Traditionally capital as a factor of production is that part of the economy that is dedicated to physical capital such as machines. Yet, a substantial and increasing part of capital in developed OECD countries is dedicated to capital that is intangible in nature and is related to knowledge, which is therefore called intangible or knowledge-based capital. These new types of capital are divided into (i) innovative property which includes Research and Development (R&D), design, or product development in financial services; (ii) economic competences which is comprised of market research, advertising or organisational capital; and finally also (iii) computerised information. This latter part of intangible capital is comprised of software and database activities and services in which firms can invest. Since the focus of this paper is on the role of ICT, the remainder of this section focuses on this category of software capital investment.

3.1 Services

Recent research has come to conclude that these new types of capital have an additional strong effect on growth and productivity and in particular have a significant contribution on what is called the Total Factor Productivity (TFP)⁵ (van Ark et al., 2009, 2008). TFP is a measure that summarises how effective our factor inputs in an economy are used as explained in the introduction.⁵ TFP in turn stimulates output and can explain to a great degree the difference in Gross Domestic Product (GDP) per capita across OECD and EU countries (OECD, 2013; Johansson et al., 2012). As previously mentioned, software plays an important role in employing these factor inputs more effectively, also for European countries, and must therefore be related to TFP. To find out how these two issues are related within Europe, this paper has selected data from various sources and calculated the software capital investment in each sector for the EU as part of their GDP and the associated annual average TFP growth rate over the period of 1995-2010, the latest year available, which are shown in Figure 3.

⁵ TFP also depends on technological innovations across the economy next to the efficient allocation of labour and capital in the wider economy. Hence, both the ability to innovate as well as the market surroundings of firms in terms of competition and additional policy settings matters (see Syverson, 2011).

Figure 3: Software investment and TFP (2010)

Source: author's calculations with data from EUKlems, Corrado *et al.* (2011),

Figure 3 only allows for a broad-based break-up of sectors in each European economy.⁶ The figure shows that software investments were greatest in the financial services sector, which also includes insurances, followed by the other services sector which is comprised of business services, administrative services, transport and storage, arts and entertainment, as well as hotels and restaurant services.⁷ In addition, both the manufacturing sector, the distribution sector plus utilities reveal to have high investments in software relative to the overall European economy. Sectors that have low levels of software capital investment are agriculture, mining and construction. These sectors are likely to be more dependent on physical capital or labour as inputs for production. Note that many sub-sectors of services in the EU invest a lot in software relatively.

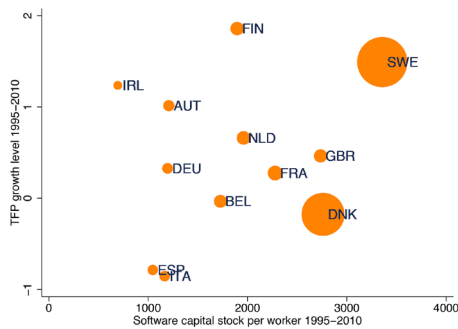
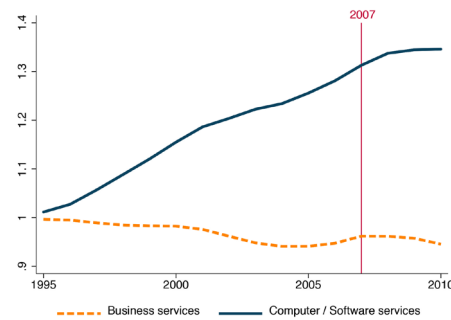
Figure 3 also shows the TFP calculations in each of these sectors. This associated TFP growth is only positively related with software investment to some extent across sectors. For instance, one can see that apart from agriculture TFP effects were greatest in the financial and manufacturing sectors, with average growth rates of 1.3 and 1.1 percent respectively while software investment in these sectors were also more than average compared to the entire economy. On the other hand, ICT investments were also relatively high in utilities, trade and other (business) services yet TFP growth in these sectors was much lower. Especially the latter category of (business) services, which is somewhat surprising in light of the fact that more and more services are becoming digitalised and produced (and traded) with the help of ICT. Given that ICT and software investment is overall highly connected with greater levels of TFP, this lower performance is puzzling.

One explanation is that the services sector as defined in Figure 3 is too crude and covers a wide variety of activities. For one, it covers services which can be supplied over the internet such as information and computer services, as well as other business and administrative services. Moreover, this category also covers services which still require proximity between producer and consumer such as art and entertainment, or transport services. When splitting up the TFP growth rate among the four narrower services sectors included in this broad sector, the ICT sector actually shows an annual average growth rate of 1.5. Yet, all other services sectors including business services have low or even negative growth rates. As stated, this is puzzling as many of these services use a lot of software, which should result in greater TFP over time.⁸

⁶ Countries include Spain, Italy, Belgium, Denmark, Germany, France, Great Britain, Netherlands, Austria, Ireland and Finland. Other countries were not available.

⁷ Admittedly, this is a broad category but unfortunately industry-level data from Corrado *et al.* (2011) on intangible capital investments do not allow for a further break down of this category. On the other hand, EUKlems data on TFP does provide more disaggregated sector-level classifications.

⁸ The negative TFP levels of the business services sectors were also found in Corrado and Jager (2014).

Figure 4: Software capital stock and TFP growth, 1995-2010**Figure 5: TFP for software and business services over time, 1995-2010**

Source: EUKlems, Corrado *et al.* (2011), WB, author's calculations, TFP for both sectors are weighted by each country and by their USD value and deflated using software and business services deflators. The size of each marker dot in the left-hand panel represents the software investment per worker in terms of gross fixed capital formation.

Why then is it that some sectors have experienced greater levels of TFP associated with software than others, particularly when looking at the services sector as illustrated in Figure 5? One potential explanation that this paper argues is that this needs to be found in the role of complementary policy measures that are connected with the use of ICT and software in particular. Countries that have implemented these policies, in which some sectors are better able to capitalise because of their ICT usage, could therefore have higher levels of productivity. In other words, the adoption and diffusion of ICT and software appears to be slow in the services sector as this sector may be particularly dependent on so-called second-tier or complementary policies to unlock the effective use of software.

4 Policy distortions

Differences in the efficiency of allocating resources in the form of factor endowments such as labour and capital, which can be achieved with the employment of software within each sector, may therefore be caused by distortions in the complementary policies countries apply. (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008). As a result, this distortion carries along important adverse consequences for productivity and eventually growth in each of these sectors.⁹ As previously stated, an example includes labour market regulations, which in the presence of rigid policies may prevent labour within a sector from flowing from the least productive firms to the most productive firms that use software. For instance, young firms which use lots of software in their product development may actually benefit from a flexible labour environment as they are resource scarce and may encounter fast entrepreneurial business cycles.¹⁰

This indicates that complementary policy factors distort the optimal attainment of greater gains stemming from using more software, which in the case of adjustment will result in TFP improvement. Our quantitative analysis, which is explained in Annex 1 and which is performed for this paper, indeed shows that this is the case to a very significant extent. Rigid regulations or stiff policies that prevent competition or otherwise increase the costs of doing business in the economy that do not optimally re-allocate resources reduces the ability to reach higher TFP growth.

As such, one could think of two levels of policies that are important for the efficient allocation of software capital, namely a first-tier policy setting to address the availability of ICT in addition

⁹ See also Colletia, A. and P. Shreyer (2002) on the importance of ICT capital services and economy-wide growth in using sectors as an early study on this issue.

¹⁰ Similarly, regulation on the distribution of private credit to firms by banks may result in this credit not being given to those firms which are most innovative and productive when using software in business models, or to those new ones which would like to enter the market. Also, start-ups costs may further inflict a higher cost for software intensive industries which may further negatively impact performance.

to a second-tier policy set that is needed to improve the allocation of ICT or software capital by firms within each sector. As stated in the introduction, a host of public policy areas could potentially fall into the second-tier group, although in this report we have assessed only those policy disciplines, which the policy literature has identified as relevant and for which data was available. The results of our research exercise on which policies areas are important determinants are summarised in order of relative importance in Figures 6 and 7 for both the level and growth of TFP, respectively.

Figure 6: Policies influencing TFP level

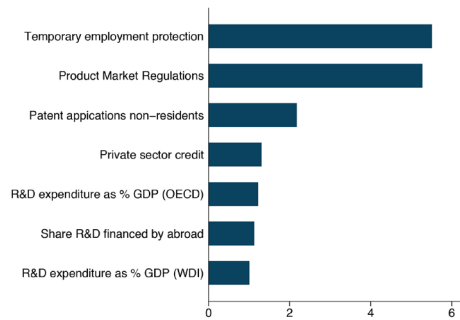
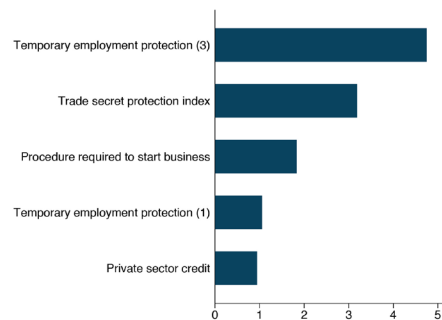


Figure 7: Policies influencing TFP growth



Source: various, see Annex 1. Note that the horizontal axis reflects the standardized coefficient results from our empirical exercise explained in the annex.

In Figure 6, where TFP levels are shown, TFP represents the so-called static productivity effects whereas in Figure 7 TFP growth used is more linked to the so-called dynamic effects over time. For example, some policies may help explain why some industries across European economies have obtained greater levels of TFP, but that does not explain how these industries might see faster growth in their TFP. Note that all policy measures summarised in Figure 6 as well as Figure 7 are contingent on the use of software in each of the industries analysed. Put differently, only in combination with a greater usage of software services will these country-wide policy indicators have an important effect in reaching greater levels of TFP.

Which policies hence appear to matter? The first and foremost point to single out in Figure 6 is that in terms of levels these are labour market flexibilities. Interestingly, these labour market policies that affect TFP through the usage of software are mainly connected to temporary employment protection as opposed to long-term labour contract protection. This latter policy indicator has also been used, but found to be insignificant. Part of the explanation may lie, as previously mentioned, in that many firms that use software are small and dynamic which for their purposes are more helped with more flexible short-term labour contracts.

A second strong issue that stands out are product market regulations, which prevent markets from introducing more competition. Third, an “open” patent application system and also policies dedicated to the diffusion of private capital, as well as policies dedicated to more R&D expenditure, are found to be having all a significant impact in reaching higher TFP for industries using employing more software. Moreover, Figure 6 also shows that countries that allow for R&D coming from abroad have stronger TFP levels in industries that use greater levels of software.

In terms of dynamic effects, different policies seem to matter. However, one strong factor that stands out again is a more flexible labour market regarding temporary contracts.¹¹ One potential explanation is that productivity effects as a consequence of using more software are particularly felt in firms that experiment in innovation. These are young dynamic firms which are hampered in their productivity as they face greater exit costs with higher labour regulations in case their innovation fails. Moreover, and in connection to this, previous literature (i.e. Bartelsman et al., 2010) have found that countries with lower labour market regulations are also the ones in which sectors generally choose high-risk innovations, which is associated with greater levels of ICT-use and can bring greater gains in TFP. If labour market policies are inflexible, it could therefore lead to lower productivity as high-firing or labour exit costs are greater.¹² Figure 7 shows that various indicators for temporary labour flexibility are used (i.e. indicated by (1) and (3)), which provide similar robust results.¹³

Other policies also matter significantly for TFP growth. Figure 7 shows, furthermore, that countries with greater levels of trade secret protection will help industries that use much software in achieving higher productivity growth. This too may be related to the innovations that many sectors undertake, in particular services industries, as a way of protecting their intangible assets. Some studies found that the enactment of trade secrets was associated with a significant increase in R&D spending (Png, 2012) and that small and medium sized firms are particularly reliant on trade secret protection (Brant and Lohse, 2013). Many services sectors, for instance, are marked by small and medium-sized firms.

The other two policy factors that affect TFP growth may also be linked to innovation and the fact that firms are small and medium-sized or young; namely private credit availability and the costs it takes to establish a firm. New firms bring new products to the market for which they first need to innovate with the help of ICT. Many new entrepreneurial activities that require credit take place in risky technologies. Limiting the availability of credit to these new firms will reduce productivity that stems from these technology-intensive undertakings. As such, when private credit is not given to these new firms and policy distortions will therefore take place, it will prevent countries from reaching greater growth rates in productivity. In a similar manner, too many burdensome administration procedures implemented by countries which create high costs for entering a market for new firms, may reduce TFP particularly strongly when this policy distortion affects firms that otherwise would have introduced new innovations and technologies.

Both Figures 6 and 7 outline the factors that have been found to be significant. That does not mean, however, that other factors do not play any role on productivity. On the contrary, our analysis has analysed all possible factors that are identified as having an influence on productivity through the use of ICT and other so-called intangible investments. However, other policy factors are found to be insensitive through our variable of interest, namely software intensity. That does not mean that these policy issues may, however, have a significant effect on other types of intangible capital such as scientific R&D, organisational capital, innovative property, etc. This may probably be true as some of the literature has found. Yet, when singling out the effects on software, these policy factors remain insignificant.

¹¹ This paper has used various proxies variable for measuring labour market regulations in the empirical exercise in Annex 1. For instance, we have used data on labour market regulations from the OECD's Employment Protection Legislation (EPL) database as well as a proxy variable from the Fraser Institute on overall regulations in labour markets. Both indicators came out as having a significant effect on TFP growth when interacted with software intensity at the sector-level.

¹² Related to this research is Griffith and Macartney (2014) which found that multinational firms have a higher share of innovative activities in countries with higher labour market regulations (i.e. EPL) greater enforceability of job contracts may increase worker investment in innovative activity, but that these firms have a higher proportion of technology advanced innovations in countries with lower labour market regulations.

¹³ Note, however, that not under any circumstances a more flexible labour market is warranted for having optimal real-location effects. Some studies such as Blanchard, Jaumotte and Loungani (2013) also find that in some circumstances stable employment relationships are beneficial for industries to reap greater productivity.

Box 1: ICT contribution to value-added growth in services

In Figure 3 it became clear that at least in the case of services, investment in software and ICT takes place without the desired effect of increasing productivity. Part of the explanation that this paper outlines is that complementary policy measures do not stand up so as to let specific non-ICT sectors benefit from the overall diffusion of ICT and software, i.e. additional policies restrict their productive use. This is particularly so in industries and countries which are in the first place lagging in productivity in services. Instead of using a productivity measure in each sector, one could also use an alternative measure for analysing this issue in more detail such as the direct ICT contribution to value-added in the services sector specifically and then relate them to these complementary policy measures. With the limited amount of data at hand, Figures 8 and 9 further illustrate these effects.

Figure 8: ICT contribution to value-added growth in retail and PMR in retail, 1995-2010

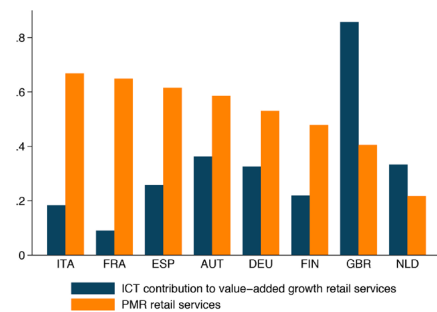
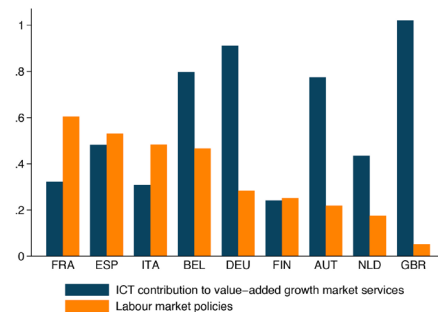


Figure 9: ICT contribution to value-added growth in market services and EPL, 1995-2010



Source: EUKLEMS, OECD PMR and EPL, author's calculations

Two of these regulatory aspects and their indirect effect on the diffusion of software or ICT are shown in these figures for services as productivity was lacking in these sectors. Figure 8 shows the ICT contribution to value-added growth in retail services and connects this to the level of product market regulations in this sector. Although a clear pattern is not visible (as there are other factors that play a role too, as discussed), some countries such as the UK seem to better capitalise on the productive use of ICT in the Retail sector. For market services as whole, Figure 9 shows that flexible labour markets in terms of short term contracts as taken up in our study is to some extent precisely adversely related to the overall ICT contribution to value-added growth, at least in some countries. In these countries, the effective dispersion of value-added from the ICT sector could hence be found in reforming complementary measures such as labour market regulations.

5 Conclusion

In terms of productivity performance, the ICT sector and, in particular software services, are the shining star of the European economy among the many other sectors which are lagging in terms of both productivity. This is particularly true when put next to business services, which is comprised of a large share in the European economy. Since these services are relatively intense in ICT, and since the majority of European economies are comprised of services, one important question is what could the EU do? This paper has found a set of policies that could further increase productivity in the EU and which are related to the use of ICT or software.

One policy issue that stands out for reaching higher productivity levels in software dependent sectors are labour market policies, in particular the flexibility of short-term employment measures in the EU. The EU has limited competences when it comes to labour market reforms, but since the onset of the financial crisis in 2008, EU institutions are pressing EU member states to reform their labour law so as to have supportive labour taxation, to develop employment protection that favours job creation, and adjusted-friend wage setting frameworks. However, regarding temporary employment contracts no specific regulatory framework exists in the EU, although some European countries still have inflexible rules such as Luxembourg, Spain, France and Italy. Some of these countries have low software stocks in each of their industries and sectors, which points to a lower amount of new technologies in these sectors.

A second cluster of results relate to patents, R&D expenditures and trade secret protections, which stimulate the use and effective diffusion of software in the economy. The EU signed a unitary patent package in 2013, which means that foreign applications of patents won't face significantly higher costs in other EU member states. This is particularly relevant, as our results have shown that non-resident patent applications have a particularly strong effect on efficiency in industries using a higher amount of software and ICT. However, both Spain and Croatia have up to this moment refused to sign the package agreement. In addition, both trade secret protection and patent protection appear to be important determinants for the use of software and ICT. On the latter, the EU is currently trying to harmonise the segmented national frameworks, particularly against the misappropriation of trade secrets and setting up a common definition across member states. A proposed package is now under review at the European Parliament. Although European countries overall have strong protection in this area, some member states such as Sweden and France form the middleman and therefore their practise can be improved. Bulgaria performs worst of all EU countries.

A final cluster relates to the product market, costs of doing business or starting a business, and other factors such as obtaining credit. Again, although product market regulations are on the whole relatively low in the EU, some issues remain. In these areas there is still some heterogeneity across the EU in terms of state control of barriers to entrepreneurship, which seem to be particularly pressing for software intensive firms and industries when entering the market. Particularly in Spain, Portugal, Luxemburg or Ireland the complexity of regulatory procedures and administrative burdens for start-ups can be improved. Overall, the contestability (i.e. entry) to EU markets are high as overall little regulatory protection for the incumbents are provided in the EU. EU policies related to private credit banking or private sector credit are currently proposed by the European Commission. This plan aims to create a true European capital market, which is still underdeveloped and fragmented across member states. For instance, SME's in the EU receive five times less funding through capital markets compared to the US. In tandem with this, strengthening the legal rights between borrower and lender in the EU would considerably enhance value-added in the whole ICT sector.

Finally, other policies that have not been taken up in this study because no data yet exists are likely to matter too, particularly for Europe. For instance, the recent proliferation of some regulations connected with the use of data are likely to have a further significant impact on how industries are likely to reach higher productivity levels. Many services today are using much ICT and in particular software in their production processes for which data is transmitted between third suppliers that can be located across various geographical locations. In such a setting it becomes important for ICT and software-using industries to have a free flow of data across borders. The EU, together with various other countries around the world has implemented some measures to restrict the free flow of data such as the storage of data within domestic borders on local services or even the prohibition of sending data to other countries outside the EU. This will likely have

an adverse effect on the ICT-using sectors to reach higher productivity. Indeed, a recent study by ECIPE (2014) has shown that this is the case also for European countries.

In all, the ICT sector, and in particular software, is an important ingredient for the economy. It affects how productive other sectors can become in this usage of ICT and software. The effective use of ICT and software is in large part dependent on other complementary policies that stimulate industries to use ICT so as to reach greater value-added and output.

Annex 1: Estimation strategy for TFP

This annex explains the estimation strategy for analysing what policy measures have an impact on TFP through the use of software in various sectors of the economy in the EU. The literature has pointed out that within-sector analysis is warranted when explaining productivity. Since there is good information on TFP and sufficient data that allows for calculating the stock of software capital in each sector for a variety of European countries, computations can be applied so as to study the various policy indicators which are described in the literature to have an effect on the relation between software and TFP (albeit not formally measured yet).

By doing so, this paper takes a comprehensive approach by assessing this linkage between economy-wide policy measures, sector-specific TFP and software capital stock for each country, over time. This estimation equation follows the specification developed by Zingales and Rajan (1998). However additional studies on growth also take account of the neo-Schumpeterian growth theory in the sense that both innovation and imitation activities also have an influence on growth and productivity such as Aghion and Howitt (2006, 2009) and Acemuglu, Zilibotti and Aghion (2006). This approach has found empirical underpinnings in studies such as Nicoletti and Scarpetti (2003), Griffith, Redding and Van Reenen (2004) and more recently McMorrow, Werner and Turrini (2010). Therefore, we take the following approach in our empirical specification, which is based on these previous works:

$$\Delta TFP_{cst} = \theta_1 \ln(\text{Tech Frontier})_{Lst(t-1)} + \theta_2 \ln(\text{Tech Gap})_{cst(t-1)} + \theta_3 \ln(\text{Software capital stock})_{cst(t-1)} + \theta_4 \ln(\text{Software capital stock})_{cst(t-1)} * \text{Country Policy}_{cst(t-1)} + \delta_c + \delta_s + \delta_t + \varepsilon_{cst} \quad (1)$$

In this equation, TFP_{cst} stands for Total Factor Productivity for each country c , sector s for both the level as well as for growth (Δ) in year t . Both *Tech Frontier* and *Tech Gap* stand for the technological frontier and technology gap respectively and follows standard practise from the literature previously mentioned and is calculated by country year sector. The technology frontier is the global frontier and is defined by the country L with the highest TFP in a particular sector and year. The technology gap is calculated as the difference between the TFP rate of the global frontier by sector, $TFP_{Lst(t-1)}$, and the TFP rate of the country-sector in question, namely $TFP_{cst(t-1)}$. Both terms are included since policies can have a differential effect on growth and productivity depending on whether the sector of a country is regarding its stage of technological development.

The variable $\ln(\text{Software capital stock})$ represents the log of the accumulated net real stock of software investments made in each sector and country over time. The *Country Policy* term is our variable of interest and denotes the various policy measures which are described in the existing policy literature to have an effect on TFP through (or in combination with) the use of software. Since we are dealing with panel data by country and sector, we apply fixed effects by country (δ_c), sector (δ_s) and time (δ_t), which control for the unobserved influences that might otherwise have an independent effect on the level and growth of TFP such as physical capital stock or high-skilled labour input. Since it takes time before the impact of policies on TFP materialises, equation (1) takes the lag of all variables with one year. The final term is the error term, which is clustered by its highest dimension, namely by country.

The years 1995-2010 are taken with 2010 being the latest year available for European economies only, namely Finland, United Kingdom, Netherlands, Sweden, France, Austria, Germany, Belgium, Italy, Spain, Denmark, Greece, Ireland and Portugal. Note that Ireland and Denmark actually report TFP figures up until 2007.

The interaction terms make sure that what is measured within this equation is the so-called match between the sector-specific amount of software capital stock and the economy-wide policy indicator for each country and year. It is precisely this linear combination of country and industry characteristics, which determines a country's productivity position in that sector. For instance, countries where a higher share of R&D is financed by industry will on average be more productive in industries that have accumulated a higher stock of software capital, precisely because they are complementary. Such interaction terms single out, above all, the role of business

R&D on TFP with θ standing for the coefficient parameter that measures how important this policy measure is for generating a higher level and growth rate of productivity. Note that all our independent variables are standardised, which means that across the regressions these various policy indicators can be readily compared with each other in terms of importance by their coefficient sizes.

The variable TFP is taken from the EUKLEMS database and selected for the main sector for which there is data on capital investments (see below). These sectors are Agriculture and Fisheries (A), Mining (B), Manufacturing (C), Utilities (D-E), Construction (F), Trade (G), Financial Services (K), and finally Other Services (H-J_M-N_R-S), which includes Transport (H), Accommodation (I), Information and Communication Services (J), Professional, Scientific, Technical and Administrative services (M-N), plus Arts and Education services (R-S). TFP figures based on value-added are taken up in the regressions in a non-logged transformation whilst the yearly growth rate (Δ) is calculated as the first difference in logs. Note that the EUKLEMS provides TFP data for each sub-category of other services separately, which means that each sub-sector in this category has been weighted by the total value-added production. Data on total value-added is also taken from the EUKLEMS. By doing so, a more precise (weighted) average for the category other services is constructed. Data on TFP for Denmark, Greece, Ireland and Portugal are until 2007.

The data for software investments are taken from Intan-Invest and recalculated into capital stocks, which is necessary if one wants to obtain meaningful measures or so-called intensities that can be linked to productivity (i.e. TFP). This methodology is based on Hall and Jones (1999) and forms standard practise in economic literature. This database is new and developed by Corrado *et al.* (2012). It sets out the so-called intangible capital investments, which next to software also comprises investments in innovation property, economic competences, organisational capital, etc. Since we are only interested in the role of ICT and software, we focus on the category of computer software.

In particular, we take the Gross Fixed Capital Formation from which we are able to compute stocks according to the perpetual inventory method. In this method one needs to have a credible depreciation rate (assumed constant over time) which is given in Corrado *et al.* (2012), namely 0.315. Using this depreciation rate together with our time-series of Gross Fixed Capital Formation and its annual average growth rate over time, we are able to compute the initial capital stock in 1995 and the accumulated stock up to 2010 for each sector and country. Of note, Gross Fixed Capital Formation data are all deflated with special software deflators and converted into US dollars. Finally, the obtained software stocks are divided by the amount of workers in each sector, which is based on country-wide variable Labour Force (i.e. amount of workers) from the World Bank's WDI, and for which each sector's amount of workers is determined by its value-share.

Our country-wide policy measures, which are of interest, cover a larger set of data sources and we will report only those which are found to have a significant influence. They are provided in Table A.1 and are selected on the basis of the previous literature discussed in this paper that provides descriptive or country-specific conclusions on the impact of each of these policy variables on the use of software and its effect on TFP, which we call the complementary policies in this paper. In large part they are inspired from OECD (2013) and Syverson (2011).

Table A.1: Sources and description of country-wide policy variables

Variable	Description	Source
Patents_nonres	Number of patents applications from non-residents	World Bank's WDI
R&DexpGDP_WB	Total R&D expenditure of GDP	World Bank's WDI
Procstartbus*	Number of procedures required to start a business	World Bank's DB
R&DexpGDP_OECD	Total R&D expenditure of GDP	OECD STI
R&DindGDP	Industry-financed R&D as a percentage of GDP	OECD STI
R&D_abr	Percentage of R&D financed by abroad	OECD STI
Cred_reg*	Credit market regulation	Fraser Institute
PrivCred_reg*	Private sector credit regulation	Fraser Institute
Lab_reg_tem (1)*	Temporary contract labour market regulations (rescaled)	OECD EPL
Lab_reg_tem (3)*	Temporary contract labour market regulations (rescaled)	OECD EPL
TSPI	Trade Secret Protection Index	OECD (2015)
PMR*	Product Market Regulations	OECD PMR

Note: variables indicated with an * are flipped so as to have increasing values associated lower regulatory costs involved

The results can be seen in Table A.2 and A.3 for the levels and growth of TFP respectively. In Table A.2 one can see that the fact of whether an industry is at the technology frontier or is further away from the frontier makes a significant difference: Industries at the frontier have a higher level of TFP and positive coefficient sign than industries that have technology gap which show a negative sign. The variable on the stock of software does not mean much on its own as this variable is part of all other interaction terms with the country-wide policy measures.

Regarding these policy measures, the extent to which there is less private credit regulations appear to have a very significant positive effect on growth in software-intensive industries as shown in column 1. Other regulatory barriers as measured by the PMR and labour market regulations also obtain a significant outcome albeit PMR at the 10 percent level. In both cases it means that industries with high levels of software exhibit higher levels of TFP in countries with lower regulations in labour and product markets. In addition, patent applications from non-residents also matter in terms of TFP for software-intensive industries with a coefficient that is very significant at the 1 percent level. Finally, R&D expenditures also matter and it matters where R&D comes from. Both variables of the level of R&D expenditure as part of GDP are significant. These variables are taken from the World Bank and OECD and since they both have a significant impact, they reassure of the validity of this policy measure. Next to this overall R&D measure, however, what also seems to matter is the extent to which R&D is coming from abroad as this last variable is also significant in column 5.

Table A.3 shows first that the patterns of industries at or further away from the frontier are reversed in the sense that industries at the frontier have lower TFP growth rates than industries further away. This is what we could expect if we express TFP in growth rates. Again, the extent to which credit is provided in the private sector without regulation is a significant policy measures in column 1. What also appears to matter is the fact that firms by their start-up are faced with low administration costs at the variable on a number of procedures for starting up a business is also significant although at a lower significance level. Yet the size of the coefficient suggests that this policy nonetheless has important effects on TFP in industries using software. Next, in both columns 3 and 4 two different types of regulations of labour market frictions regarding short-term contracts are entered, but both with a significant effect. The former variable reflects the temporary employment variable from the OECD EPL EPT_V1 whereas the latter one is the EPT_V3 with a shorter time span. Last, a rather significant and sizable outcome is whether countries have high protection for trade secrets which seem to have an impact on TFP in sectors using more software.

Note that the R-squared in Table A.3 in all specifications are low, which is common for measuring productivity (i.e. TFP) in terms of growth in the literature, and means that there are many other factors that can in addition impact the level of TFP. Overall, it's extremely hard to trace back which policy measures really have an effect on growth. Furthermore, all policy indicators are entered separately as they are highly collinear with each other and are therefore not put together in a separate final column. As a final note, spurious correlations or endogenous effects are dealt with as much as possible. For instance, all independent variables have lagged values of one year. Even taking more lags shows the results obtained in Figure A.2 and A.3 are robust (output can be obtained upon request). Moreover, fixed effects should, in addition, take away some of the endogeneity that could occur at country and industry level separately. Finally, by taking the year-on-year growth rates, any further endogeneity that may otherwise be measured by taking TFP levels are eliminated in such specification.

One last note on the selection of policy indicators. Although all coefficient variables are significant in both tables, it does not mean other policy variables that have been assessed in the literature as important for productivity and software have been tested. On the contrary, additional policy factors such as collective employment protection, other items of the cost of doing business (as taken from the World Bank's Doing Business database), or the quality of the digital infrastructure (as measured by the WEF's Network Readiness Indicator) and various others policy variables do not have any effect in our empirical set-up. That is, when interacting with the level of software capital stock for each sector (i.e. software intensity) no significant impact was found for these additional policy indicators.

Table A.2: TFP level and policy impacts through sectoral software intensities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	TFP	TFP	TFP	TFP	TFP	TFP	TFP
Technology Frontier	0.8618*** (0.0324)	0.8568*** (0.0331)	0.8575*** (0.0348)	0.8422*** (0.0413)	0.8520*** (0.0353)	0.8600*** (0.0335)	0.5536*** (0.1605)
Technology Gap	-0.8481*** (0.0180)	-0.8448*** (0.0174)	-0.8408*** (0.0203)	-0.8059*** (0.0285)	-0.8516*** (0.0191)	-0.8477*** (0.0174)	-0.8638*** (0.0795)
lnSoft (K/L)	-0.6682 (0.3922)	0.4352 (0.3025)	0.1448 (0.2105)	-4.1909* (2.0937)	0.0605 (0.3201)	-0.0258 (0.2562)	-3.0833* (1.4334)
lnSoft (K/L) * PrivCred_reg	1.3101*** (0.2987)						
lnSoft (K/L) * Patents_nonres		2.1737*** (0.3619)					
lnSoft (K/L) * R&DexpGDP_WB			1.0055* (0.5199)				
lnSoft (K/L) * PMR				5.2742* (2.4000)			
lnSoft (K/L) * R&D_abr					1.1242** (0.3816)		
lnSoft (K/L) * R&DexpGDP_OECD						1.2210** (0.5200)	
lnSoft (K/L) * Lab_reg_tem (3)							5.5071*** (1.1298)
FE country	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FE sector	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FE year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,376	1,304	1,242	1,094	1,169	1,336	160
R-squared	0.8231	0.8224	0.8030	0.7598	0.8254	0.8204	0.8363
RMSE	5.682	5.780	5.704	5.431	5.859	5.738	5.668

Source: various, see text above in this box. Authors' own calculations. ***, ** and * indicates significance at the 1%, 5% and 10% level respectively. Robust standard errors clustered by countries applied. In each specification, fixed affects by country, sector and year are included. All variables are standardised.

Table A.3: TFP growth and policy impacts through sectoral software intensities

	(1)	(2)	(3)	(4)	(5)
	D.lnTFP	D.lnTFP	D.lnTFP	D.lnTFP	D.lnTFP
Technology Frontier	-0.1223* (0.0572)	0.0472 (0.1103)	-0.1201* (0.0585)	-0.6264** (0.2176)	-0.1507* (0.0760)
Technology Gap	0.0868* (0.0457)	0.0492 (0.0574)	0.0851 (0.0476)	0.1622** (0.0642)	0.1192* (0.0588)
lnSoft (K/L)	-0.1090 (0.5371)	-0.5963 (0.7191)	0.1429 (0.4324)	-3.2903** (1.3325)	-2.6319* (1.3179)
lnSoft (K/L) * PrivCred_reg	0.9434** (0.3503)				
lnSoft (K/L) * Procstartbus		1.8322* (0.9305)			
lnSoft (K/L) * Lab_reg_tem (1)			1.0563* (0.4931)		
lnSoft (K/L) * Lab_reg_tem (3)				4.7478** (1.5811)	
lnSoft (K/L) * TSPI					3.1866** (1.0705)
FE country	Yes	Yes	Yes	Yes	Yes
FE sector	Yes	Yes	Yes	Yes	Yes
FE year	Yes	Yes	Yes	Yes	Yes
Observations	1,282	430	1,282	160	861
R-squared	0.1221	0.2055	0.1212	0.3310	0.1445
RMSE	5.513	5.728	5.516	5.778	5.531

Source: various, see text above in this box. Authors' own calculations. ***, ** and * indicates significance at the 1%, 5% and 10% level respectively. Robust standard errors clustered by countries applied. In each specification, fixed affects by country, sector and year are included. All variables are standardised.

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