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European Competitiveness Report 2013 :
Towards knowledge driven reindustrialisation

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Chapter 3.

REDUCING PRODUCTIVITY AND EFFICIENCY GAPS: THE ROLE OF KNOWLEDGE ASSETS, ABSORPTIVE CAPACITY AND INSTITUTIONS

From the mid-1990s productivity growth in the EU slowed down compared to the US, which in contrast was experiencing rapid productivity acceleration (O'Mahony and van Ark, 2003). As a result, the US-EU productivity gap widened. While the post-1995 productivity slowdown was felt across all EU countries, productivity trends have differed and economic disparities have amplified (Mas, 2010) since the economic and financial crisis, which hit countries with different intensities. Understanding the reasons underlying productivity differentials has become a priority for policy makers so that useful policies to promote and restore long-lasting economic growth in Europe, beyond the traditional models of catch-up and convergence, can be implemented.

Productivity, a key source of economic growth and competitiveness, is defined as the amount of output that can be produced per unit of input. The term productivity, however, is used to describe two related concepts: labour productivity and total factor productivity (TFP). Labour productivity, which refers to the amount produced per each unit of labour, can be improved through either a greater use of capital relative to labour (capital deepening), or through an increase in TFP growth as an essential component of labour productivity growth. TFP measures the part of an output increase not accounted for by increases in the quantity and quality of inputs. TFP movements are mainly due to technical efficiency increases, which imply catching up to the existing technology frontier, or due to technological improvements as the frontier shifts outwards over time.

Prior to the financial and economic crisis which started during 2007-2008, the debate on the European labour productivity slowdown pointed to ICT capital accumulation as a major reason for the under-performance of EU labour productivity. This largely reflected the significantly slower adoption of ICT technologies in the EU compared to the US, in particular in services sectors. Moreover, industry-based studies revealed that the US productivity advantage was concentrated in specific services sectors, mainly trade, finance and business services (Timmer et al. 2010). In these ICT-intensive using sectors, the large ICT investment flows during the second half of the 1990s together with complementary investments in organizational capital led to a rapid TFP growth during the first half of the 2000s (Van Ark et al, 2008; Brynjolfsson and Saunders 2010).

The initial hypothesis was that Europe was merely lagging behind the US in the adoption of ICT technologies, and therefore, it would take some time for its benefits to materialise. Now, it has become apparent that high levels of investment alone do not produce faster economic growth and better productivity performance. Several years after the 'ICT revolution', the EU is not only still lagging behind the US, but the productivity growth gap has recently widened.

Empirical findings show that in the EU there was insufficient investment in the skills and organizational changes necessary to reap the benefits of ICT technologies (Brynjolfsson and Hitt 2000; O'Mahony and Vecchi 2005). Lower investments in intangible assets broadly conceived (R&D, human capital, etc.) are likely to explain a portion of the US-EU productivity gap as these factors affect countries' absorptive capacity, i.e. their ability to take advantage of the technology developed elsewhere (international technology transfers).

Most of the leading technologies available worldwide are developed by a few frontier countries which dominate the entire global market. Technological laggards can benefit by imitating such technologies through international trade. However, in order to assimilate and exploit the foreign knowledge in the production of their own goods, it is indispensable for laggard countries to develop a certain degree of absorptive capacity, i.e. to reach a minimum threshold of technological competence. Absorptive capacity is considered essential to close the gap with the technology leaders and spur economic growth (Griffith et al. 2004).

Another factor that has recently been identified as a cause of the lower TFP performance in the EU, is the more rigid regulatory framework compared to that in the US (Nicodème and Sauner-Leroy 2004, Bourlés et al. 2012). For example, it has been shown that low levels of competition and strict employment laws prevent the necessary optimal adjustments to factor allocation in order to take full advantage of new technologies (Conway et al. 2006; Bassanini et al. 2009; Arnold et al. 2011).

An issue largely unexplored, and to which this study wishes to contribute, is whether the regulatory environment determines the efficiency with which resources are used in production (technical efficiency). This has become a major issue in recent years as the ability to exploit existing resources emerges as one of the most important sources of productivity gains in the most mature economies (van Ark et al., 2012).

Although the recent downturn has shifted the focus on the functioning of markets as, a possible mechanism driving productivity differentials across areas of the world, understanding the channels through which the regulatory environment determines TFP growth, remains a challenge.

The main contribution of this chapter is to provide a comprehensive analysis of the determinants of productivity growth, focusing on the role played by the restrictions in the product, labour and financial markets as well as, the role of intangible assets (e.g. ICT, R&D) and absorptive capacity (e.g. skills). The use of Stochastic Frontier Analysis, is used to investigate the main factors affecting changes in technical efficiency for a large sample of countries and industries in the EU, an issue largely unexplored in the literature to date.

Specifically, this chapter addresses the following questions:

- What are the recent trends in productivity growth in the EU and the US? Which areas of the economy are driving the most recent growth patterns? What is the relative role of the various factors inputs?
- Do the institutional framework and laws governing the functioning of the factor and product markets shape the EU's ability to benefit from technology originated in the frontier countries?
- Does the EU regulatory setting influence the level of production efficiency, i.e. the ability of firms/industries to use factor inputs in the most technically feasible way? What are the main institutional factors that explain the efficiency gap with the US? To what extent do these factors interact with the use of ICT and with the technology characteristics of EU industries?

Section 3.1 of this chapter highlights the main productivity and growth trends in the EU in comparison with other major world economies for the period from 1995 to 2012. A decomposition of labour productivity growth into its main components, and a detailed up-to-date account of sectoral productivity developments are provided. Section 3.2 reports econometric evidence on the factors affecting international diffusion of R&D focusing on the institutional determinants of a country's absorptive capacity, Section 3.3 quantifies the extent to which ICT and institutional factors have had an impact on the efficient use of resources. Assessing both the economic and institutional drivers of technical efficiency is helpful to understand the sources of the productivity gap and to design policies that might reduce it. Section 3.4 integrates the analysis by presenting evidence on firm behaviour at the outset of the crisis, focusing on firms' strategic decisions regarding investments in tangible and knowledge assets and their impact on productivity. Section 3.5 concludes the analysis and outlines the policy implications.

3.1. GROWTH ACCOUNTING AND THE EFFECT OF THE CRISIS AT COUNTRY AND SECTOR LEVEL

3.1.1. Economic performance of the EU and other major economies: overview of aggregate output and productivity trends

This section presents an overview of recent output and productivity trends in the EU, highlighting the main convergence and divergence patterns from a comparative perspective. From the mid-1990s the US economy has grown at a higher rate than the EU and Japan (see Figure 3.1). During the period 1995-2004, the average GDP[1] growth rate in the US was 3.3%, around 0.85 percentage points higher than that experienced by the EU-27. This trend reversed briefly during the period 2004-2007, as the EU-27 started to grow faster than the US (3% versus 2.5%). This performance was partly driven by the newest Member States, as GDP growth in the EU-27 was higher than the EU-15. Japan performed considerably worse than Europe during the period 1995-2007, achieving only moderate GDP growth rates (between 1 % and 1.5%).

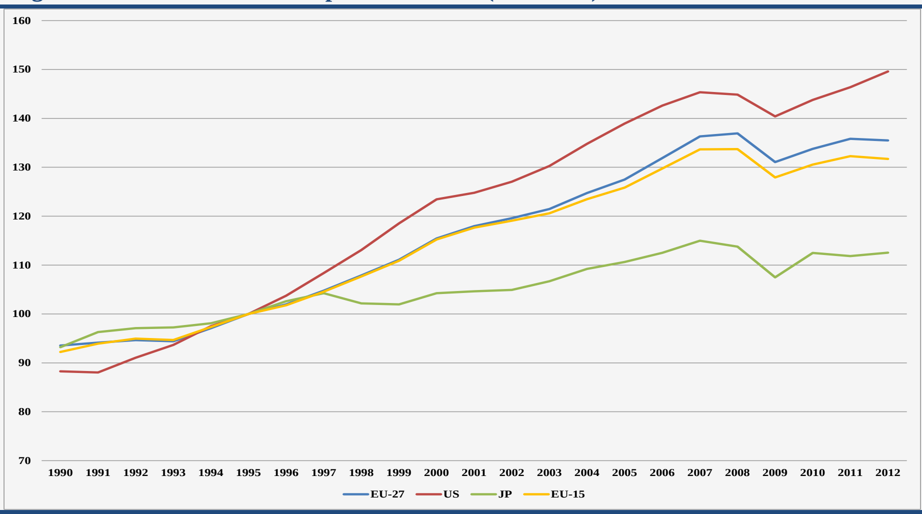
At the outset of the crisis, in 2008, output growth slowed down across all areas, and in 2009 output levels fell globally. By 2010, however growth had resumed across the US, EU and Japan. The US exhibited the strongest recovery. Performance in the EU improved during 2010 and 2011; however, the sovereign debt crisis caused a fall in GDP growth in

1 The source for the Gross Domestic Product data is the Total Economy database, The Conference Board, January 2013 release.

2012. Japan's output level has remained largely flat since 2010.

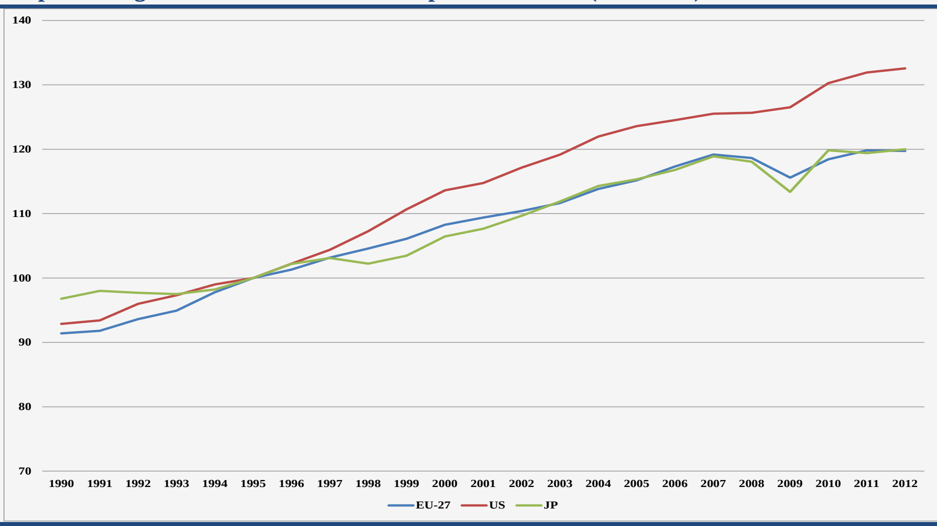
aftermath of the crisis, only to recover from 2010. As a result, the gap in labour productivity between the US and the EU widened again. Between 2007 and

Figure 3.1. GDP growth in the EU, US and Japan. 1990-2012 (1995=100)



Source : The Conference Board Database and own calculations.

Figure 3.2. GDP per hour growth in the EU, US and Japan. 1990-2012 (1995=100)



Source: The Conference Board Total Economy Database and own calculations.

Figure 3.2 illustrates trends in productivity, measured as GDP per hour, in the EU, US and Japan. From the mid-1990s to the early 2000s productivity accelerated in the US but not in Europe or Japan. In a period characterised by the widespread diffusion of Information and Communication Technologies (ICT), the US's productivity lead was amplified thanks to its greater ability to invest and benefit from the new technology. While EU productivity showed signs of catching up towards US levels during 2004-2007 (see Figure 3.1), the onset of the crisis has worsened the EU position. Although slower than in the pre-crisis period, the US labour US labour productivity growth rate fluctuated around 1% per annum, even at the height of the global downturn. In contrast, in the EU and in Japan, labour productivity levels fell in the

2012, the US labour productivity growth was approximately 2 percentage points higher than Europe and 3 percentage points higher than Japan.

From 2010 onwards Japan experienced a strong productivity recovery, outperforming the EU and the US. This contrasts with the slowdown in output growth shown in Figure 3.1. This finding is a consequence of the large reduction in the total number of hours worked, which testifies the flexibility of the Japanese wage system and its labour hoarding tradition (Darby et al. 2001). In the case of the EU, which is characterised by a large degree of heterogeneity in the institutional and policy environment, labour market responses were largely country-specific. While some countries were able to adjust to worsening demand conditions via a reduction in hours worked (e.g. UK, Germany, France, Netherlands) others carried out major labour shedding, mostly concentrated in low-skill sectors, resulting into an overall increase in productivity levels (e.g. Spain and Ireland).

3.1.2. Growth accounting analysis: Sources of productivity growth at aggregate level

The objective of this section is to explore the role of inputs to production and Total Factor Productivity (TFP) in explaining aggregate labour productivity developments, measured by GDP per hour. The inputs considered are capital assets, distinguished into ICT and non-ICT assets, and labour composition, which represents the contribution of skilled labour. The TFP component, which is derived using the neoclassical growth accounting methodology, quantifies the part of the output growth not accounted for by growth in the quantity and quality of inputs; TFP captures the influence of unmeasured factors on productivity, such as efficiency improvements, technological change and spillovers. The different factors contributing to labour productivity growth are shown in Figure 3.3 for Europe and Figure 3.4 for the US.

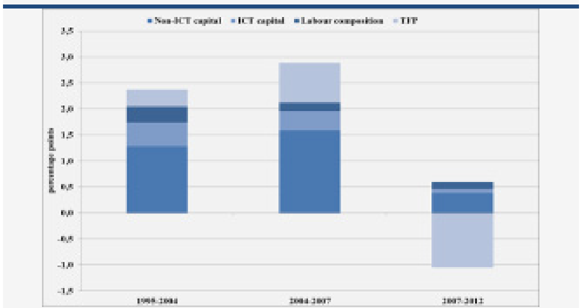
During the period 1995-2004, the most important contributor to labour productivity in the EU[2] was the accumulation of capital assets. TFP gains in the EU were significant during this period but growth rates were considerably lower than in the US. In the US, the main factor driving labour productivity growth during the period 1995-2004 was ICT capital. The growth contribution of ICT was substantially slower in the EU.

The EU experienced significant TFP acceleration during the subsequent period, 2004-2007. Non-ICT capital accumulation and TFP were the main factors contributing to labour productivity growth and to the catching up process towards the US, shown in the main output trends. During the same period, the US experienced a productivity slowdown, mainly caused by a decrease in the speed of ICT capital accumulation and a lower contribution of TFP growth.

After 2007, the effect of the crisis was particularly strong in Europe and negatively affected the contribution of all factors of production, with the sole exception of labour composition. The latter finding is consistent with prior evidence of labour quality growth in many European countries. For example, Kang et al. (2012) find that the average skill level of the workforce, which mainly reflects qualifications achieved through the general education system, rose during the recession years. TFP growth was mostly affected by the financial crisis as its contribution turned negative. The contribution of capital, although still positive, declined substantially compared to the pre-crisis period, reflecting the consequences of tightening credit conditions for European firms.

Goodridge et al. (2013) observed that in the UK, while capital investment decreased considerably with the recession, investments in intangible assets increased, particularly investments in R&D and software. This, together with a higher proportion of skilled workers, increases future growth potential, facilitating recovery.

Figure 3.3 Growth accounting in the EU: Decomposition of labour productivity growth, 1995-2012



Source: EUKLEMS and own calculations.

In the US, the crisis also affected the contribution of TFP and non-ICT capital, although neither turned negative. The contribution of ICT capital decreased slightly compared to the 2004-2007 period, while labour composition increased slightly. This testifies that, as in the UK, US firms prioritised the employment of highly skilled workers.

Figure 3.4. Growth accounting in the US: Decomposition of labour productivity growth, 1995-2012

Source: EUKLEMS and own calculations.

The analysis of growth trends at the aggregate level is consistent with the hypothesis that the US productivity lead in the late 1990s and early 2000s resulted from a first mover advantage in ICT. Large

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2 The EU includes the following eight countries: AT, BE, DE, ES, FR, IT, NL, UK.

TFP gains at the time of rapid ICT investment suggests that ICT may have had an impact on productivity beyond that of ICT-capital deepening (O'Mahony and van Ark 2003); this has been attributed, for instance, to the existence of spillovers related to knowledge assets and to large investments in organizational capital (Bryonjolffson and Saunders 2010). The EU experience reveals that TFP movements may have followed the US productivity developments, albeit with a time-lag. Basu et al. (2004) argue that the `missing' TFP growth in the United Kingdom, compared to the US, in the second half of the 1990 is likely to have been caused by a delay in undertaking investments that would complement the adoption of the new technology.

In the EU, substantial declines in TFP have been recorded since 2007. TFP appears to have behaved in a highly pro-cyclical way and existing contributions suggest that this reflects a decline in the overall efficiency of the production process. However, these results should be treated cautiously as it is too soon to draw conclusions based on the most recent TFP movements (OECD, 2012).

3.1.3. Productivity developments in the EU and the United States: a sectoral perspective

A more detailed explanation of the nature of the EU-US productivity gap is provided by looking at the contribution of each sector in the economy. Labour productivity growth trends are examined for specific industries (Figures 3.5 and 3.6). While the analysis of these sectoral productivity trends are informative, offering an interesting snapshot of pockets of growth, the relative industry contribution to the overall EU-US productivity gap will be determined by the size of each sector and by the differences in industrial structure.

Due to limited data availability[3], the focus here is on a group of eight EU countries[4] (Austria, Belgium, Spain, France, Germany, Italy, Netherlands and the UK). Industry productivity data are drawn from the latest release of the EUKLEMS database (O'Mahony and Timmer 2009) and follow the NACE Rev. 2 classification of economic activities.

During the period 1995-2004, the sectors experiencing the highest growth rates in the US include the ICT-producing sector electrical and optical equipment, with an average growth of almost 21%, followed by coke and refined petroleum products[5], with a rate of 15%. Then come information and communication activities[6] and wholesale and retail activities, which experienced productivity growth rates of around 4%.

In the EU, the best performing sectors during the same period included coke and refined petroleum, with rate of labour productivity growth rate of 8%, finance and insurance activities, and electricity, gas and water supply, both with rates of around 6%. Next were chemicals and chemical products, with a rate of 5%. During that period in the EU the lowest labour productivity growth rates were observed in retail trade, professional, scientific, technical, administrative and support services; community, social and personal services; and arts, entertainment, recreation and other service activities.

Between 1995 and 2004, the European failure to match the US acceleration in output and productivity has largely been attributed to developments in market services (Timmer et al. 2010). The analysis in this section reveals that the sector which most contributed to amplify the US productivity advantage was in fact wholesale and retail distribution, due to its strong productivity performance and its relatively large share in the economy. Other services sectors with sizeable contributions include the professional, scientific, technical, administrative and support services, and finance and insurance activities. These findings are consistent with previous evidence (EC 2008). The electrical and optical equipment sector also made a key contribution with its outstanding growth performance.

Throughout the period 2004-2007, two factors jointly contributed to the reduction of the EU-US productivity gap: the acceleration of productivity in most EU manufacturing industries relative to the productivity performance in US manufacturing, and a robust performance of many EU services sectors.

The highest productivity growth rates in the EU manufacturing sector[7] were achieved in chemicals and chemical products, with a rate of 13%; in contrast, the US electrical and optical equipment sector continued to show impressive growth while in the EU growth remained modest.

In services, labour productivity slowed significantly between 2004 and 2007 in the US wholesale and

[3] EUKLEMS most recent updates, covering up to year 2010 are only available for a limited number of European countries.

[4] These economies represented in 2012 approximately the 80% of EU output.

[5] Care needs to be taken in interpreting these results as measurement issues in this sector may be important.

[6] The Information and Communication sector (J code in NACE Rev. 2) comprises the following activities: publishing, audiovisual and broadcasting activities; telecommunications; IT and information services activities.

[7] The coke and refined petroleum products sector (code 19 in NACE Rev.1) is excluded from this picture.

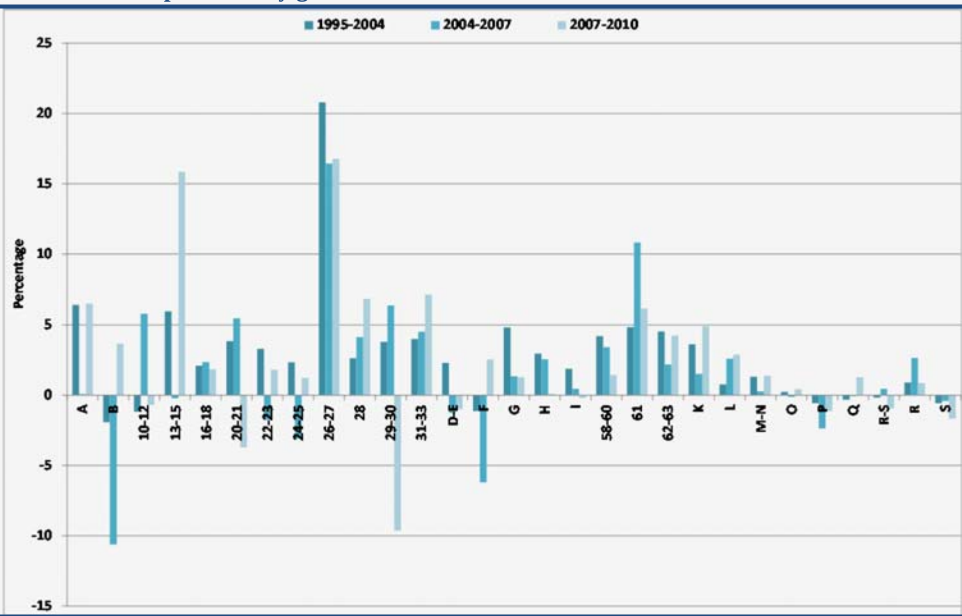
retail sector compared to the exceptional performance observed in the earlier period. On the other hand, the EU performance in the same sector improved substantially, reaching a 3% productivity growth, nearly doubling the growth rate achieved in previous periods. The information and communication activities sector experienced robust labour productivity growth in both the US and the EU; in the latter area, this meant a considerable improvement as labour productivity had previously followed a deteriorating trend. In most EU services, labour productivity improved, particularly in the professional, scientific, technical activities, and community, social and personal services. This is in contrast to the poor performance of both sectors in the period 1995-2004. Overall the evidence shows that those sectors which contributed to narrowing the EU productivity gap relative to the US between 2004 and 2007, were those responsible for the stagnant EU productivity in the previous decade.

professional, scientific, technical activities and retail trade growing by around 2% per annum.

In the US, manufacturing productivity grew by over 4% annually during 2007-2010. One of the few sectors that experienced a worsening in productivity levels was chemicals. The majority of services activities though experienced robust growth, in particular telecommunications, finance and insurance and IT and information services. Productivity growth in the electrical and optical equipment sector did not show signs of slowing down.

Other interesting lessons can be drawn from the analysis of post-crisis industry trends. In summary, the sectors which contributed to further increase the US productivity advantage are electrical and optical equipment and the majority of manufacturing sectors, as well as construction, and telecommunications (which in contrast had shown an outstanding performance in the EU prior to the crisis). Those

Figure 3.5. Sectoral labour productivity growth rates, US, 1995-2010

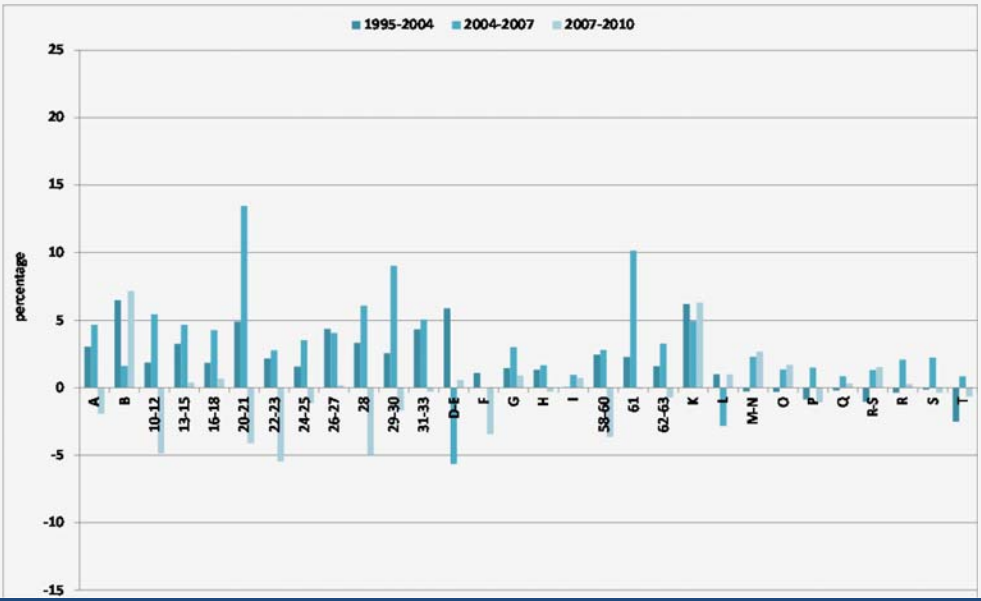


Source: EUKLEMS and own calculations.

During the financial crisis (2007-2010), labour productivity stalled in the EU, while it continued to improve in the US. The majority of manufacturing sectors in the EU-8 experienced a fall in productivity levels, probably reflecting a higher exposure to global demand fluctuations compared to the services sectors. Manufacturing productivity as a whole decreased by more than 1% annually, with chemicals, decreasing by more than 4% annually. Productivity in the construction sector also deteriorated considerably as well as in some services activities, such as wholesale and information and communications. Those sectors that showed the most resilience to the weakening economic conditions in the EU-8 were in financial and insurance activities growing by 6% annually,

sectors which helped the EU to narrow the gap in the most recent period include financial activities and business services, accommodation and food, some public services and other services activities. Many of the ICT-using services sectors that had improved their labour productivity in the pre-crisis years continued to perform well; the exception was wholesale and retail, greatly affected by weak consumer demand. A further extension of the industry level analysis based on growth accounting allows the identification of those factors that played a major contribution in determining productivity growth performance in selected industries. The results, discussed in detail in the background study, reveal that up to 2007 TFP was the main driver of productivity growth in the EU and

Figure 3.6. Sectoral labour productivity growth rates, EU-8, 1995-2010



Source: EUKLEMS and own calculations.

US manufacturing. In the EU, TFP was also the main source of declining productivity trends after the crisis, next to physical capital contributions. In services the picture is more heterogeneous. In wholesale and retail, the contribution of TFP in Europe is delayed compared to the US, and it particularly affects productivity in the latest years before the financial crisis. In information and communication services, the contribution of TFP was particularly large since the mid-1990s in both countries. Despite a declining productivity performance since the crisis, this sector continues to fare considerably well.

3.2. THE ROLE OF KNOWLEDGE TRANSFER, ABSORPTIVE CAPACITY AND INSTITUTIONS FOR PRODUCTIVITY GROWTH

One way to better understand possible causes of the productivity gap is to consider the impact of investments in intangible assets such as R&D. The importance of investing in innovation activity has long been recognised in the theoretical and empirical literature (Romer 1990, Aghion and Howitt 1992, Park 2008, Nishioka and Ripoll 2012). What is perhaps less often acknowledged is that resources for such innovations tend to be highly concentrated in a small number of advanced OECD countries[8], which have the required skills and institutions in place to invest heavily in R&D. This implies that for countries whose firms are not at the technological frontier, the diffusion of technology from the frontier is likely to be an important source of productivity growth, through both imitation and follow-on innovation and adaptation (Evenson and Westphal, 1995). Knowledge transfers can occur via different channels, such as FDI, joint ventures, reverse engineering, and collaborations. A survey of the biggest EU R&D investing companies shows that knowledge transfer is more important among companies than between companies and the public sector. Knowledge transfer is especially relevant for companies in high R&D intensity sectors[9]. In this section the focus is on the diffusion of technology via intermediate goods trade an approach consistent with existing theoretical models (e.g. Grossman and Helpman 1991). The first objective of the analysis is to assess how knowledge transfers affect productivity growth; secondly, the role of absorptive capacities and barriers to diffusion is taken into account, as these can make an important difference to the extent to which countries benefit from innovations carried out elsewhere.

The methodology used to study the impact of foreign R&D spillovers follows closely the contribution by Nishioka and Ripoll (2012), which requires data on R&D stocks by country and industry and input-output tables capturing inter-industry and inter-country

8 The share of R&D financed by enterprises in advanced countries was 98% in the 1980s and 94% in the 1990s (UNIDO, 2002). Even within developed countries however R&D is concentrated, with Eaton and Kortum (1999) noting that in the late 1980s, 80 percent of OECD research scientists and engineers were employed in five countries (US, UK, Germany, Japan and France).

9 See: www.jrc.es: Tübke, A.; Hervás, F. and Zimmermann, J.: "The 2012 EU Survey on R&D Investment Business Trends", European Commission, Joint Research Centre, EUR 25424 EN, pp.21.

linkages. This is carried out using data on R&D expenditure from the OECD ANBERD database[10], from which a R&D stock for ten manufacturing industries and 20 countries is calculated using the perpetual inventory method. Information on intermediate flows required for the calculation of the R&D stock of intermediates is taken from the recently compiled World-Input-Output-Database (WIOD), which reports data on socio-economic accounts, international input-output tables and bilateral trade data across 35 industries and 41 countries over the period 1995-2009 (see Dietzenbacher et al. 2013)[11].

Though R&D stocks could only be calculated for a limited number of countries and industries, two interesting stylised facts emerge: firstly, over 80% of the R&D stock is concentrated in a small number of industries (electrical and optical equipment, transport equipment and chemicals and chemical products and in particular the pharmaceutical sector which plays a key role among highly innovative industries); secondly, the US and Japan dominate R&D stocks in the sample of countries considered, with respectively 40% and 28% of the total, followed by Germany (11%), France (8%) and the UK (7%). This indicates that these five countries account for 80% of the overall R&D stock, consistent with Eaton and Kortum (1999).

Using these R&D stocks and the information on inter-industry and inter-country linkages makes it possible to calculate the variables capturing the 'direct and indirect R&D content' of intermediate input flows: First, the R&D stocks divided by gross output provides a vector containing the direct R&D requirements by sector and country. This vector is then multiplied with the global Leontief inverse, derived from the WIOD and the global inter-industry, transaction matrix. The latter only includes the foreign inter-industry flows therefore capturing the role of international R&D spillovers.[12]

As expected, those countries and industries which dominate R&D expenditures also tend to have the highest shares in the direct and indirect use of R&D[13]. Relatively large shares are also found for construction, suggesting that there are strong linkages between manufacturing and this sector. With respect to countries, large increases in the indirect use of R&D can be found for the US, Japan and the rest of the world between 1995 and 2010. China has also experienced a large increase in both direct and indirect R&D usage over time. This increase is solely due to increased flows of R&D intensive intermediates into China over this period (China is excluded from the list of R&D source countries given the limited industry data).

The assessment of the role of absorptive capacity and barriers to diffusion requires the inclusion of additional variables. Absorptive capacity is measured using information from the 2013 release of Barro and Lee's dataset on the average years of secondary schooling in the population over 15 years of age (*Syr*)[14]. As additional indicator of absorptive capacity, the analysis includes the level of R&D taken in logs (Cohen and Levinthal 1989). Data on R&D are extracted from the OECD ANBERD dataset. The role of absorption barriers is assessed by using several OECD indicators. A first set describes regulation in the labour market and includes: an indicator on strictness of regulation of employees on regular contracts (*EPR*), an indicator for strictness of regulations for temporary forms of employment (*EPT*), and an indicator of strictness of regulation and specific requirements for collective dismissal (*EPC*). These variables are on a scale of 0 to 6, with 0 having the least and 6 the most restrictions. To be consistent with the hypotheses of Parente and Prescott (1994, 1999) R&D spillovers are expected to be weaker in countries with higher values for these indices. To examine whether R&D spillovers are affected by the power of labour unions in limiting the take-up of potentially labour-saving technology, further information on trade union density from the OECD is included (*Union*). A further indicator employed is the OECD indicator of product market regulation (*PMR*). The indicator captures the stringency of product market regulatory policy, with higher values being associated with policies that are more restrictive to competition[15]. A further variable that is included is an indicator of the strength of Intellectual Property Rights (*IPR*). IPRs are a policy tool to encourage innovative activities. By preventing the copying and imitation of a patent, IPRs may reduce technology

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[10] It is important to stress that the BERD data are territory based. Alternatively, attention might be paid to this issue at the company level (e.g. Cincera and Veugelers, 2010).

[11] Some of the associated data have been updated to 2011.

[12] Technical details are provided in the background study to this chapter.

[13] It should be stressed here that these results are confined to those countries and industries for which reliable R&D data are available. As R&D is concentrated in a few industries and countries, the computation of direct and indirect R&D stocks provide good proxies for international R&D spillovers that can be used in empirical econometric analysis. However, no more detailed inference on source and use country and industries can be made without having better knowledge of R&D stocks across all countries and industries.

[14] See http://www.barrolee.com/. These data have been used as a measure of absorptive capacity in similar studies (see for example Falvey et al. 2007).

[15] This indicator ranges on a scale from 0 to 6. The data is available at the country-level only and for three years (i.e. 1998, 2003, 2008). Missing years are imputed using linear interpolation. For further details see Wölfl et al. (2009).

diffusion. However, since information on patents is made public, stronger IPRs may encourage technology diffusion (Breitwieser and Foster 2012). The index of IPRs used is developed by Ginarte and Park (1997) and updated by Park (2008). This index uses information on the coverage of patents, membership in international treaties, enforcement mechanisms, and restrictions on patent rights and duration, with higher numbers indicating stronger protection[16].

Finally, information from the Heritage Foundation's Index of Economic Freedom is used for additional variables. In particular, the sub-indices on investment freedom (*invest*) and financial freedom (*finance*) are included, where higher numbers imply more restrictions[17].

3.2.1. Empirical model and estimation

To study the impact of foreign R&D content of intermediates on labour productivity the following production function is used:

$$\Delta \ln y_{iht} = \Delta \ln F_{F,iht} + \beta_1 \Delta \ln k_{iht} + \beta_2 \ln y_{ih1995} + \alpha_i + \delta_h + \pi_t + \varepsilon_{iht}$$

(3.1)

The growth rate of labour productivity Δlny Δlny is dependent on the growth rate of foreign R&D spillovers ΔlnF_F ΔlnF_F, the growth rate of the capital-labour ratio Δlnk and the initial lagged value of output per worker to allow for conditional convergence. Further industry i, country h and time t fixed effects are included, while ε is an error term. The inclusion of fixed effects controls for unobserved heterogeneity across the respective dimensions. Results are reported in Table 3.1. The negative and significant coefficient on initial output per worker confirms the presence of conditional convergence.

The coefficient on the capital-labour ratio is positive and significant in all specifications, indicating that greater capital intensities are associated with higher labour productivity growth. With respect to the main variable of interest, the coefficient estimates indicate that a 1% increase in the growth of foreign R&D content of intermediates is associated with a higher growth rate of labour productivity of between 0.15% and 0.19%. Thus, these results suggest that the R&D stock of intermediates is positively associated with output per worker.

The second question to address is whether the relationship between the foreign R&D stock of intermediates and labour productivity is affected by the indicators of absorptive capacity and absorption barriers described above. The econometric strategy involves estimating a model of the following form:

$$\Delta \ln y_{iht} = \gamma_1 \Delta \ln F_{F,iht} 1(Z_{iht} \leq \lambda) + \gamma_2 \Delta \ln F_{F,iht} 1(Z_{iht} > \lambda) + \beta_1 \Delta \ln k_{iht} + \beta_2 \ln y_{ih1995} + \beta_3 Z_{iht} + \alpha_i + \delta_h + \pi_t + \varepsilon_{iht}$$

(3.2)

where Z is the indicator of absorptive capacity or absorption barriers and 1 is the indicator function taking the value one if the term in brackets is true. The model differs from a standard linear model in that the elasticity of labour productivity with respect to foreign R&D (i.e. γ) is allowed to differ depending upon whether absorptive capacity is above or below some threshold value (λ). In particular, the elasticity of labour productivity is given by γ_1 if absorptive capacity is below (or equal to) the threshold and is given by γ_2 if absorptive capacity is above the threshold. The actual threshold value is calculated endogenously following Hansen (1996, 1999 and 2000) with significance of the thresholds determined by bootstrapping. When estimating this model the threshold variable, Z, is included linearly. The set of threshold variables capturing absorptive capacity and absorption barriers also includes the initial values of labour productivity ($\ln y_{1995}$). This allows for the examination of whether an indicator of relative backwardness impacts upon the relationship between foreign R&D and labour productivity. While being further behind the technological frontier usually means that there is more scope for technological catch-up it could also imply that a country or sector does not have the ability to make use and benefit from advanced technology (see Falvey et al. 2007). As such, the impact of backwardness measures on the relationship between foreign R&D and labour productivity growth is ambiguous from a theoretical point of view.

Results from estimating a single threshold are presented in Table 3.2 where each column presents the threshold estimates for the variable indicated in the header line as motivated in the text above. Coefficients on initial output per worker and the growth of the capital-labour ratio are consistent with

16 The index takes on a value between zero and five.

17 The raw data are on a scale of zero to 100, with 100 implying no restrictions. To be consistent with the other measures of absorption barriers this variable is redefined to be equal to $100 - freedom\ variable$. For further details on the construction of these indicators see the background study.

the results in Table 3.1. In terms of the threshold results, a variety of outcomes appears. The *backwardness* measure shows that the lower the labour productivity the larger the spillover effects.[18] The coefficient in the low regime (0.264) is more than twice the coefficient in the high regime (0.105) – though both are significant – indicating that foreign R&D spillovers appear to be significantly stronger in countries and industries that are further away from the frontier.

The indicators of *absorptive capacity* (i.e. average years of secondary schooling, *Syr*, and ln*R&D*), produce consistent results. The coefficients indicate that foreign R&D spillovers are larger in countries with a higher number of average years of secondary schooling and in countries and industries which are more R&D intensive. While the difference in coefficients (0.11 versus 0.27) in the case of *Syr* is significantly different, the differences in the case of lnR&D (0.15 versus 0.17) are not significant, i.e. the linear model is preferred.

Table 3.1. Foreign R&D and labour productivity growth

	(1)	(2)	(3)
	$\Delta \ln y$	$\Delta \ln y$	$\Delta \ln y$
$\ln y_{1995}$	-0.0104***	-0.0106***	-0.0142***
	(0.000741)	(0.000797)	(0.00289)
$\Delta \ln k$	0.482***	0.422***	0.465***
	(0.0278)	(0.0301)	(0.0334)
$\Delta \ln F_F$	0.190***	0.176***	0.150***
	(0.0180)	(0.0192)	(0.0202)
Time F.E.	No	Yes	Yes
Country F.E.	No	No	Yes
Industry F.E.	No	No	Yes
Observations	15,850	15,850	15,850
R-squared	0.372	0.419	0.455
F-stat	289.2***	338.2***	87.04***

*Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

When labour market indicators are used as a threshold variable, results vary across the different indicators. When using indicators of the strength of regulation on regular contracts and collective dismissal, spillover effects are larger in the low regime (i.e. in countries with less regulations). The coefficient estimates imply that a 1% increase in the growth of the foreign R&D stock has a 0.13% increase in labour productivity growth for countries with a value of the *EPR* below the threshold and a -0.001% decrease for countries above the threshold. A similar change increases labour productivity growth by 0.21% for countries with *EPC* below the threshold, and by just 0.04% for countries above the threshold. The strength of regulation on temporary contracts produces the opposite result. In particular, while a 1% increase in the growth of the foreign R&D stock is associated with an increase in labour productivity of 0.24% for countries with *EPT* above the threshold, the change for countries below the threshold is just 0.03%. Finally, when using union

[18] Alternatively one might use interaction terms between R&D and absorptive capacities and barriers. However, the use of the threshold model rather than interaction terms has a number of advantages. Firstly, using threshold models doesn't impose a monotonic change in the effect of the explanatory variable as the threshold or interaction term increases (i.e. the impact of the explanatory variable on the dependent variable can switch signs and change size at different points on the distribution of the threshold variable). Secondly, the coefficients are easier to interpret. The impact of the explanatory variable on the dependent variable is given by a fixed parameter for all observations within a particular regime. With interaction terms it is more difficult to identify the overall impact of a change in the explanatory variable, with researchers often resorting to graphing the relationship for different values of the threshold/interaction variable. Thirdly, when the threshold/interaction variables are bound as in our case (e.g. between zero and six) the threshold model is less open to misinterpretation (e.g. extrapolating beyond the range of the threshold/interaction variable).

density as threshold variable results show that foreign R&D spillovers are larger in the low union density regime. A 1% increase in the growth of foreign R&D is associated with a 0.19% increase in labour productivity growth in the low regime, and a 0.03% increase in the high regime.

In terms of the remaining indicators, one finds that, in the cases of PMR, $Invest$ *and* $Finance$, the relationship between foreign R&D growth and labour productivity growth is stronger in the high regime, that is, in the regime with more stringent product market, investment and financial regulation. In the case of PMR the coefficient in the low regime is negative and significant. For $Invest$ the difference in the coefficients on the foreign R&D variable between the two regimes is relatively small – though still significantly so (0.149 versus 0.172), while for $Finance$ the differences are much larger (0.08 versus 0.237). Though this might be an unexpected result, it should be noted that these indicators could also reflect institutional quality in a broader sense. As countries with higher institutional quality might attract more R&D intensive firms or have tighter cooperation in R&D activities, etc. these results would be in line with the literature stating that the quality of institutions matters.

Summarising, the results confirm those from the simple model reported in Table 3.1 whereby the foreign R&D content of intermediates is positively associated with labour productivity growth. However, the size of these spillovers depends on absorptive capacities and barriers; countries and industries further behind the technological frontier enjoy stronger foreign R&D spillovers, in line with Falvey et al. (2007). The results also support Falvey et al (2007) as well as Crespo-Cuaresma et al (2008) in finding that foreign R&D spillovers are stronger in countries with greater absorptive capacity (as measured by average years of secondary schooling and R&D spending). In terms of absorption barriers, the results are mixed. With the exception of regulations on temporary workers, stronger labour market regulation and greater union density are associated with lower foreign R&D spillovers, consistently with Crespo-Cuaresma et al. (2008) and Parente and Prescott (1994, 1999 and 2003). Concerning the other absorption barriers related to product market, financial and investment regulation there is no evidence that lower anti-competitive barriers encourage foreign R&D spillovers. Indeed, the reverse appears to hold though these indicators might reflect the overall institutional quality, which is conducive to growth. Finally, one finds that stronger levels of IPR protection can limit the extent of foreign R&D spillovers, possibly by limiting the ability to replicate and borrow technology from abroad.

Table 3.2. Single threshold results

Threshold	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
variable	$\ln y_{1995}$	Syr	$\ln R\&D$	EPR	EPT	EPC	Union	PMR	IPR	Invest	Finance
$\ln y_{1995}$	-0.011***	-0.014***	-0.014***	-0.00488	-0.00430	-0.00452	-0.00488	-0.00428	-0.013***	-0.0143***	-0.0142***
	(0.00226)	(0.00225)	(0.00226)	(0.00305)	(0.00304)	(0.00325)	(0.00300)	(0.00292)	(0.00234)	(0.00226)	(0.00224)
$\Delta\ln k$	0.457***	0.465***	0.465***	0.629***	0.632***	0.664***	0.631***	0.621***	0.467***	0.465***	0.454***
	(0.00587)	(0.00586)	(0.00587)	(0.0104)	(0.0104)	(0.0115)	(0.00993)	(0.00999)	(0.00611)	(0.00589)	(0.00588)
$\Delta\ln F_F^{LOW}$	0.264***	0.111***	0.149***	0.126***	0.0307***	0.208***	0.191***	-0.0291**	0.211***	0.139***	0.0807***
	(0.0107)	(0.00766)	(0.00631)	(0.0110)	(0.00999)	(0.0239)	(0.0129)	(0.0121)	(0.00759)	(0.00732)	(0.00792)
$\Delta\ln F_F^{HIGH}$	0.105***	0.212***	0.174***	-0.000967	0.241***	0.0357***	0.0339***	0.156***	-0.057***	0.172***	0.237***
	(0.00705)	(0.00952)	(0.0226)	(0.0145)	(0.0182)	(0.0104)	(0.00963)	(0.0108)	(0.0127)	(0.0103)	(0.00904)
Z		0.00358	9.47e-05	-0.00574	-0.026***	-0.072***	0.000722	-0.00141	-0.00102	-0.00041***	0.000384***
		(0.00754)	(0.000390)	(0.0131)	(0.00347)	(0.0111)	(0.000475)	(0.00830)	(0.00376)	(0.000133)	(0.000126)
Threshold	1.566	3.958	12.270	2.470	3.444	1.959	16.498	1.737	4.180	49.506	32.222
Percentile	21	66	50	64	79	13	18	47	70	90	46
P-value	0.000***	0.000***	0.297	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.008***	0.000***
Observations	15,850	15,850	15,850	9,559	9,559	8,061	10,372	9,742	14,200	15,850	15,850
R-squared	0.461	0.458	0.455	0.448	0.453	0.471	0.461	0.479	0.468	0.455	0.462
F-stat	158.4***	154.6***	153.0***	98.60***	100.5***	93.59***	120.8***	119.9***	151.5***	153.3***	157.7***

*Notes: ***, **, * significant at 1, 5 and 10%. Robust standard errors in parentheses. All models include unreported time, industry and country fixed effects*

3.3. EFFICIENCY ANALYSIS AT THE INDUSTRY LEVEL

This section provides an analysis of the determinants of technical efficiency in Europe, the US and Japan, using stochastic frontier analysis (SFA). Technical efficiency in this study refers to the ability of a firm/industry to achieve the maximum output using the set of available resources. The growth accounting and the regression analysis framework used in the previous sections are based on the assumption that all resources, i.e. capital and labour inputs, are fully utilised and therefore it cannot account for changes in productivity originating from efficiency improvements. Technical efficiency analysis relaxes this assumption and assumes that only the top performing industry is able to use resources in the most efficient way. The other industries will lie below the frontier and the distance to the frontier output defines the efficiency gap. Identifying which industry/country is at the frontier and how efficiency levels have changed over time is important to direct policies towards the correct tool to promote performance. In fact, the best performing industry in terms of productivity might not be the most efficient one, and higher productivity could be achieved by improving the allocation and usage of the available resources. On the other hand, a highly efficient industry might not be the most productive because of, for example, low investments in strategic assets such as ICT and R&D capital; in this case, policies should be directed towards promotion of investments.

The most intuitive way of understanding frontier analysis is to assume that the actual output produced can be lower than the maximum output, given the level of available resources. By defining actual output in industry *i* at time *t* as YA_{it} and the maximum output as YF_{it}, technical efficiency can be expressed as:

$$TE_{it} = YA_{it}/YF_{it} \tag{3.3}$$

Efficiency levels in each industry range between 0 and 1, with higher scores indicating higher efficiency. The derivation of technical efficiency levels requires the estimation of a production function where output, measured by value added, is produced with a combination of inputs. The most basic model includes the total number of hours worked (*H*) and total capital (*K*) as factor inputs. Below, a more extended specification will also be considered that accounts for different types of capital (ICT and non-ICT capital) and intangible assets (labour quality and R&D capital).

The analysis is carried out using industry-level data, extracted from the EUKLEMS database. The total sample includes 16 countries. Of these, 14 are European (AT, BE, CZ, DE, DK, ES, FI, FR, HU, IE, IT NL, SE and UK); the other two being Japan and the US. For each country, data are available for 21 industries, including manufacturing and services[19]. The analysis is conducted between 1995 and 2007 outlining industry performance in the pre-financial crisis period. The exclusion of the downturn is motivated not only by data availability, but also by the consideration that technical efficiency relates to the structure of the industry, and this is less likely to be affected by cyclical factors or exogenous shocks.

Results from the estimation of a frontier production function, expressed in log-levels, are presented in Table 3.3. [20]. The first column (1) displays estimates for total capital services, while column (2) distinguishes between ICT and non-ICT capital services. Results are robust across the two specifications and, with the exception of ICT capital, all coefficient estimates are positive and statistically significant. They are consistent with prior knowledge of factor shares. Human capital, measured by the labour quality variable, has a positive, albeit small, effect on productivity. In column (2), the impact of ICT is positive with an elasticity of 0.04%, which is consistent with the existing evidence (Kretschsmer 2012). However, the coefficient is not statistically significant at conventional levels. It is possible that the model specification needs to account for additional complementary assets (Diedrick et al. 2003). In fact, when R&D is included, the significance of the ICT variable improves as in column (4). Another possible explanation is that the impact of ICT is highly heterogeneous across countries and industries, and its effect is likely to be higher in the most ICT intensive users. More importantly, further developments of this analysis will show that ICT exerts an indirect effect on productivity, via the reduction of technical inefficiencies.

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[19] Industries included in the analysis are: Food and Beverages, Textile and Leather, Wood & Cork, Pulp, Paper and Printing, Coke, refined petroleum and nuclear fuel, Chemicals, Rubber and Plastic, Other non-metallic minerals, Basic metals, fabricated metal products, Machinery NEC, Electrical Equipment, Transport Equipment, Manufacturing NEC, Transport and Storage, Post and Telecommunication, Business Services, Electricity, Gas and Water, Construction, Wholesale and Retail, Financial Intermediation, Other Community and Social Services. This classification is based on NACE Rev. 1 and differs from the one used in the Section 3.1.3.

[20] The estimation of the production function in the panel dimension requires the introduction of fixed effects to control for cross-sectional time-invariant heterogeneity. Along with country- and industry-specific intercepts, the specification also includes a set of time dummies to control for unknown or unobserved factors that are likely to affect all industries at different points in time.

Table 3.3. Estimation of stochastic frontier production function Dependent variable: Value added				
	(1)	(2)	(3)	(4)
Total number of hours worked	0.790***	0.755***	0.632***	0.612***
	(0.031)	(0.031)	(0.036)	(0.037)
Tangible assets				
Total capital	0.351***		0.446***	
	(0.024)		(0.028)	
Non-ICT capital		0.394***		0.445***
		(0.024)		(0.029)
ICT capital		0.019		0.026
		(0.017)		(0.020)
Intangible assets				
Labour quality	0.011***	0.010***	0.008***	0.007***
	(0.002)	(0.002)	(0.002)	(0.002)
R&D capital			0.061***	0.061***
			(0.008)	(0.008)
Constant	1.418***	1.154***	1.246***	1.248***
	(0.168)	(0.171)	(0.189)	(0.189)
Gamma	0.401	0.343	0.394	0.433
Likelihood ratio test	11.025	5.176	7.434	9.663
(P-value)	(0.000)	(0.011)	(0.000)	(0.000)
Observations	4532	4519	3650	3488

*Notes: ***, **, * significant at 1, 5 and 10%. Gamma is the proportion of the total error variance due to inefficiencies. The Likelihood ratio test is a test of the null hypothesis that there are no technical inefficiencies in production.*
Source: EUKLEMS and OECD ANBERD

Results in Table 3.3 columns (3) and (4), confirm the importance of R&D in increasing productivity, consistently with the reference literature, where this value generally ranges between 0.04 and 0.18 (Griliches and Mairesse 1984; Kumbhakar et al. 2010; Bloom et al. 2013).

The inclusion of R&D does not significantly affect the coefficient estimates for labour quality, and generates only a marginal increase in the effect of total capital – see column (3) and non-ICT capital in column (4)[21]. This is a consequence of the complementary relationship between R&D and capital assets[22].

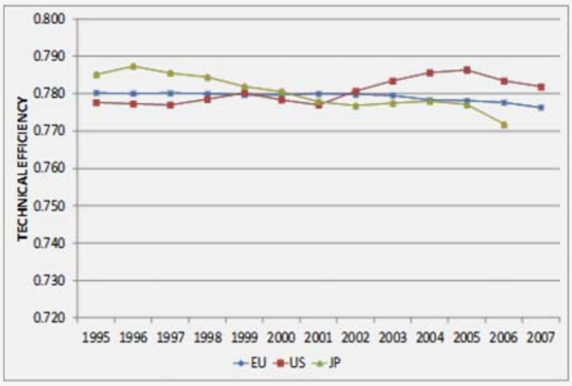
The SFA modelling framework allows the derivation of technical efficiency (TE) for each industry/time period. Estimates of technical efficiency can be derived from any of the specifications presented in Table 3.3, hence a choice needs to be made to carry out the analysis. The last row of the table shows that the number of observations drops substantially when

[21] Diagnostic statistics are presented at the bottom of Table 3.3. The Gamma parameter measures how important inefficiencies are in each model. A value of 1 indicates that all deviations from the frontier are due to inefficiency, while a value of 0 implies that there are no inefficiencies; in the latter case, SFA does not provide any additional information compared to OLS. In this study, the Gamma parameter is approximately equal to 0.4 meaning that inefficiencies are important and explain 40% of the total residual variation. The presence of inefficiencies is also assessed via the Likelihood Ratio test, which confirms that this component is statistically significant.

[22] The impact of the total number of hours worked is significantly lower in regressions 3 and 4, compared to the first two columns of Table 3.3. This is related to the fact that a large proportion of R&D costs is composed of the wages of employees involved in R&D activities. This 'double counting' is a well-known phenomenon in productivity studies (Schankerman1981, Guellec and van Pottelsberghe 2004).

including R&D, as information on this asset is missing for several service industries in various countries. Given that the main objective of this section is to analyse efficiency trends across the full spectrum of manufacturing and services, the specification in column (2) is used to derive technical efficiency scores[23].

Figure 3.7. Average technical efficiency (TE) in the EU, US, and Japan



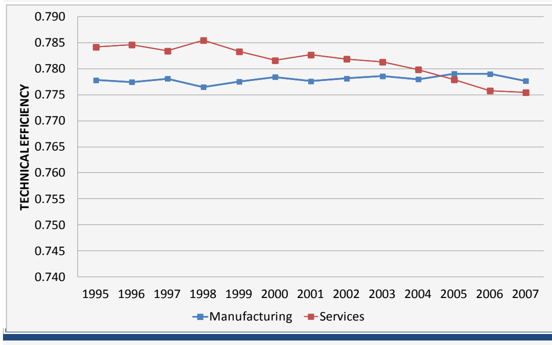
Source: EUKLEMS Database and authors' computations.

Figure 3.7 presents average efficiency scores for the EU, the US and Japan. Although actual efficiency levels do not differ greatly across economies, their variation over time shows some interesting patterns. In the mid-1990s, the US had lower efficiency levels than Japan and Europe, but then TE increased rapidly placing the US at the frontier since 2002. Existing evidence dates the resurgence of US productivity to 1995, around seven years before the aggregate increase in efficiency. This difference can be explained by the presence of lags in the full implementation of the new technology and the reorganisation of production, emphasised in the General Purpose Technology (GPT) literature (Hornstein and Krusell 1996, Aghion 2002). While the existing evidence mainly refers to the direct impact of ICT on productivity, here the analysis provides new results supporting the GPT nature of new digital technologies looking at technical efficiency. From 2002 to 2005 the efficiency gap between the US and the other two economies widened. However, from 2005 efficiency levels fell in the US, while the EU trend remains virtually unchanged. Japan was the frontier country in 1995 but its efficiency declined from 1996, and since 2000 its efficiency has been below the European average. These patterns are not dissimilar from trends in TFP levels discussed in Jorgenson and Nomura (2007). Similarly to the US, in Japan changes in efficiency follow changes in productivity with a lag of about five years.

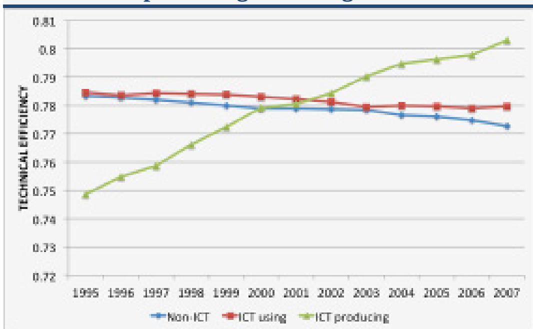
[23] The correlation of TE scores arising from the four specifications is very high, ranging between 0.97 and 0.99. Hence, the exclusion of R&D does not affect the estimation of TE.

A look at average TE in selected groups of industries provides insights on the ones performing better. Panel A of Figure 3.8 presents mean efficiency

Figure 3.8. Technical efficiency
Panel A. Manufacturing and services



Panel B. ICT producing and using industries

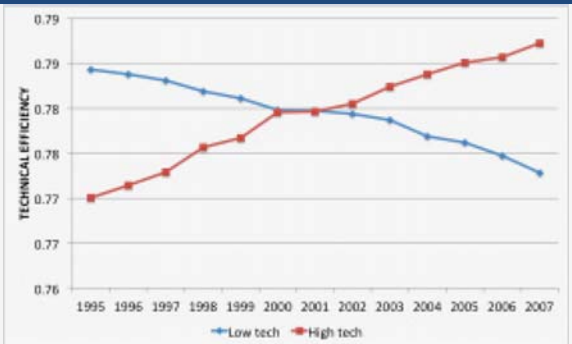


Source: EUKLEMS Database and authors' computations.

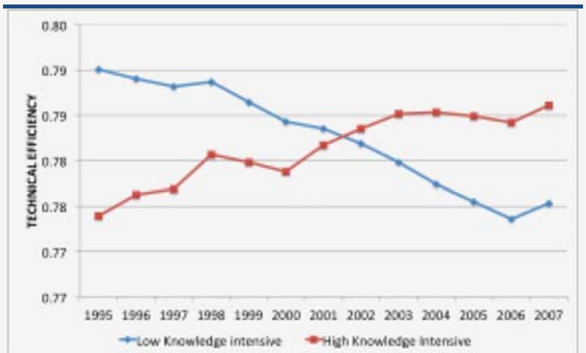
trends in manufacturing and services. This shows that services have experienced a declining efficiency performance over time, while in manufacturing efficiency has remained fairly stable over the period. **Error! Reference source not found.**Figure 3.8 Panel B and Figure 3.9 Panel A show that efficiency has been increasing over time in the most innovative sectors, namely ICT producing and high-tech industries. This suggests that increases in productivity went hand-in-hand with increases in efficiency until 2007. The efficiency in the ICT-producing sector increased by 5%, from 0.75 in 1995 to 0.80 in 2007, while improvements were more moderate in high-tech industries (approximately 2%).

Panel B of Figure 3.9 focuses on services, distinguishing between knowledge-intensive and non-knowledge intensive industries. While the overall performance of the tertiary sector has been declining over time, this figure reveals that the average picture is influenced by the dynamics of low knowledge-intensive services, as they are characterised by a steady decrease in TE. On the other hand, the most knowledge intensive industries, after a dip in efficiency in 2000, performed relatively well, with increasing efficiency throughout the period.

Figure 3.9. Technical efficiency in high-tech and low-tech industries
Panel A. High-tech and low-tech



Panel B. Knowledge and non-knowledge intensive services



Source: EUKLEMS Database and authors' computations.

3.3.1. Reducing efficiency gaps: discussion of the main determinants

Understanding why industries vary in the extent to which they use resources effectively, and what policies might be more suitable to foster efficiency performance, requires the extension of frontier analysis to account for the factors that might cause industries to fall below the frontier and therefore widen efficiency gaps. This study focuses on the role played by ICT capital and the business environment where industries operate. The assessment of the impact of these factors on technical efficiency is obtained by the empirical estimation of the following relationship:

$$TE\ GAP_{it} = a_0 + \sum a_j Indicator_{ct} + \theta K\_ICT_{it} + \gamma time_{it} + \varepsilon_{it}$$

(3.4)

δ is a simple time trend that captures how an efficiency gap is determined by exogenous technological changes[24]. ε_{it} is the error term. The inclusion of a large number of indicators naturally causes co-linearity problems, hence the researcher needs to deal with the trade-off between efficiency of the estimator (which is reduced in the presence of collinearity) and omitted variable bias. To address this issue, the estimation will sequentially include different indicators, checking for the presence of ICT and the degree of competitiveness in all specifications[25]. The decision to include these two factors is driven by the existing evidence that suggests the presence of complementarities between, for example, product market regulation and employment protection legislations (Griffith et al. 2007, Fiori et al. 2012)[26]. The analysis uses a wide range of indicators that have been rescaled so that all vary between 0 and 1, with larger values indicating more stringent regulation.

Table 3.4 to 3.6 present the sign of the impact for each of the factors affecting technical efficiency, and the related statistical significance. Table 3.6 presents a summary of the results based on a specification that includes ICT and a set of indicators capturing the degree of market competitiveness. The latter includes the Upstream Regulation Index (RI), which assesses the impact of anti-competitive legislation in the tertiary sector on the performance of downstream sectors that use services as a production input (Conway et al. 2006); Enforcing Contract Time (ECT), which is based on the number of days to enforce a contract in each country (World Bank 2012); and two alternative measures of competitiveness, the Herfindal index and the degree of industry fragmentation[27]. The coefficient for ICT is negative and statistically significant in all specifications, indicating that this asset plays a very important role in lowering inefficiencies in the use of resources. Although ICT did not have a significant effect in the estimation of the production function, it plays an important role in reducing efficiency gaps, which will also affect productivity but in an indirect way. This result is particularly interesting when compared with the existing industry-level evidence, which usually fails to find significant effects of ICT on TFP growth

24 The estimation of the efficiency gap is carried out simultaneously with the estimation of the productivity frontier, using Maximum Likelihood methods. This one-step procedure guarantees consistency in the coefficient estimates.

25 The authors also tried to include intangible assets (R&D and labour quality) as determinants of both productivity and efficiency. However, these estimates were highly unstable, hence such factors were only included in the specification of the production function (see Table 3.3).

26 The impact of the latter factor is always accounted for with the use of the upstream Product Market Regulation index (RI), unless otherwise specified.

27 The Herfindal index and the indicator of industry fragmentation are derived using information from the Amadeus database, made available via EUKLEMS.

(Stiroh 2002, Basu et al. 2004, Acharya and Basu 2010). This implies that distinguishing between TFP and TE can provide important insights on the role of ICT. Up to now, this issue has been unexplored by the economic literature.

Consistently with the existing evidence on the link between the lack of competition and productivity (Buccirossi et al. 2012, Conway et al. 2006), Table 3.4 indicates that higher values of upstream regulation significantly increase the efficiency gap. In other words, administrative restrictions on competition in the services market have widespread negative effects on production efficiency, well beyond the tertiary sector. This effect is robust to the use of alternative variables that describe the degree of competitiveness of the market, such as the Enforcing Contract Time (ECT), the Herfindal index and industry fragmentation. Note that the sign of the latter is negative as higher values indicate higher fragmentation, which is associated with more competition. Hence, results in Table 3.4 provide strong support for the hypothesis that a more competitive business environment reduces the efficiency gap.

Table 3.4. Reducing the efficiency gap: the role of product market competition

	(1)	(2)	(3)	(4)
ICT capital	-0.623***	-0.636***	-0.693***	-0.004
Upstream regulation (RI)	3.081***	3.111***		
Enforcing contract time		0.639***		
Herfindal			0.747**	
Industry fragmentation				-1.097***
Observations	3648	3648	2454	2256

*Note: ***, **, * significant at 1, 5 and 10%. All specifications include a time trend. A negative sign implies that the variable decreases the efficiency gap*

Table 3.5. reports results based on a specification that includes indicators of employment protection legislation. Three of these (EPR, EPT, EPC) are described in Section 3.2. The EPL burden indicator is an industry level variable based on the notion that EPL, although it applies uniformly to all industries within a country, is more binding in those industries that rely on lay-offs than in industries characterised by a higher degree of voluntary turnover (Bassanini et al. 2009). NMW stands for National Minimum Wage and it is only available for those countries where NMW is prescribed by law (Visser 2011). Considering the role of NMW is interesting in the light of the political and economic debate concerning its effect on employment outcomes (Card and Krueger 1995, Neumark and Washer 2008). Results in Table 3.4 show that more stringent EPL for regular workers and collective dismissals significantly increases the efficiency gap. On the other hand, regulation on temporary workers has the opposite effect, indicating that stronger protection on this kind of contracts decreases inefficiencies. This finding is not unexpected as existing evidence shows that the legal discipline on regular and temporary workers can have opposite effects on performance. For example, Damiani et al. (2013) document that deregulation of temporary contracts negatively influences TFP growth in European industries. These findings suggest that excessive flexibility in the use of temporary workers leads firms to use this category of workers to buffer cyclical demand movements (Gordon 2011), rather than attempting to find the most efficient way to combine factor inputs[28]. The introduction of minimum wage legislation also constrains the efficient use of labour input by increasing the efficiency gap, through reducing competitiveness in the labour market, a claim that is frequently used by those scholars who opose the introduction of the minimum wage (Currie and Fallick 1996)[29].

The final set of indicators accounts for the effect of financial market regulation, property right protection and regulation of FDI on the efficiency gap. Financial market regulation is measured using three indicators: the financial reform index, constructed by combining liberalisation scores on seven different areas of the financial market (Abiad et al. 2008); the financial freedom index, as defined in Section 3.2; and the ratio of product market capitalisation over GDP (Beck et al. 2009). The indicator of property rights regulation is defined in Section 3.2. The FDI regulation index summarises information on four forms of legal intervention (equity restrictions, screening and approval requirements, restrictions on foreign key personnel and other operational restrictions; see Kalinova et al. 2010). Results

[28] This result is also consistent with those in section 3.3 of this chapter, where countries with higher employment protection for temporary workers enjoyed higher spillovers from foreign R&D stocks.

[29] In the basic textbook model of labour demand an increase in the minimum wage reduces the employment in the covered sectors of those workers whose wage rates would otherwise fall below the minimum" (Currie and Fallick 1996; p. 405).

including these indicators are presented in Table 3.6. Both the financial reform and the financial freedom indicators consistently show that lower levels of regulation in this market increase the efficiency gap. Conversely, access to alternative sources of finance, like the bond market, significantly improves TE performance. This follows the main results of the literature, where a positive relationship between financial development and growth is usually found (Rajan and Zingales 1998, Maskus et al. 2012), but where it is also suggested that excessive financial liberalisation may be detrimental for performance when it discourages savings or triggers financial instability (Ang 2011, Ang and Madsen 2012). The recent financial crisis has shown that excessive freedom in the financial market can have catastrophic consequences.

Results also show that increasing protection of intellectual property reduces the efficiency gap, although the effect is not statistically significant. This suggests that property rights regulations might not be relevant for efficiency improvements. The measure of openness to external markets, summarised by the FDI regulation index, shows that stricter FDI rules decrease the efficiency gap. Although this goes against the extensive literature on the positive relation between trade openness and growth, there are several reasons that might explain this result in the sample used in this study. Firstly, the countries considered have very low levels of regulations, hence trade openness is not a major issue (note that the coefficient is only significant at the 10% significance level). Additionally, next to the literature which emphasises the importance of trade openness for growth, there are also contributions that support the positive role of protectionist measures. For example, estimates in Yanikkaya (2003) predict a positive and significant relationship between trade barriers and growth. Although these results are driven by developing countries, they nevertheless imply that the relationship between trade and growth is quite complex. Moreover, the present analysis deals with the specific issue of technical efficiency and it is possible that the impact of FDI openness on growth differs from the effect of this factor on technical efficiency. Additionally, product market and labour market regulations might prevent or delay the necessary adjustments in the combination of inputs, which would allow countries to fully benefit from globalisation. Hence, it is possible that increasing international openness may lead to higher levels of production efficiency only

Table 3.5. Reducing the efficiency gap: the role of employment protection legislation

	(1)	(2)	(3)
ICT	-0.574***	-0.559***	-0.557***
Upstream regulation (RI)	4.304***	2.926***	3.141***
EPL burden indicator	0.142***		
EPL regular		4.351***	3.513***
EPL temporary		-2.173***	-3.007***
EPL collective dismissal			2.716**
NMW			1.372***
Observations	3146	3648	3021

*Note: ***, **, * significant at 1, 5 and 10%. All specifications include a time trend.*

Table 3.6. Reducing the efficiency gap: financial regulation, intellectual property rights protection, openness

	(1)	(2)	(3)	(4)
ICT capital	-0.626***	-0.545***	-0.496***	-0.502***
Upstream Regulation (RI)	3.057***	2.441***	2.204***	2.255***
Financial Reform Index	-1.451	-1.849**		
Private Bond Mkt Cap/GDP		-0.307***	-0.317***	-0.288***
Financial Freedom			-2.650***	-2.776***
IPR				-0.080
Regulation of FDI				-1.303*
Observations	3648	3648	3648	3648

*Note: ***, **, * significant at 1, 5 and 10%. All specifications include a time trend.*

over a relatively long time horizon. Further investigation of this issue goes beyond the scope of the present analysis but suggests an interesting development for future research.

3.4. EU PRODUCTIVITY PERFORMANCE AT THE FIRM LEVEL: EVIDENCE FROM EU-EFIGE SURVEY ON MANUFACTURING FIRMS

This section complements the industry level analysis with evidence based on a newly available firm level dataset (EU-EFIGE) which collects information on 14,759 manufacturing firms across seven EU countries (Austria, France, Germany, Hungary, Italy, Spain and the UK)[30], over the period 2007-2009. The analysis focuses on how the financial crisis has affected performance and innovation strategies at the micro level. The focus is on productivity (TFP) rather than efficiency, as data constraints prevent the use of Stochastic Frontier methods.

The financial crisis of 2008-2009 was a watershed for the European Union as it widened growth disparities among the Member States.

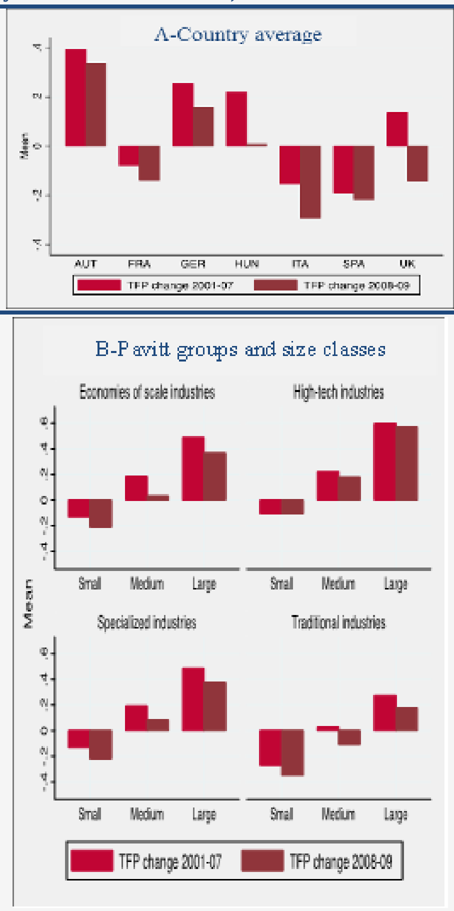
Figure 3.10 (panel A) describes TFP changes between 2008 and 2009 compared to the average annual rate of growth in the pre-crisis period (2001-2007). The average rate of TFP growth was negative in the early 2000s, i.e. before the crisis, in France, Italy and Spain. With the downturn, productivity performance worsened in all countries, but remained positive in Austria, Germany and Hungary. The UK is the country where the deceleration in TFP was most dramatic between the two sub-periods, falling from a positive rate of 16.5% to -15%. In absolute values, Italian firms registered the worst rates of TFP change in the downturn (-29%). There are some important regularities in productivity dynamics in firm-level performance. On average, those firms performing better in terms of TFP growth before the downturn, as measured by the average rate of change between 2001 and 2007, also presented higher rates of productivity growth during the period 2008-2009.

Panel B in Figure 3.10 provides a breakdown of TFP performance, distinguishing among size classes and industry categories. Confidentiality issues prevent the use of detailed industry information, hence the analysis will follow the Pavitt (1984) taxonomy to control for major industry characteristics.

Small-sized companies (fewer than 50 employees) were diffusely characterised by negative productivity dynamics. Large companies (over 249 employees) outperformed other types of firms in all productions[31].

After a period of moderately positive rates of TFP growth, medium-sized firms (50-249 employees) faced a severe drop during the crisis. A relevant exception is in the science-based firms whose productivity growth was positive although slightly reduced during the crisis with respect to the early 2000s. The collapse of the market in 2008-2009 severely hit traditional industries, which experienced a fall in TFP levels of almost 30%, especially because of small firms' performance.

Figure 3.10. TFP growth 2001-07 and 2008-09 (by country, size class and Pavitt)



Note: S=small firms. M=medium firms. L=large firm, Source: EFIGE dataset

[30] The number of firms varies across countries, with approximately 3,000 firms in France, Germany, Italy and Spain, 2067 firms in the UK, 443 in Austria and 488 in Hungary. The sample was originally designed to be representative of the manufacturing sector and, to this aim, was stratified along three dimensions: industries (11 NACE-CLIO industry codes), regions (at the NUTS-1 level of aggregation) and size class (10-19; 20-49; 50-250; more than 250 employees). The dataset does not provide information on firms exiting the market due to the crisis.

[31] Small firms (less than 50 employees) make up 73% of the overall sample, medium firms (between 50 and 249 employees) account for 20% and large firms (more than 249 employees) accounts for 7% of the sample. This implies that large firms are over-represented, due to their relevance in aggregate competitiveness dynamics (Altomonte and Aquilante 2012; p. 5).

Table 3.7. experiencing a turnover reduction in 2009 compared to 2008 (by size class)								
	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Small firms	60.3	69.6	61.6	75.4	74.3	82.2	66.7	71.5
Medium firms	72.2	73.4	68.9	82.2	80.0	80.8	64.7	72.9
Large firms	67.4	73.8	56.9	68.9	80.0	84.3	65.7	69.7
Total	63.7	70.7	63.1	76.4	75.4	82.1	66.1	71.7

Source: EFIGE dataset

Table 3.8. Percentage of firms experiencing a turnover reduction in 2009 compared to 2008 (by Pavitt groups)								
	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Economies of scale	66.7	71.9	64.5	77.4	75.3	87.4	68.4	73.0
High-tech	65.2	49.2	48.0	73.3	54.5	69.8	49.5	53.9
Specialised	74.2	72.2	71.9	76.4	77.5	83.9	68.1	74.8
Traditional	61.4	71.9	59.7	75.7	76.5	80.8	65.1	71.9

Source: EFIGE dataset

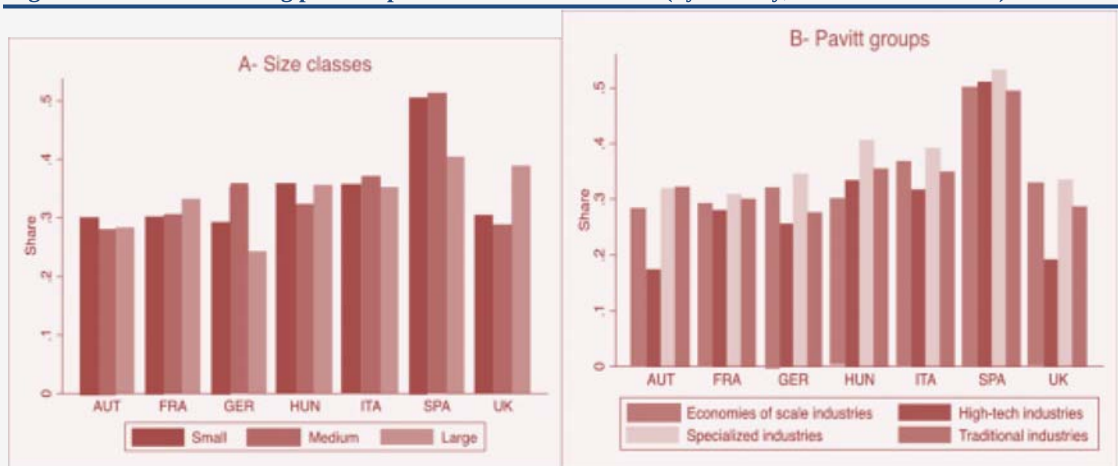
Firm-level productivity is pro-cyclical as, in the short term, it reflects shocks to demand conditions.

Therefore, to better understand cross-country differentials in TFP dynamics, it is necessary to look at how the 2008-2009 crisis affected the performance of EU firms in terms of turnover fall. In Europe, sales declined in 72% of the companies in 2009 compared to the pre-crisis values. This share is considerably higher for Spain (82%), Hungary and Italy (around 75%). In Germany, the percentage of the sample facing a turnover fall is 63%. As Table 3.7 shows, the financial turmoil caused a real downturn that was very pervasive involving all types of firms.

The industry breakdown provided by Table 3.8 illustrates that specialized suppliers were hit by the crisis as 75% of companies experienced a decrease in sales. From this perspective, the crisis looks more severe in Spain, Italy, and Hungary where the proportion of firms facing a turnover reduction was above the EU average. Scale-intensive firms were also considerably affected by the crisis, particularly in Spain where almost 90% of the total sample reduced sales. On the other hand, the fall of turnover was less pervasive among high-tech firms.

Rates of investment fluctuate remarkably along the business cycle, reflecting firms' expectations of future sales and profitability. In the recent downturn, the fall in investment was exacerbated by the credit crunch. Along with the intensity of the business cycle, cross-country differentials in firms' capital formation reflect disparities in the structure of the domestic financial systems. In Europe, 43% of firms reduced planned investment in equipment between 2008 and 2009 (ICT and non-ICT assets). This proportion rises with firm size, from 42% for small firms to 47.6% of large firms (Table 3.9). The

Figure 3.11. Firms reducing product/process innovation in 2009 (by country, size class and Pavitt)



Source: EFIGE datase

greater sensitivity of investment in large companies probably depends on a wider exposure to the international market, and therefore to the collapse of foreign demand.

However, there are big differences among countries, as large firms performed relatively better in Germany, Austria and, to a lesser extent, in the UK.

The decrease in investment was quite diffuse throughout the economy in France and Spain, where between 55% and 60% of the sample reduced their commitments. Conversely, the effect of the credit crunch and the demand fall appears less severe in Austria, Germany and Italy, where only 30-35% of manufacturing firms cut investment plans. The analysis of investment dynamics following the Pavitt groupings provides additional insights (Table 3.10). Although the overall average is similar for traditional, specialised suppliers and scale intensive industries, there is large heterogeneity across countries. Supplier-dominated (traditional) firms performed relatively better in Germany, Italy and Austria, but struggled in France. Among high-tech firms, Austria is the country with the smallest decrease in investments, followed by Germany, the UK and Italy. Spain and France show a parallel performance in specialised providers and scale-intensive firms.

Innovation performance of EU firms is examined using a large spectrum of indicators. The most comprehensive measure at hand from the EU-EFIGE dataset is the percentage of companies introducing a process or/and product innovation between 2007 and 2009 (Table 3.11).

In Europe, 65% of companies were engaged in such activities. The breakdown is 61% for small firms, 73% for the medium-sized firms and 79% for the largest ones. Austria leads in terms of the proportion of firms involved in innovation, followed by Spain and Italy. It is well known that this kind of qualitative indicator is more suited to describe the innovative capacity in less technologically advanced production, which explains why Germany is at the bottom of the ranking. Germany recovers in the ranking when looking at proxies for formal innovation such as the proportion of R&D-performing firms, R&D intensity over sales and patenting.

On average, one out of two EU firms declares that it carries out R&D projects. Again, Austria shows the largest proportion of innovators, closely followed by Germany and Italy. Engagement in formal research is rather low in Spain and in Hungary[32].

The financial crisis and the consequent downturn caused a drop in firm demand and severely clouded expectations of future sales. These issues, combined with tighter credit conditions, led one third of EU firms to postpone their programmes for product or/and process innovation (Figure 3.11, Panel A). The share of firms reducing their engagement in innovation activities reaches 50% among Spanish SMEs. A larger heterogeneity emerges when looking at how firms changed their innovation programmes because of the deepening crisis across industry groupings (Figure 3.11, Panel B). Half of the Spanish firms postponed product/process innovation; this proportion is similar among Pavitt categories. Apart from Spain, innovation activities of high-tech companies were less affected by the turmoil.

[32] For a comparison of the EU with non-EU R&D performance see Moncado-Paternò-Castello et al. (2010). This study shows that the US has a stronger sectoral specialisation in the R&D intensive (especially ICT related) sectors, compared to the EU. Furthermore, the population of R&D investing firms within these sectors is relatively larger.

Table 3.9. Percentage of firms reducing investment in 2009 compared to 2008 (by size class)

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Small firms	32.3	55.1	26.8	46.4	35.8	52.0	39.5	42.0
Medium firms	45.5	54.9	36.0	41.5	36.0	55.5	43.2	44.2
Large firms	40.6	62.6	31.5	60.5	50.4	58.6	43.0	47.6
Total	35.8	55.7	29.8	46.6	36.7	52.9	40.6	42.9

Source: EFIGE dataset

Table 3.10. Percentage of firms experiencing a turnover reduction in 2009 compared to 2008 (by Pavitt groups)

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Economies of scale	37.8	52.8	29.1	46.6	38.2	56.7	40.8	43.0
High-tech	21.1	43.7	22.7	41.7	29.4	42.4	24.7	31.3
Specialised	41.7	55.0	37.4	39.3	40.2	57.8	40.9	44.9
Traditional	37.2	58.8	26.7	50.6	35.6	51.1	41.9	43.2

Source: EFIGE dataset

Table 3.11. Firm innovation performance in 2007-2009: summary of results (% of total)

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Product/process innovation	75.9	56.3	64.6	55.7	67.5	69.6	67.3	64.9
Reduction product/process innovation (in 2009)	29.4	30.2	30.4	34.8	35.8	50.1	30.3	35.4
Doing R&D	55.5	50.7	54.6	26.8	55.0	46.0	53.2	51.2
R&D intensity on turnover	6.5	6.2	7.8	5.7	7.3	7.1	6.9	7.0
Patent an innovation	19.4	11.7	15.8	4.3	14.2	11.2	14.0	13.2

Source: EFIGE dataset

3.4.1. Analysis of the productivity effect of the crisis: econometric evidence

This section investigates how the financial crisis affected firms' productivity performance by developing an empirical model where the rate of growth of TFP between 2008 and 2009 ($\Delta lnTFP_{i,2008-2009}$) is explained by a large set of company characteristics, all defined as dummy variables[33]. The analysis is based on the following specification:

$$\Delta \ln TFP_{i,2008-09} = \alpha_1 \ln TFP_{i,2008} + \alpha_2 CRISIS_i + \alpha_3 INTAG_i + \alpha_4 OPENESS_i + \alpha_5 LABOUR_i + \alpha_6 FINANCE_i + \alpha_7 OTHER_i + size_i + pavitt_i \; country_i + \varepsilon_i \quad (3.5)$$

To allow for the dynamic profile of productivity performance, the level of TFP in 2008 is included among the regressors. A negative coefficient on this variable would indicate the presence of a catch-up effect, whereby lower productivity firms fill the gap with the best performing ones. The first set of dummy variables (*CRISIS* in eq. 3.5*)* seeks to check for the effect of the financial crisis on TFP. This set includes information on the reduction of turnover, investment and innovations. These are all expected to negatively impact on TFP growth. A second set of dummies (*INTANG*) captures firms' decisions in relation to invest in intangible assets and provides information on whether the firm has conducted R&D investments over the period[34], employed a higher proportion of educated workers compared to the national average (human capital) or implemented some relevant organisational changes. Extensive evidence at the micro economic level shows that

[33] The cross-sectional regression model is estimated by OLS, using heteroskedasticity robust standard errors.

[34] R&D-performing firms is the preferred measure of innovation effort among those available as its effect is more robust across specifications.

intangible factors concur to build the knowledge stock of the company, enhancing its productivity performance and, more generally, the degree of competitiveness (Hall et al. 2009, O'Mahony and Vecchi 2009).

Another set of controls looks for firms' engagement in the international market (*OPENESS*). These include firms' decision to import material or service intermediate inputs in 2008 or before, and the decision to carry out FDI. An additional dummy variable for companies belonging to foreign groups is also considered to assess whether there is a positive relationship between firms' participation in international networks and productivity growth. The existing literature generally supports the evidence that international firms are more productive than those less prone to undertake foreign activities (Wagner 2012). However, little is known about the performance of these firms during particularly critical economic conditions.

The model also accounts for the role of institutional settings on firms' productivity, consistently with the analysis in previous sections of the chapter. The information on the EFIGE data set makes it possible to check how companies adjusted their activities as a result of the changes in labour market regulations throughout the 2000s (*LABOUR* variable in the econometric model 3.5). The impact of such reforms is captured by a dummy variable which identifies companies resorting to temporary and part-time contracts. Existing evidence shows that a high share of temporary workers is negatively associated with productivity growth, due to the low experience and low endowments of firm-specific human capital of such employees (Daveri and Parisi 2010).

Table 3.12. Determinants of TFP growth 2008-2009: OLS regression (by total sample, size classes and Pavitt groups) Dependent variable: TFP change 2008-2009

	(1) Total sample	(2) Small firms	(3) Medium firms	(4) Large firms	(5) Scale intensive	(6) High-tech	(7) Specia-lized	(8) Traditional
Log TFP 2008	0.881***	0.880***	0.903***	0.843***	0.898***	0.900***	0.886***	0.868***
	(0.010)	(0.012)	(0.017)	(0.043)	(0.017)	(0.054)	(0.019)	(0.016)
Crisis effect								
Turnover reduction	-0.063***	-0.065***	-0.048***	-0.079***	-0.063***	-0.074***	-0.055***	-0.063***
	(0.005)	(0.005)	(0.010)	(0.021)	(0.010)	(0.021)	(0.011)	(0.006)
Investment reduction	-0.019***	-0.013**	-0.034***	-0.025	-0.019**	-0.013	-0.032***	-0.013**
	(0.004)	(0.005)	(0.009)	(0.019)	(0.009)	(0.026)	(0.011)	(0.006)
Innovation reduction	-0.006	-0.008	-0.003	0.018	-0.018**	0.030	0.008	-0.007
	(0.004)	(0.005)	(0.008)	(0.018)	(0.009)	(0.023)	(0.010)	(0.006)
Intangibles								
R&D-doing firm	0.011**	0.011**	0.009	0.014	0.031***	-0.010	-0.004	0.005
	(0.005)	(0.005)	(0.009)	(0.021)	(0.010)	(0.024)	(0.010)	(0.006)
Human capital	0.008*	0.011**	-0.006	0.010	0.006	-0.034	-0.002	0.015**
	(0.005)	(0.006)	(0.010)	(0.025)	(0.010)	(0.021)	(0.010)	(0.007)
Organizational change	0.003	-0.002	0.003	0.019	0.003	-0.016	-0.007	0.007
	(0.004)	(0.006)	(0.009)	(0.017)	(0.009)	(0.026)	(0.009)	(0.006)
Controls								
Openness								
Importer of materials	0.005	0.009	-0.009	0.005	0.003	0.030	0.010	0.002
	(0.004)	(0.005)	(0.009)	(0.020)	(0.010)	(0.023)	(0.010)	(0.006)
Importer of services	0.013**	0.011	0.013	0.020	0.017	0.047**	-0.001	0.012
	(0.005)	(0.007)	(0.009)	(0.019)	(0.011)	(0.023)	(0.010)	(0.007)
FDI active	0.012	0.009	0.019	0.010	0.056**	0.006	0.003	-0.013
	(0.011)	(0.031)	(0.015)	(0.019)	(0.024)	(0.033)	(0.019)	(0.018)
FDI passive (foreign group)	0.022***	0.032**	0.012	0.045**	0.017	0.037	0.014	0.029*
	(0.008)	(0.016)	(0.011)	(0.020)	(0.014)	(0.033)	(0.015)	(0.016)
Labour input								
Flexible contracts	-0.003	0.002	-0.036**	0.018	0.006	0.001	-0.037***	0.002
	(0.006)	(0.007)	(0.017)	(0.028)	(0.014)	(0.034)	(0.012)	(0.008)
Financial input								
Rationed credit	-0.017	-0.027*	0.026	0.011	0.010	-0.028	-0.041	-0.020
	(0.012)	(0.014)	(0.018)	(0.051)	(0.023)	(0.045)	(0.032)	(0.015)
Other firm characteristics								
Family management	-0.013***	-0.012**	-0.023	0.052	-0.004	-0.007	-0.031**	-0.013**
	(0.005)	(0.005)	(0.020)	(0.040)	(0.011)	(0.030)	(0.014)	(0.006)
Quality certification	0.009**	0.009*	0.007	0.007	-0.005	0.032	0.032***	0.009
	(0.004)	(0.005)	(0.009)	(0.021)	(0.009)	(0.028)	(0.010)	(0.006)
Young (less than 6 yrs)	-0.001	0.008	-0.026***	-0.032	-0.008	-0.057**	0.014	0.000
	(0.004)	(0.005)	(0.009)	(0.025)	(0.009)	(0.027)	(0.009)	(0.006)
Constant	0.081***	-0.005	0.083**	0.150***	0.055*	0.123	0.126***	0.046*
	(0.021)	(0.043)	(0.036)	(0.047)	(0.031)	(0.082)	(0.031)	(0.025)
Size dummies	Yes	No	No	No	Yes	Yes	Yes	Yes
Pavitt dummies	Yes	Yes	Yes	Yes	No	No	No	No
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,077	4,852	1,641	584	1,844	273	1,349	3,611
R-squared	0.878	0.844	0.882	0.867	0.883	0.900	0.872	0.865

*Notes: Robust Standard errors in parentheses. ***,**,* significant at 1,5, and 10%.*

Due to the financial nature of the downturn, it is also important to check whether worsening conditions in the credit market affected firms' performance (variable '*FINANCE'* in the econometric model 3.5). This is captured by the inclusion of a dummy variable that takes value of 1 if the firm required credit during the crisis but did not obtain it. There is considerable evidence that EU SMEs were severely hampered in accessing credit but the issue of whether this translated into lower rates of productivity growth is less explored (Houlton et al. 2012). Firms' decisions to invest in intangible assets and to compete on international markets are related to their managerial abilities (Castellani and Giovannetti 2010). The analysis accounts for this issue by including a family management variable (a dummy equals 1 if the share of managers of the controlling family is higher than the national mean) and a quality certification dummy, which equals 1 if the firm has received some quality equivalent certification. Managerial practices explain large variation in firm productivity growth, negatively affecting aggregate productivity growth (Bloom and Van Reenen 2007, 2010).

Other control variables include the age of the firm, country, size and industry (Pavitt) dummies. The productivity impact of firms' age is captured by a dummy variable taking the unit value if the firm is less than six year old. This controls for possible differences in performance between young and relatively old firms. The former have higher growth potential, but they are not necessarily as productive (or efficient) as the incumbents. During the 1990s, highly innovative start-ups were found to make an important contribution to aggregate productivity growth in the US, whilst their role in the EU was less clear (Bassanini and Scarpetta 2002).

Regression results are presented in Table 3.12. Estimates are provided for the overall sample, and then split according to size classes and Pavitt groups. Overall, results corroborate most of the trends highlighted in the earlier sections. The positive coefficient on the level of TFP in 2008 suggests that there has been no productivity catch-up among companies during the crisis. This feature is common across size classes and industry groups. This implies that, within any single country, those firms which were most productive at the outset of the downturn accommodated better the negative shock, with above-average outperformance in terms of TFP growth during 2008-2009.

Firms which experienced a turnover and an investment reduction underperformed compared to those less affected by the crisis. The significance of both variables indicates that the downturn impacted distinctly on these two dimensions of firm performance and this, in turn, negatively affected TFP growth. The effect of turnover reduction was relatively more severe among large and high-tech firms, while the decline in investment particularly affected productivity growth in medium firms and specialised producers. On average, firms endowed with intangible assets performed better, especially when these factors were the outcome of research activities or resulted from the employment of highly educated workers. Results in Table 3.12 indicate that intangible assets are important drivers of productivity growth, particularly for small firms and those specialised in scale-intensive production. The fact that intangible inputs were not associated with better productivity performance in more technologically advanced productions, such as science-based industries, may be due to the low variation among these firms in R&D engagement and human capital endowment. Interestingly, companies that had undertaken organisational changes before the crisis did not display a different productivity performance from the rest of the sample during the downturn.

This may reflect the long time necessary before these changes affect productivity (Rincon et al. 2012). International firms were more productive with respect to those active solely in the domestic market, in particular those affiliated to a foreign group. This feature is common to both small and large firms. Conversely, the industry breakdown does not offer insights on the role of this variable among Pavitt categories, apart from the weakly significant effect found for traditional firms. Among high-tech firms, productivity grew faster in those importing service intermediate inputs; scale intensive firms that had previously carried out some production tasks abroad also experienced higher productivity growth (FDI active). In accordance with the literature on the regulation governing the labour market, firms relying upon flexible contracts experienced lower productivity growth.However, this effect is confined to medium-sized firms and specialised suppliers. Results also provide evidence on the negative impact of worsening credit conditions on productivity for small firms (Houlton et al. 2012). Concerning other firm characteristics, results show that family management is another condition which hampered the productivity growth of smaller firms, traditional companies and specialised suppliers. Apart from this last group of firms, going through quality certification does not signal better managerial practices and, as a consequence, faster productivity growth. Looking at the age profile, productivity did not grow at a differential speed among young firms; rather, young medium-sized and high-tech firms underperformed compared to more mature firms. Probably, young companies were not sufficiently structured to tackle the collapse of the market between 2008 and 2009, or were not able to fully exploit their growth potential due to the worsening in demand conditions.

3.5. SUMMARY AND POLICY IMPLICATIONS

This chapter has described the main features of recent EU aggregate and industry productivity performance from an international perspective, and has provided empirical evidences on the key forces behind the productivity growth differentials with respect to the US. Identifying these factors is crucial for designing policies able to reduce the gap and to restore sustained growth in Europe. In the late 1990s, characterised by the emergence of ICT technologies, market services were the main culprit of the EU productivity disadvantage. In the years leading to the financial crisis, however, the EU experienced strong ICT-related labour productivity growth in these sectors, mirroring earlier developments in the US, and boosting convergence towards US productivity levels. Since the crisis, however, the EU-US productivity gap has widened again.

The responses to the downturn have been heterogeneous across the different sectors in the EU. Overall, service sectors appear to have been relatively less affected by the global economic crisis compared to manufacturing. Some key sectors, such as business services, have helped in narrowing the productivity gap with the US in recent years. A plausible explanation is that these sectors are usually more sheltered from international competition than manufacturing sectors, and therefore, less exposed to global economic shocks. It is also possible that these sectors have continued to reap the benefits of strong tangible and intangible investments undertaken over the past decade.

This positive outlook for labour productivity expansion in some EU services sectors, however, contrasts with a poor TFP performance. This finding suggests that the EU continues to experience lower levels of efficiency, with which inputs are used in the production process, than the US. These results call for a more in-depth analysis of factors affecting TFP since, this is one of the main engines for increasing income levels in the long run.

The econometric analysis has considered two main channels through which it is possible to raise the productivity growth potential and close the gap with technology leaders. First, consideration has been given to the role of absorptive capacity and knowledge-base (intangible) assets – i.e. R&D and human capital – in activating, and benefiting from, international technology transfers. This mechanism has been found in the literature to be highly conducive to productivity growth through spillovers. However, its growth-enhancing effect is heterogeneous and it requires the ability to accommodate the inflow of new technological knowledge by re-allocating factors or, for instance, expanding new product lines. The set of rules that regulate the functioning of internal markets is important in process of checking for the productivity effects of technology transfers. This analysis has not found convincing evidence that more restrictive regulations on the labour, product and financial markets significantly hamper the capacity of a country to reap the benefits of knowledge developed elsewhere.

The second channel, is the role of production efficiency as a possible driving force behind the widening productivity gaps between the EU and the US. The analysis has shown that productive efficiency is significantly higher in countries with less restrictive product market regulations or employment protection laws. However, when there are few restrictions on the use of temporary contracts and in financial markets, the efficiency gaps with respect to the frontier are likely to increase, as these might encourage firms to adopt cost-cutting strategies rather than the most efficient methods of production. Investment in ICT assets, on the other hand, is one of the crucial factors that help in reducing the distance from the most efficient country and/or industry.

Broadly consistent evidence also emerges from the analysis of firm-level performance at the outset of the financial crisis. The analysis undertaken for seven EU economies provides strong micro foundations to the observed widening productivity differentials at a more aggregate level. This study shows that the most productive firms, prior to the crisis, which experienced faster TFP growth afterwards. This finding confirms that, even within the EU, the recent downturn seems to have reinforced the trend of diverging productivity patterns which emerged in the earlier period.

Overall, the analysis carried out in this chapter provides insights into which policies may be more effective in raising productivity performance within the EU and closing the gap with the US. A common finding throughout the chapter is that intangible assets (R&D, human capital, organizational change) are important sources of TFP growth and sustained long-run competitiveness. From this perspective, initiatives aimed at stimulating such investments may be particularly useful.

Albeit EU countries represent an important share of R&D at a worldwide level, they are less specialized in high-tech sectors compared to the US. The different structural specialisation of the EU countries explains why they have fewer young firms among its leading innovators and their young firms are less innovative than in the US (Cincera and Veugelers 2010). Also, in Europe the proportion of R&D-doing firms is considerably lower than the US. These factors can explain the discussed research gap

(Moncada-释Paternò-Castello et al. 2010).

Ample evidence can be found in the literature, for example, about the effectiveness of tax incentives to raise research effort. This policy instrument does not distort market incentives because; it reduces the cost of R&D without influencing firms' choices regarding specific projects (David et al. 2000)[35]. In the OECD area, public policies to directly sustain R&D have also been implemented through a combination of measures favouring a large spectrum of knowledge-intensive sectors (ICT, pharmaceuticals, biotechnologies, etc.). In this way, these countries have sought to shift their industrial structures towards high-tech productions and increase thus their international competitiveness.

Specific policy initiatives may also be put in place to increase a firm's endowment of qualified workers, for instance facilitating hiring of highly qualified workers (such as professional managers) or to sustain workforce training to enhance the endowment of firm-specific human capital. Other sound policies could be directed towards raising investment in inputs such as ICT, which can assist in the reorganisation of production. Specific ICT applications, such as enterprise software systems, have been related to increasing productivity at the firm level in the existing literature (Engelstatter 2009). These measures would also be viable for smaller firms which do not always have the necessary resources to embark on formal R&D activities and need alternative ways of increasing their competitiveness (EC 2012 and 2013). It should be borne in mind that ICT may spur productivity performance by increasing efficiency in production tasks and this effect may occur with some lags. These measures may therefore be accompanied by other policies targeted to facilitating factors. Policies aimed at improving the functioning of product and factor markets may be particularly effective. Reducing the strictness of product market regulations, largely concentrated in key service-providing industries, is likely to be conducive to higher levels of efficiency across the whole economy, by allowing input re-allocation, outsourcing of marginal tasks, and the adoption of the best production and managerial practices. Changes in the regulatory setting of the labour market should also be tailored to restore an optimal mix of regular and temporary workers, bearing in mind that an excessive liberalisation of temporary workers' contracts may hinder productivity and efficiency performance.

Given the role of financial input on productivity performance, it appears useful to promote policies designed to increase firms' access to external funding, such as bank credit and private bonds. These measures should be conceived and applied within an appropriate regulatory framework which will safeguard the stability and facilitate the reduction of productivity and efficiency gaps.

[35] A possible drawback is that it influences the composition of research project favouring those with a higher profitability in the short run.