SEPTEMBER 2014

Research Report 396

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This report is based on the Background Study for the European Competitiveness Report 2013. The work was done for the European Commission, DG Enterprise and Industry, under the Framework Contract ENTR/2009/033. The opinions expressed are those of the authors only and do not represent the Commission's official position.

Abstract

This study analyses the impact of knowledge assets on productivity and technical efficiency in the EU, as well as their role in the process of knowledge transfer. The analysis covers the role of the institutional and regulatory environment in affecting productivity and technical efficiency and how different regulations interact with both the accumulation of knowledge assets and the transfer of technology. Special emphasis is put on the analysis of trends and performance within the EU, across countries and sectors. The trends and performance of the EU at aggregate and sectoral levels are also contrasted with those of other major competitors, such as the United States, Japan or Korea. Further, the effects of the recent crisis on productivity and efficiency at firm level are explored.

Keywords: competitiveness, industrial organisation, manufacturing, services

JEL classification: O11,O12,O43,O57,L60

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Introduction

The EU has experienced a productivity slowdown over the last fifteen years; as a result, the productivity gap relative to the US has widened. Numerous industry-level studies, based on growth accounting, have pointed to the relative productivity under-performance of just a few sectors in the EU, mainly within market services (Timmer et al., 2010). Indeed, O'Mahony and van Ark (2003) found that productivity deceleration in Europe can be attributed to the same industries that had an outstanding performance in the US, namely wholesale and retail and finance. Further, these studies indicated that the EU's relative under-performance was the outcome of total factor productivity (TFP) lagging behind that in the US.

The debate on the European productivity slowdown mainly focused on the slower adoption of the new technology, compared to the US (Jorgenson and Stiroh, 2000; O'Mahony and Vecchi, 2005; Venturini, 2009), and on the insufficient level of investments in complementary assets, such as skills and organisational changes. Lower investments in complementary assets are likely to play an important role as they affect countries' absorptive capacity, i.e. their ability to take advantage of the international diffusion of technology (technology transfers). Given that the bulk of technological innovations is concentrated in few frontier countries, improvements in the absorptive capacity of countries/industries that are far away from the frontier is likely to be an important source of productivity growth. However, several years after the 'ICT revolution', the EU is not only still lagging behind the US, but the productivity gap has widened, particularly since the financial and economic crisis of 2007-2008. Therefore, taken alone, the 'delayed hypothesis' for the productivity effect of ICT is not sufficient to understand differences in growth performance1. Understanding the reasons behind the EU productivity gap with respect to the US is necessary to draw policies that will promote a fast catching-up process.

Recent contributions have also focused on the more rigid institutional and regulatory framework in Europe compared to the US as one of the main culprits for the lower productivity performance. The importance of addressing issues concerning regulation and performance has become even more urgent after the financial crisis, which has particularly affected advanced economies (Lane and Milesi-Ferretti, 2010), and appears to have amplified income disparities. Excessive regulation in the product and the labour markets are traditionally associated with lower competition and lower productivity (Nicodeme and Saumer-Leroi, 2007; Bourlés et al., 2012). For example, there is some evidence suggesting that more rigid institutional environment hinders the reallocation of resources from less to more efficient uses thus preventing the necessary adjustments to take full advantage of the new technology (Arnold et al., 2011; Bassanini et al., 2009; Conway et al., 2006). Despite suggestive evidence, understanding the channels through which the regulatory and institutional environment determine TFP growth remains a challenge for empirical economists. An issue that has largely been unexplored is whether both ICT and the institutional framework have an impact on the overall levels of efficiency in the use of resources, i.e. technical efficiency. Identifying both the economic and institutional drivers of productive efficiency may hence be crucial to understand the sources of productivity gap and to design policies that might reduce growth divide. Growth accounting studies, and standard regression analyses, are based on the

[1] In addition, the link between ICT and TFP performance is particularly hard to identify (Stiroh, 2002; Basu et al., 2004; Basu and Fernald, 2007).

assumption that all inputs are fully utilised and that any variation in unmeasured factors' contributions to productivity is due to TFP growth. There are two potential shortcomings in this approach: firstly, it does not account for the fact that firms might be producing below their potential over the business cycle; secondly, although technical efficiency is a component of TFP, its role cannot be disentangled from that of the other components such as technological change, measurement errors and spillovers. This has become a major issue in recent years as one of the main sources of productivity gains in mature economies is greater efficiency, i.e. a higher ability to exploit the existing resources (van Ark et al. 2011). This calls for the use of an additional methodology, next to growth accounting, that specifically addresses the issue of estimating efficiency and the factors that contribute to efficiency improvements.

The first section of this study presents the main output and productivity trends from 1995 to 2012, comparing EU performance with that of the US, Japan, and China. Labour productivity growth is then decomposed into its main components, i.e. capital deepening, labour quality and TFP growth, to assess the relative importance of each factor to explain the economy-wide productivity differentials. Particular attention is devoted to the latest productivity developments in the EU and to the impact of the global financial and economic crisis, accounting for the fact that countries are characterised by different phases of economic development and different growth patterns, and may therefore have reacted differently to cyclical shocks. The call for policy action is particularly pressing in view of the need to address the negative effects of the crisis has had on demand and potential output. The study provides further details on the productivity gap by comparing industry performance and the relative importance of each of the sectors in explaining aggregate productivity developments; this section provides a framework to the industry-level econometric analyses of the report. Section 2 presents a discussion of the recent literature on the topic, focusing on evidence on the impact of ICT and the institutional environment on productivity and growth and the main factors determining technology flows. Section 3 reports econometric evidence on the factors affecting diffusion of R&D focusing on the institutional determinants of absorptive capacity; section 4 quantifies differences in technical efficiency across countries and industries and identifies the factors that determine the efficient use of resources. Section 5 further refines the analysis by presenting current evidence on firm behaviour, focusing not only on firm productivity outcomes but also on firms' strategic decisions regarding investments in tangible and knowledge assets at the outset of the crisis. Section 6 concludes the analysis and outlines policy implications.

1. Growth accounting and the effect of the crisis at country and sector level

This section of the report presents an overview of recent output and labour productivity trends in the EU in comparison with the US and Japan. With the aim of understanding what lies behind the aggregate growth trends, a complete analysis of industry productivity performance is also provided. Emphasis is put on the role played by the different sectors in explaining EU-US productivity differentials, as well as on the changing growth contribution of different inputs to production.

1.1. ECONOMIC PERFORMANCE OF THE EU AND OTHER MAJOR ECONOMIES: THE AGGREGATE PICTURE

1.1.1. OVERVIEW OF AGGREGATE OUTPUT AND PRODUCTIVITY TRENDS

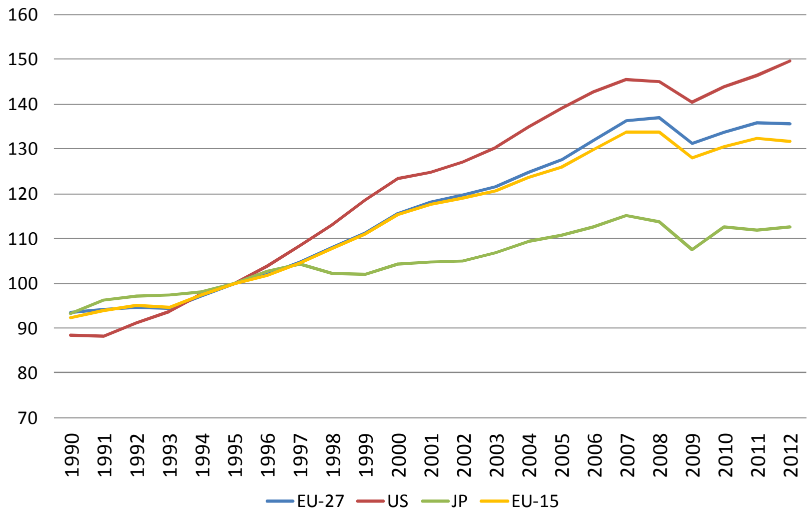
This section presents an overview of recent aggregate output trends in the EU, focusing on the main convergence and divergence patterns, relative to two major competitors: the US and Japan. Information is presented for two different groups of EU countries: the EU-27 and the EU-15. Data on Gross Domestic Product data is drawn from the latest available release of The Conference Board Total Economy Database (January 2013). This source contains economic performance data for individual countries only, therefore an aggregation methodology is employed to convert country output trends into EU aggregate figures, following Timmer et al. (2007). See Appendix Box 1 for a detailed description of this methodology. Figure 1.1 illustrates the evolution of real GDP in the EU, US and Japan from 1990 to 2012, taking 1995 as a benchmark year 2. If during the early 1990s GDP growth was sluggish in all these regions, from the mid-1990s the EU and US economies recovered substantially, although the US expanded at a higher rate than the EU. Between 1995 and 2004, the average GDP growth rate in the US was 3.3%, approximately 0.85 percentage points higher than that experienced by the EU-27 and 0.96 higher than that experienced by the EU-15. Around the same period Japan remained entrapped into a stagnant growth path, with GDP expanding at a rate of just below 1% per annum.

During the period 2004-2007, the EU-27 grew at an annual rate of approximately 3%, while the US growth fell slightly behind, experiencing rates of changes of about 2.5%. In aggregate, the EU-27 economy also showed faster rates of expansion than the group of EU-15 countries, signalling the presence of convergence driven by the newest Member States. Japan's economy fared considerably worse than the European economy between 1995 and 2007, achieving moderate output growth rates (between 1 and 1.5%). Between 2007 and 2012, the US labour productivity growth advantage with respect the EU-27 was approximately 2 percentage points per annum, slightly above 2 percentage points with respect to the EU-15, and 3 percentage points with respect to Japan.

[2] The value of GDP value is set equal to 100 in year 1995 for each region.

At the outset of the crisis, around 2008, output growth started to weaken across all areas, and in 2009 output levels fell globally. By 2010, GDP growth resumed across the US, EU and Japan, with the US exhibiting the strongest recovery. The EU economy also grew again during 2010 and 2011, but it was greatly affected by the sovereign debt crisis, and contracted again in 2012. Japan's output level has remained largely flat since 2010.

Figure 1.1 / GDP growth in the EU-27, the US and Japan, 1990-2012 (Index 1995=100)



Source: The Conference Board Total Economy Database, January 2013; own calculations.

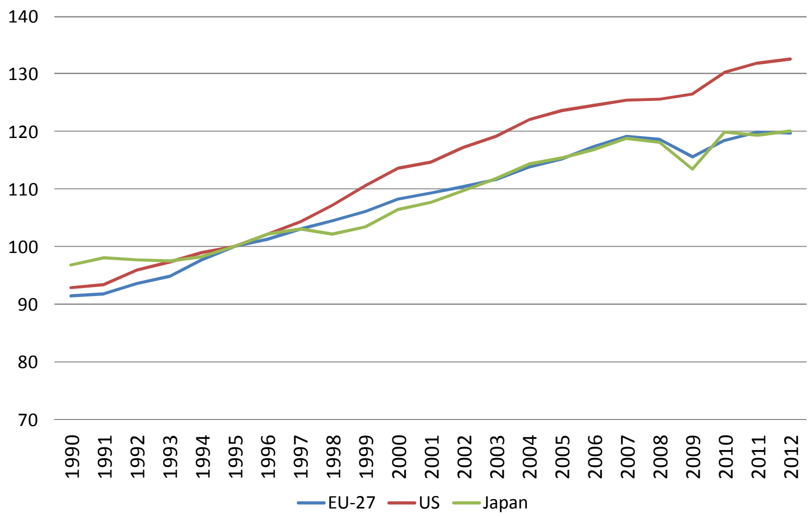
Figure 1.2 plots labour productivity trends in the EU, in comparison to the US and Japan. Productivity is denoted here by GDP per person employed, a measure strongly related to income per capita, and it is set equal to 100 in year 1995 for each region. It can be seen that, from the mid-1990s to the early 2000s, the US experienced strong labour productivity acceleration. This was a period characterised by the widespread diffusion of Information and Communication Technologies (ICT), during which computers, the Internet and e-commerce were rapidly changing the way businesses and consumers operate. Figure 1.3 summarises labour productivity growth rates across detailed sub-periods.

During the period 1995-2004, productivity in the EU grew at a lower speed than in the US. In the latter region, the average growth rate of GDP per person reached 2.46% between 1995 and 2000, i.e. approximately 1 percentage point higher than in the EU-27 (1.44%). This outstanding performance allowed the US to amplify its productivity lead with respect to Europe; this phenomenon is largely attributed to the higher ability of US companies to invest and benefit from the new technology, in particular in the services sector. The view that the EU was simply lagging behind the US in the adoption of new technologies had wide support, as it was recognised that many EU countries were undergoing an adjustment process, moving from less capital intensive manufacturing towards more technology intensive services (O'Mahony and van Ark, 2003). The main question that arose was whether the EU would have been able to resume the catching-up process with the frontier economy, as occurred in the early 1990s, whenever the rate of expansion of the US economy started decelerating (O'Mahony and van Ark, 2003). Indeed, this was observed, to some extent, in the following years, when the EU productivity showed signs of catching up towards the US productivity levels: between 2004 and 2007, GDP per person in the EU-27 grew at 1.53%, slightly faster than in the previous period while in the US productivity growth slowed down considerably, to just below 1% annually.

Although this robust performance helped the EU to close the gap with respect to the US, with the advent of the crisis since 2008 the EU competitiveness deteriorated again. GDP per person fell sharply during the period 2007-2009 in the EU-27 (at a rate of -2.78%) although recovered firmly afterwards (1.68%). Even though moderately, productivity in the United States continued to growth during 2007-2009, at a rate of 0.3% (see also Gordon 2012). Subsequently (2009-2012), the US showed average productivity growth of 1.56%; however, this was still below the rates reached in the late 1990s. Japan experienced lower rates of labour productivity growth compared to the EU in the late 1990s, but it started to catch up since the early 2000s. The productivity slowdown was considerably deeper in the former region than in Europe during the period 2007-2009, but the subsequent recovery was more robust as Japan experienced an average growth rate of 2.84% per annum.

Figure 1.3 also illustrates labour productivity growth rates experienced in China during the period under assessment. The average growth rate of labour productivity between 1995 and 2004 was above 6% per annum, and soared to 11% between 2004 and 2007. During the global recession, GDP person declined slightly, but since 2009 it appears to have picked up again.

Figure 1.2 / GDP per person in the EU-27, the US and Japan, 1990-2012 (Index 1995=100)

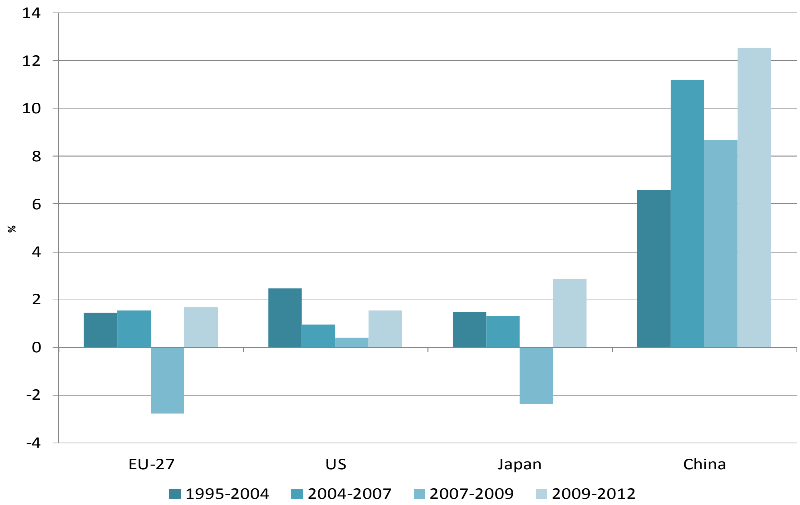


Source: The Conference Board Total Economy Database, January 2013; own calculations.

Tables A.1 and Figure A.1 in the Appendix illustrate trends in GDP per person for detailed sub-periods for individual EU countries. There is substantial variation in labour productivity performance across the EU-27 countries. During the years 2007-2009, labour productivity fell in many of the EU Member States, but has recovered since then. This is the case for Austria, Belgium, the Czech Republic, Germany, Denmark, Italy, the Netherlands and Sweden. In other smaller EU economies, these fluctuations appeared more pronounced, and a stronger improvement followed a more acute productivity decline. This is the case for the Nordic economies such as Finland and Sweden, and some of the newest Member States, such as the Slovak Republic and Slovenia. In some of the most troubled economies labour productivity, as measured by GDP per person, continued to rise during and after the recession;

this is the case of countries like Spain or Ireland (in the former the rate of productivity expansion reached almost 3%). The only country that shows a prolonged worsening of productivity after the financial crisis is Greece. In countries such as the UK, the Netherlands, Belgium, Hungary, Romania the recovery was particularly weak, with output per worker increasing at rates close to zero.

Figure 1.3 / GDP per person by region and sub-period, average growth rates, 1995-2012 (%)



Source: The Conference Board Total Economy Database, January 2013; own calculations.

Figure 1.4 plots average rates of change for a different measure of labour productivity, namely GDP per hour, for the EU-27, the EU-15, the US and Japan. Figure 1.5 summarises these figures by sub-periods. This measure is considered a more accurate indicator of productivity developments over the cycle, as it accounts for actual hours worked, which can be more easily adjusted compared to the number of persons employed.

In the US, labour productivity growth rate was just below 1% per annum between 2004 and 2007, over 1 percentage point lower than in the earlier period. In the EU the growth in GDP per hour during the 2004-2007 period was at similar levels than in 1995-2004. In Japan, labour productivity only slowed down mildly. Between 2007 and 2009, productivity substantially fell in the EU-27 (-0.77 per annum), in the EU-15 (-0.90%), and in Japan (-0.5%). In the latter country, the fall in GDP per hour during 2007-2009 was much lower than the fall in GDP per person. During the period 2009-2012, GDP per hour recovered in the EU and Japan. The average growth rate was just above 1% in the EU-27, just below 1% in the EU-15 whilst it amounted to 2.4% in Japan. Even at the height of the global downturn, productivity continued to grow in the US, by 1.23% in 2007-2009 and by 1% in the subsequent period.

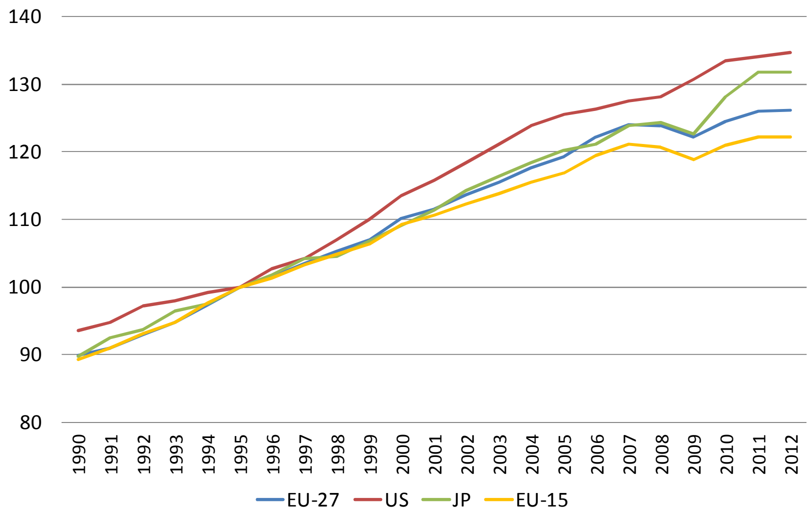
While the general trends are similar to those in Figure 1.2 (GDP per person), Japan's productivity recovery (GDP per hour) after the recession appears stronger, outperforming the EU and the US. From 2010 onwards Japan has experienced a strong productivity recovery, outperforming the EU and the US; this can be explained in the light of the peculiarity of the Japanese labour market. In fact, while employment was largely preserved during the downturn, Japan’s flexible wage system and historical tradition to hoard labour enabled adjustment through the number of hours worked.

In terms of GDP per hour, the EU productivity slowdown and recovery was more moderate than the one shown by GDP per person movements. This is because the fall in hours was greater than the fall in the number of workers, and proportionally larger with the decrease in output. 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 mostly relied on labour shedding, especially in low-skill sectors, resulting into an overall increase in productivity levels (e.g. Spain and Ireland).

Overall, the figures reveal that, in terms of GDP per hour growth, the US has followed a steady declining trend, but still showing a robust performance over the whole period under assessment. As a result of this divergent growth performance, the labour productivity gap between the US and the EU widened again in recent years, in particular during the period 2007-2009. These recent developments have raised concerns that the EU economic outlook is destined to deteriorate even without having reaped the full benefits of the information revolution (see also Gordon 2012).

Appendix Figure A.2 shows the levels of labour productivity (GDP per hour worked) for the EU-27 countries compared to the US and other major economies, in 2012. Currently, the UK's productivity levels for the aggregate economy are 75% of those in the US; the level of productivity in France is approximately 90% of the US levels, in Germany and Denmark it is 77%, in the Netherlands and Sweden 85%, and in Italy and Spain around 60%. The level of productivity in Japan is about 65% of that in the US.

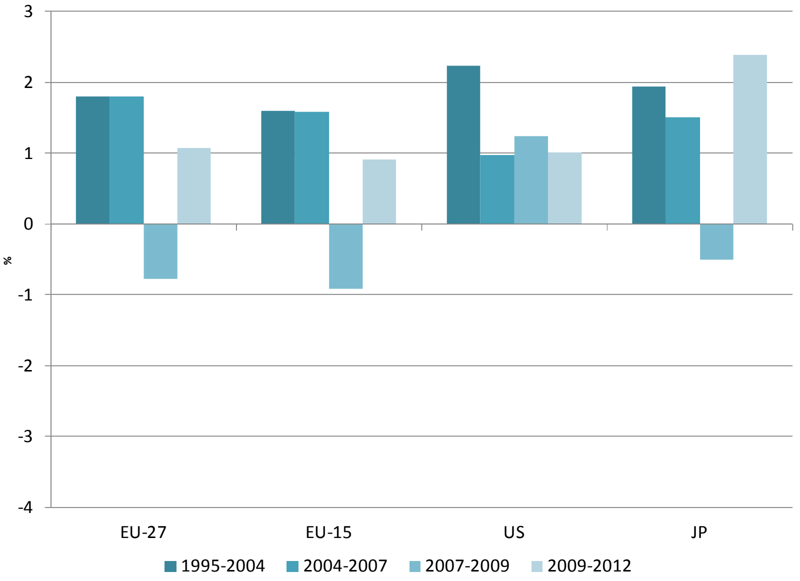
Figure 1.4 / GDP per hour in the EU-27, the US and Japan, 1990-2012 (Index 1995= 100)



Source: The Conference Board Total Economy Database, January 2013; own calculations.

In order to properly capture which forces drive labour productivity growth (output vs labour), it is crucial to look at the occupational dynamics. Table A.2 shows the evolution of employment since 1995 for the different sub-periods. Occupational levels fell significantly in the US during the period 2007-2009 (-2.8%) while in Japan the drop in employment was milder (-1% approximately). This shows that the US economy adjusted to the crisis mostly by decreasing employment, hence productivity kept rising through the downturn. Across EU-27 countries, labour market performance was rather heterogeneous. Important employment losses took place in Spain, Portugal and Ireland and in the majority of the newest Member States (except in Poland, where the number of people employed continued to increase). In the rest of the EU, employment responses to the global financial crisis were of smaller magnitude.

Figure 1.5 / GDP per hour by region and sub-period, 1995-2012 (average growth rates in %)[3]



Source: The Conference Board Total Economy Database, January 2013, own calculations.

Albeit productivity is widely recognised as essential to sustain higher living standards, it is important to look at possible trade-offs between this performance measure and employment (Boulhol and Turner, 2009). In the past fifteen years the United States performed very well in terms of productivity, while employment increases were more modest. In Europe, productivity advances were slow, and employment fared much better than output. A factor that may have contributed to the sluggish long-term productivity performance in Europe is the incorporation of less-qualified workers into the workforce as a result of extensive labour market reforms that promoted higher labour market participation. The relative decline in capital intensity experienced in Europe is another feasible explanation, although there is little evidence that a trade-off between employment and productivity should hold in the long run (McGuckin and van Ark, 2005).

Table A.3 shows that there has been significant variation in hours worked across countries [4]. Both the US and Japan experienced, on average, a decrease in hours worked of nearly 3% per annum during the period 2007-2009. Over the period 2009-2011 total number of hours worked grew again in the US (1.1%), but continued to decrease in Japan (-0.92%) explaining thus the significant increase in GDP per hour in this country. This issue has largely been explored by Steinberg and Nakane (2011) in a work focused on Japan's cyclical labour market response to the global financial crisis. Together with labour

3 For 2011, US GDP per hour is unavailable within the Total Economy Database; a linear interpolation between the values of 2010 and 2012 has been applied to infer the figure for this year.

4 Data on GDP per hour is not reported for China as information on hours worked is not available within The Total Economy Database.

hoarding, a flexible wage system, where firms adjust pay mainly through overtime and bonus payments, can explain the Japanese's better labour market performance compared to other countries [5]. A quick implementation of a subsidy programme and a corporate governance structure that increasingly place workers rights above shareholders are additional measures that contribute to a less cyclical employment response. Although there were important employment losses in the manufacturing and construction sector, these reflected more long-run structural trends. Employment losses were also concentrated in SMEs, as this group of companies was less able to react through cuts in wages. The outlook for the labour market in Japan however remains uncertain as wages have started to increase in line with output recovery, reversing some of the fall during the crisis.

The heterogeneous labour market responses in Europe have largely been driven by country-specific factors. In Europe, the decrease in hours worked was sizeable in some economies, such as Greece, Estonia, Spain and Ireland (see Table A.3 in the Appendix). Job losses largely explain the increase in labour productivity performance experienced by Ireland and Spain. In most of the other EU countries hours worked increased after the crisis, although the recovery was particularly weak in France and Poland, with rates of growth of 0.3% and 0.2% respectively. Some countries (Belgium, Germany, Estonia and Sweden) achieved higher rates of growth in total hours worked between 2009 and 2011 than in the pre-crisis period (2001-2007).

A particular case is the UK where the good employment performance contrasts with a marked productivity slowdown. Productivity has remained weak since the onset of the financial crisis, if compared to previous experiences and to other countries (Hughes et al. 2012). In the UK, GDP per hour grew at an average rate of just under 2.5% per annum from the mid-1990s to 2007; during the period 2007-2009 productivity experienced a decrease of -1.2% per annum and during 2009-2012 the growth was virtually zero (see Table A.4). The high employment-low productivity phenomenon that has emerged in recent times has been termed the ‘UK's labour productivity puzzle’. According to estimates by the Institute of Fiscal Studies, on average British workers are producing 12.8% less than they did in the pre-recession period. The UK economy started to recover in 2009 but labour productivity was still below the pre-crisis values (Oulton and Sebastia-Barriel, 2013).

Two main reasons have been advanced to explain this productivity puzzle. At the start of the crisis, firms might have been hoarding labour as they were reluctant to fire employees, despite the deteriorating demand conditions, in anticipation of a recovery in demand. This hypothesis has lost support over time as the UK faces a slower recovery than expected. Other hypotheses focus on the damage that the financial crisis has produced to the productive capacity of the economy. Capital formation has been hindered by tighter financing conditions, as investment projects have become more costly, and this had led to a process of substitution of capital for labour. Existing evidence also points to a misallocation of capital, as the financial sector has lent more willingly to low productivity firms rather than firms undertaking new projects because of high levels of uncertainty. While some evidence supports this finding (Goodridge et al., 2013), the fall in investment was not large enough to cause a significant decline in capital input per worker and therefore explain entirely the fall in labour productivity). Recent evidence presented by Goodridge et al. (2013) suggests that problems in the measurement of output may help explain the UK's productivity paradox, in particular the lack of an appropriate capitalisation of intangibles.

[5] Balakrishnan et al. (2010) find that in Japan a 10% change in output is followed by a change in unemployment of about 1 to 2 percentage points, compared to about 4% in the rest of the G-7 countries.

The role played by the regulatory and institutional environment may help explain different responses across EU countries. In the UK and Japan the labour market is relatively flexible, which facilitates the process of input substitution. In countries such as Germany the introduction of discretional modifications of the institutional framework, in conjunction with various flexibility measures at the firm level, contributed to the mild response of employment to the crisis (Caliendo and Hogenacker, 2012; Brenke et al., 2011). In Germany, long-existing regulations governing short-term work were modified at the start of the crisis and subsidies for temporary reductions in working time were introduced, resulting in a significant increase in the number of workers with short-time contracts. The implementation of these flexibility instruments thus enabled the adjustment of the workforce at the intensive rather than the extensive margin and proved helpful when firms needed to resume production levels. This type of short-time schemes was supported with government subsidies also in Netherlands and France.

In Spain the massive destruction of employment since 2007 affected disproportionately workers on temporary contracts. This trend contrasted with that in France where unemployment soared only slightly. Bentolila et al. (2010) investigate the reasons underlying the divergent labour market outcomes in these two countries, characterised by similar institutional background and similar employment rates at the start the crisis. These authors argue that a key explanation factor is the stronger segmentation of the labour market prevailing in Spain, revealed by a large gap between firing costs of workers with permanent and temporary contracts. The strict employment laws governing those workers on regular contracts combined with lax regulations for those on temporary contracts discouraged the transformation of temporary jobs into permanent jobs. This fed into the pattern of industry specialisation (in the construction industry), as strict employment laws are not adequate to boost specialisation in highly innovative industries, which require a high degree of labour market flexibility to adapt the composition of the workforce to technological changes (Saint Paul, 1997).

1.1.2. GROWTH ACCOUNTING RESULTS

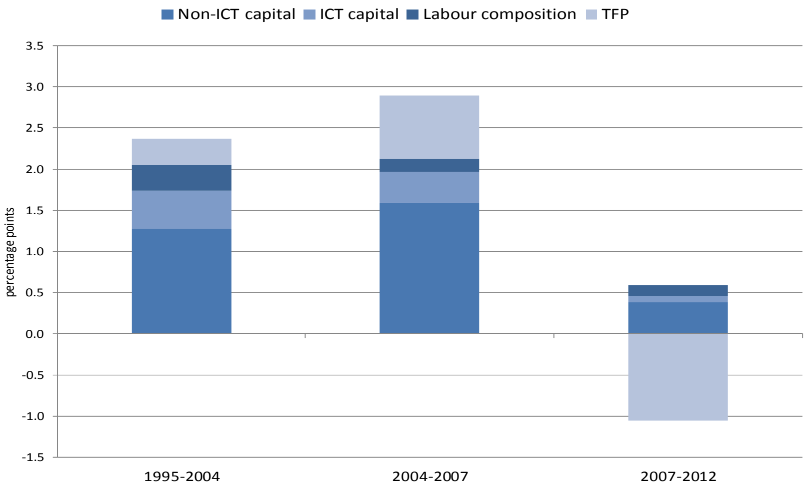
This section extends the overview of the recent labour productivity trends presented above by analysing the different components of productivity growth (Figures 1.6-1.9). This analysis is based on the neoclassical growth accounting methodology, which computes the contribution of each factor input and TFP to the overall output per hour growth. Box 2 in the Appendix includes a detailed description of the growth accounting methodology. If during the ICT revolution and the productivity boom years, differences in the accumulation of ICT capital largely explained EU-US differences in productivity growth, it is legitimate to ask what are the main factors explaining the widening productivity gap observed in the most recent years. In this section, due to limited data availability, the analysis is confined to a group of eight EU countries (Austria, Belgium, Germany, Spain, France, Italy, Netherlands, United Kingdom). Data comes from the EUKLEMS database, which provides detailed information on input contribution, as well as information on capital and labour compensation for these eight countries for up to 2010. Data from The Conference Board is used to extend the growth accounting analysis to 2012.

Figures 1.6 illustrates the contributions of capital deepening, labour composition and total factor productivity growth [6] in the EU. The contribution of capital deepening is distinguished between ICT assets (computers, communications equipment and software) and non-ICT assets (machinery and

[6] A similar aggregation procedure to the one outlined in Section 3.3.1 to construct aggregate EU productivity figures (see Box 1) is followed to calculate the input contributions and TFP for the whole of the EU.

equipment, transport equipment, residential buildings and infrastructure). During the period 1995-2004, the most important contributor to labour productivity in the EU was the accumulation of capital assets. While total factor productivity growth was also positive it was during the subsequent period, 2004-2007, that TFP experienced a significant acceleration. Over the period 2007-2012, total factor productivity growth turned negative in the EU, and the contribution of capital declined significantly, due to tightening credit conditions on European firms. In contrast, the relative contribution of labour composition soared. The latter finding is consistent with prior evidence suggesting that a process of up-skilling of the workforce during these recessive years has taken place in many European countries as businesses may have been hoarding those employees with higher skills (Kang et al., 2012). Goodridge et al. (2013) argue that higher skilled workers are likely to be employed in the creation of intangible assets, thus increasing the potential to achieve faster productivity growth, as witnessed in the UK.

Figure 1.6 / Growth accounting in the EU: Decomposition of labour productivity growth, 1995-2012



Source: EUKLEMS dataset, 2013 release; The Conference Board Total Economy Database, January 2013; own calculations.

Figure A.3 in the Appendix illustrates in detail the results of the growth accounting exercise for each of the EU 27 countries for more detailed sub-periods. In some EU-15, countries such as Germany, Denmark, Finland, Netherlands and the UK the contribution of ICT-capital was relatively larger than the contribution of non-ICT capital from the mid-1990s to the mid-2000s. In countries such as Spain, Italy and Sweden the contribution of ICT-capital was considerably smaller. In the newest Member States (Bulgaria and the Czech Republic), the accumulation of non-ICT capital was the most important source of productivity growth, although the role of ICT capital [7] was quite sizeable in some economies (Czech Republic, Hungary and Slovakia). In other Central and Eastern European economies, namely Estonia, Lithuania, Poland, Romania and Slovakia, growth in multifactor productivity was a main contributor to growth. In the majority of the EU economies the contribution of TFP to labour productivity growth was negative during 2007-2009 and positive between 2010 and 2011. In some countries, however, the contribution of TFP continued to be negative. This is the case for Portugal, Greece, Spain, Luxembourg and, to a lesser extent, the UK. In some countries TFP appears to be more pro-cyclical than in others, perhaps reflecting the speed of adjustment in the use of capital and labour inputs in response to the

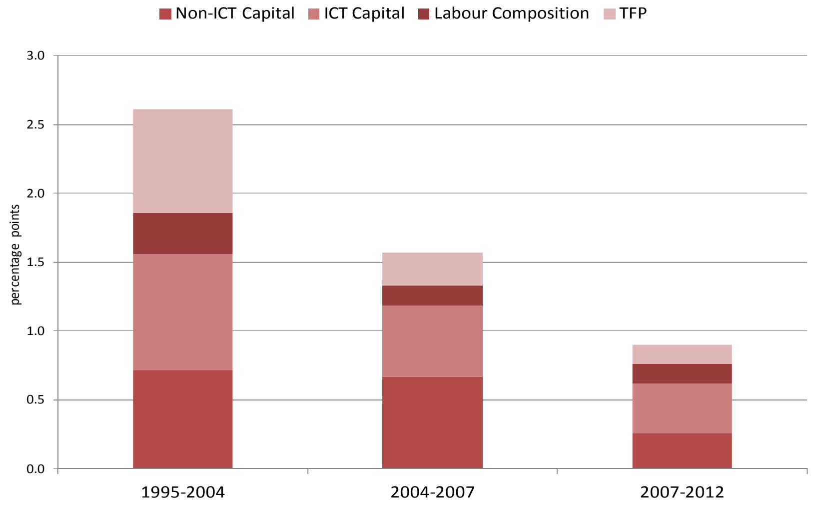
[7] Contribution of ICT-Capital was not available for some countries (LV, LU, EE).

downturn (OECD, 2012). Some evidence also suggests that TFP may be picking up unmeasured input variation over the cycle. Table A.5 in the Appendix contains figures for multifactor productivity growth by country.

During the period 2007-2009 the contribution of non-ICT capital to labour productivity growth rose significantly in most economies; this is because of the increase in the amount of capital per worker, resulting from the decline in employment. However, since 2010 the contribution of non-ICT capital deteriorated significantly in most of the EU economies, following a decrease in capital investment. Since the crisis, the contribution of ICT capital has remained small but stable, while the contribution of non-ICT investment has fallen sharply. The contribution of labour composition, which mostly measures up-skilling of the workforce, was particularly important in the late 1990s and early 2000s, consistently with the hypothesis of complementarity between skills and ICTs. The impact of this factor slightly improved since the crisis, and in 2011 was of similar magnitude to the contribution provided by the ICT and the non-ICT capital inputs; however, it comes to be higher than the contribution of multifactor productivity.

Figure 1.7 shows the growth accounting results for the US. For this country, the main factor driving labour productivity growth during the period 1995-2004 was ICT capital; the relative growth contribution of ICT was substantially larger than in the EU. In the US, the average contribution of ICT capital during the period 1995-2004 was in fact larger than that of non-ICT capital. During the period 2004-2007, the contribution of ICT capital was at much lower levels; the slowdown in US labour productivity during those years can mostly be explained by a decrease in the speed of ICT capital accumulation and a moderation in total factor productivity growth. During the period 2007-2012 the contribution of MFP slowed down but remained positive, and the relative contribution of labour composition increased, in line with the findings for the EU.

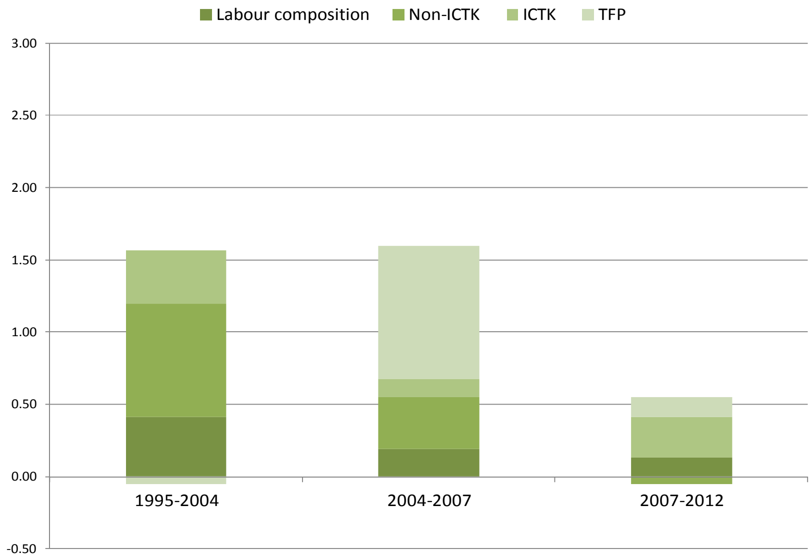
Figure 1.7 / Growth accounting in the US: Decomposition of labour productivity growth, 1995-2012



Source: The Conference Board Total Economy Database, January 2013; own calculations.

Figure 1.8 decomposes labour productivity growth into its main determinants for the Japanese aggregate economy. The growth contribution of capital input has been decreasing over time, in particular for the case of non-ICT capital. During the period 1995-2004, the contribution of TFP was negative but accelerated significantly during 2004-2007. TFP gains were the main driving factor of labour productivity gains during that period. Since the crisis, the contribution of non-ICT capital has become negative; therefore, in relative terms, the contributions of ICT-capital and labour composition have increased.

Figure 1.8 / Growth accounting in Japan: Decomposition of labour productivity growth, 1995-2012



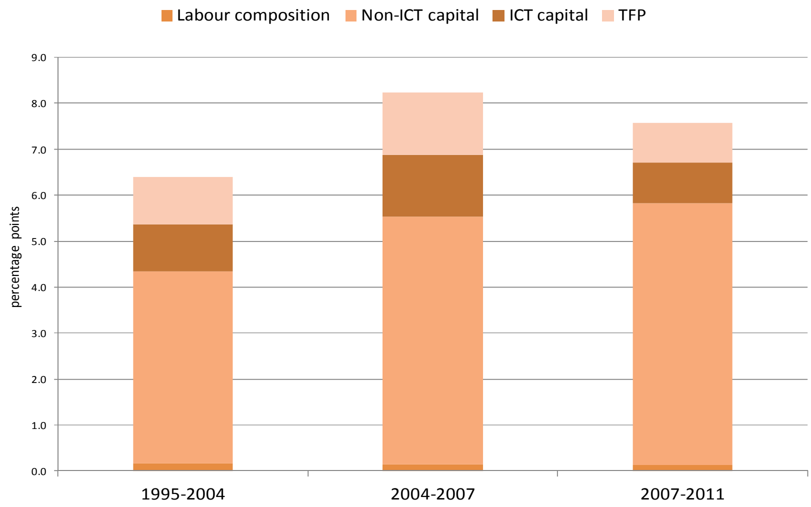
Source: The Conference Board Total Economy Database, January 2013; own calculations.

CASE STUDY: CHINA AND THE FORCES DRIVING AN OUTSTANDING GROWTH PERFORMANCE

In this section a standard neoclassical growth accounting framework is used to analyse the drivers and components of China's growth performance; China has grown at an average rate of 9.3% per annum since the introduction of market-oriented reforms in 1979. Section 1.1.1 has shown that GDP per person grew at 11% annually during the period 2004-2007 in the aftermath of the global financial crisis showed signs of slowing down. Despite growth momentum has improved in the most recent years doubts have arisen concerning the long-term sustainability of China's growth, due to important economic imbalances (NIER, 2013). Figure 1.9 below shows that non-ICT capital accumulation has been the main driver of growth in output per worker, consistently with the catching-up phenomenon, whereby economic growth in developing countries is mainly driven by capital investment (Wu, 2003). The contribution of non-ICT capital is much larger than that of ICT capital and total factor productivity in the Chinese economy; the role played by labour composition appears minor. Figure 1.9 reveals that while labour productivity has risen rapidly, growth in multifactor productivity has been more modest. Since the mid-2000s, however, TFP has been increasing at a higher speed, consistently with the existing evidence (Yeuh, 2013). However, caution needs to be taken in interpreting these results, as the peculiarities of the Chinese economy and the role played by its institutions may have a distortive effect on total factor productivity, which captures reallocation of resources from less efficiency to more efficient parts of the economy.

Several studies have investigated the sources of TFP growth in China offering a variety of results. Yueh (2013) argues that on-going structural reforms are the main force behind TFP increases in China, while productivity gains due to factor reallocation and efficiency-driven improvements account less than one eighth of China's annual GDP growth. Using firm level data, Brandt et al. (2012), find that the widespread TFP gains in the Chinese manufacturing sector were driven by the productivity performance of both incumbents (the intensive margin of TFP growth) and new coming firms (the extensive margin of TFP growth). In this study, TFP growth accounted for about two-thirds of total labour productivity growth between 1998 and 2007. Van Reenen and Yueh (2012) explore the role of technology transfer as a mechanism to catch up in China. They find that technology transfer mechanism such as international joint ventures raised TFP in Chinese firms, mainly through imitation and absorption of the international partner's know-how.

Figure 1.9 / Growth accounting in China: Decomposition of labour productivity growth, 1995-2011



Source: The Conference Board Total Economy Database, January 2013; own calculations.

1.2. THE EU-US PRODUCTIVITY GAP: A SECTORAL PERSPECTIVE

1.2.1. SECTORAL LABOUR PRODUCTIVITY GROWTH TRENDS

A better understanding of the sources of the productivity gap between the EU and the US, discussed in the previous section, can be achieved by looking at labour productivity trends at the industry level. The analysis is conducted using industry data, drawn from the latest release of the EUKLEMS database which follows the NACE Rev. 2 classification of economic activities (see O'Mahony and Timmer, 2009 for a detailed account of sources and methodology underlying the construction of this database). Due to data constraints, the analysis of the most recent productivity developments is again only possible for eight major EU economies: Austria, Belgium, Spain, France, Germany, Italy, Netherlands and the United Kingdom [8]. The latest information refers to the year 2010, except in the case of the United Kingdom, where information is only available until 2009. Based on this newly-released country-specific productivity

8 These economies represented in 2012 approximately 80 per the output of the EU (see Appendix Figure A.3)

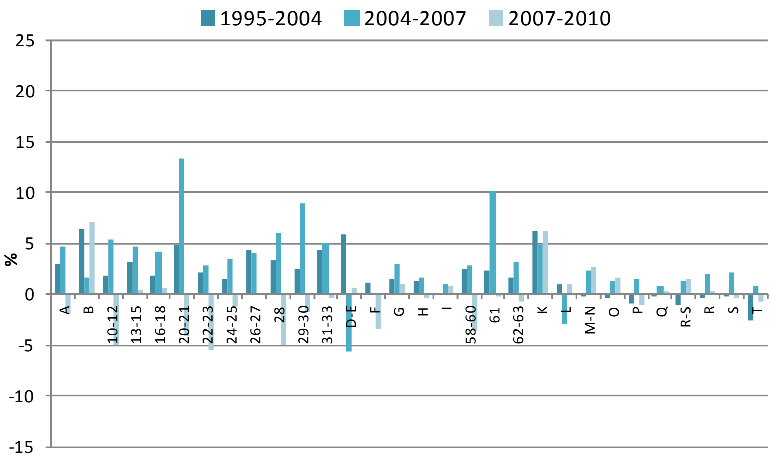
data, an aggregate figure for the EU-8 is constructed using country output shares (Box 1 in the Appendix outlines details of the aggregation methodology employed to convert country productivity tends into EU aggregate trends; this is largely based on the recommendations set out in Timmer et al. (2007).

Figures 1.10 and 3.1.11 below illustrate labour productivity growth performance for the overall EU-8 economy and the US respectively, broken down by sub-periods and detailed industry sectors. The measure of labour productivity considered here is real value added per hour worked. Appendix Table A.6 complements the two figures by providing detailed information on growth rates by industry. During the period 1995-2004 the US was growing at a rate of 2.32% per annum, which implied a 0.64% point advantage compared to the EU-8. The US performance was mainly driven by four industries: electrical and optical equipment, with an average growth of almost 21%; coke and refined petroleum products, with a 15% rate; and information and communication, and wholesale and retail, which experienced an average productivity growth of around 4% per annum. In Europe, the best performing industries over the same period achieved between 5% (chemical and chemical products) and 8% (coke and refined petroleum) annual rate of productivity growth. These figures, which are consistent with those provided by the Total Economy Database covered in Section 1, testify the stronger performance of US industries compared to the EU. Particularly weak was the performance of the EU service sector, where several industries experienced negative rates of growth. These were particularly concentrated in the personal, community and entertainment services, with rates between -0.14 (Other service activities) and -2.52 (activities of households as employers), and in wholesale, retail and repair of motor vehicles (-0.67%). The US also experienced negative rates of productivity growth in the personal services and in the entertainment industry; however, differently from the EU, the wholesale industry grew at a rate of nearly 6% over the 1994-2005 period.

In the next sub-period (2004-2007), the EU-8 grew at a higher rate than the US (Table A.6), therefore experiencing a significant productivity catch-up to the US levels. The EU-8 average growth rate during that period was 2.82%, while the annual average growth rate in the US was only 1%. The EU performance was particularly strong in manufacturing, where the chemical industry played a major role, with a 13% rate of productivity growth. Productivity in electrical and optical equipment grew at 4% annually, a similar rate than that achieved in the earlier sub-period. The growth rate of the EU wholesale and retail sector instead reached 3%, doubling the 1.5% growth rate experienced during the previous period. The information and communication activities sector experienced a labour productivity growth rate of over 5% in both the US and the EU; in the EU this meant a considerable improvement, as labour productivity had been deteriorating in the previous period. In most of EU services activities labour productivity showed an improvement; this is the case of professional, scientific, technical activities, and community, social and personal services, with growth rates ranging between 1 and 2% annually. In the US, performance in manufacturing worsened, decreasing from 6% in 1995-2004 to 4% in 2004-2007. Particularly strong was the productivity slowdown in the Coke and refined petroleum industry, which dropped from 15% to -6.65%. The mining sector also experienced a large negative rate of productivity growth (-10.61%). The electrical and optical equipment sector continues to show a strong performance, with a rate of 16.43% per annum. The wholesale and retail sector labour productivity slowed down significantly during 2004-2007, averaging a rate of 1.3%.

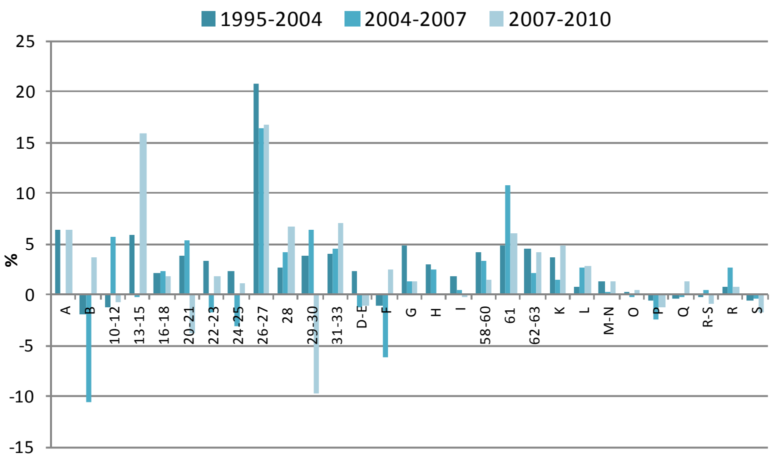
In the aftermath of the global financial and economic crisis, labour productivity growth stalled across both regions, but to a larger extent in the EU. During the period 2007-2009 labour productivity fell by -0.14, while experienced a small increase in the US (-0.8% per annum). When the period 2007-2010 is considered, however, the recovery was apparent, with labour productivity growing by 0.6% in the EU and 1.7% in the US. Across sectors, the performance was quite heterogeneous. Between 2007 and 2010, productivity in the US manufacturing sectors grew at a similar rate than in the earlier period (4.46%); in the EU, on the other hand, productivity declined significantly (-1.3%). The majority of EU manufacturing sectors suffered a decline in productivity, with the exception of some of the more traditional sectors (wood and products of wood and cork, and textiles, wearing apparel and leather products), electricity, water and gas supply, and the electrical and optical sector. In the US only the chemical and the transport equipment sectors suffered important decreases in productivity; the electrical and optical sector continued to show an outstanding productivity growth performance (16% per year), as well as the textiles sectors (15%). In services, productivity fell in wholesale and retail in both the US and the EU during 2007-2009, but recovered in 2010. Other sectors greatly affected by the crisis in the US comprised accommodation and food, services; arts, entertainment, and recreation, and the education sector.

Figure 1.10 / Sectoral labour productivity growth rates, EU, 1995-2010



Source: EUKLEMS and own calculations.

Figure 1.11 / Sectoral labour productivity growth rates, US, 1995-2010



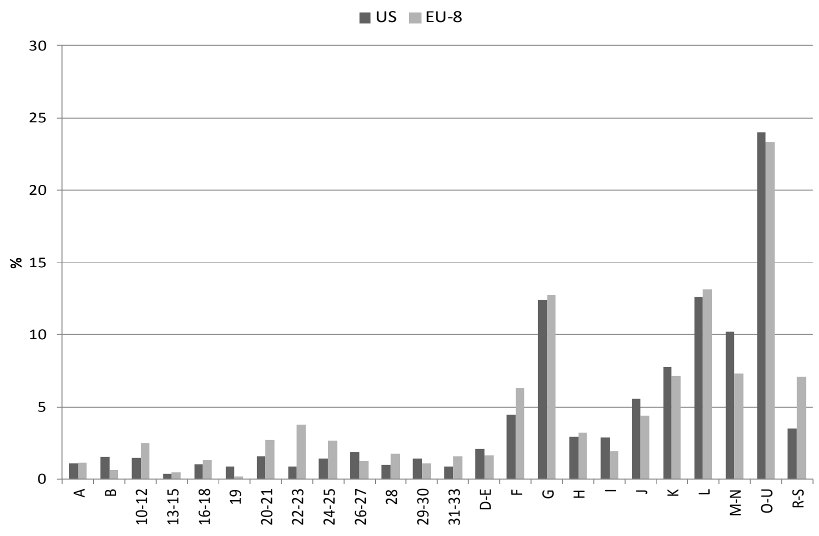
Source: EUKLEMS and own calculations.

The sectors that showed the most resilience to the weakness of the economic conditions in the EU-8 were the finance and insurance activities sectors, where the labour productivity growth rate was 6% annually, and professional, scientific, technical, administrative and support service activities (2.7%). In the US, the most resilient sectors were the telecommunications industry, which achieved a growth rate of 6%, and finance and insurance activities, with a rate of growth of approximately 5%.

1.2.2. SECTORAL CONTRIBUTIONS TO AGGREGATE LABOUR PRODUCTIVITY GROWTH

While the discussion of sectoral growth provides interesting information on industries' performance, a complete assessment of the main drivers of productivity trends requires extending the analysis to account for the size of the sectors and hence their overall contribution to labour productivity growth. During the late 1990s and early 2000s, the superior performance of the US was attributed to the performance of a few industries, mainly electrical and optical equipment within manufacturing, and wholesale and retail and business services within the market service sector. A full account of productivity developments during the period this period can be found in Peneder et al. (2008). In order to understand the extent to which each of the sectors contributed to the overall labour productivity growth in light of recent productivity developments labour productivity growth rates are weighted according to the size of the sector [9].

Figure 1.12 / Output shares (%) by industry in the EU and the US, 1995-2010



Source: EUKLEMS database; own calculations.

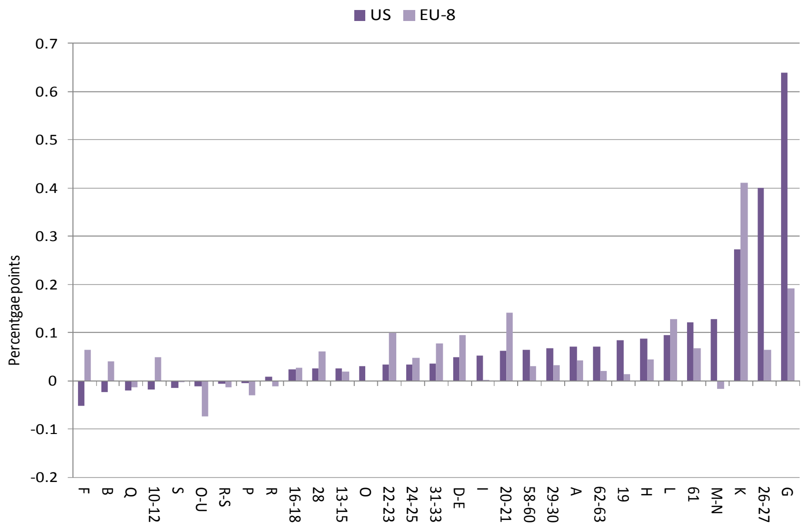
Figure 1.12 shows the shares of output (value added) accounted for by each of the industry sectors in both the EU and the US for the period 1995-2010. Table A.7 in the Appendix shows changes in value added shares over this period). The largest share of output is accounted for by the community, social and personal services sector, which includes services such as public administration and defence, education and health and social work. The share of this sector is almost 24% in the US, and slightly

9 The size of each sector is computed using information on output. Other previous studies have used employment shares (Peneder et al. 2008) but this cannot be done within this study due to the lack of recent information on employment for the US.

lower in the EU. The second sector in importance is the manufacturing sector. On average, manufacturing represents around 16% of output in the EU and 13% in the US. The share of manufacturing is higher in the EU-8 (17%), than in the US (13%), but its importance in both regions has been declining. The weight of the different manufacturing sectors varies across both regions. Those manufacturing sectors that have a higher share in the EU-8 economy include: chemicals, wood, rubber and plastics, basic metals, machinery and equipment; those manufacturing sectors that have a larger share in the US include electrical and optical equipment and transport equipment.

Third in importance is the wholesale and retail sector, which represents on average around 12% of the total output in both the EU-8 and the US. The importance of the wholesale and retail sector has declined in the US while in the EU-8 it has remained quite stable. The Real estate sector is also important in both economies, but there are significant measurement issues that limit the study of this sector.

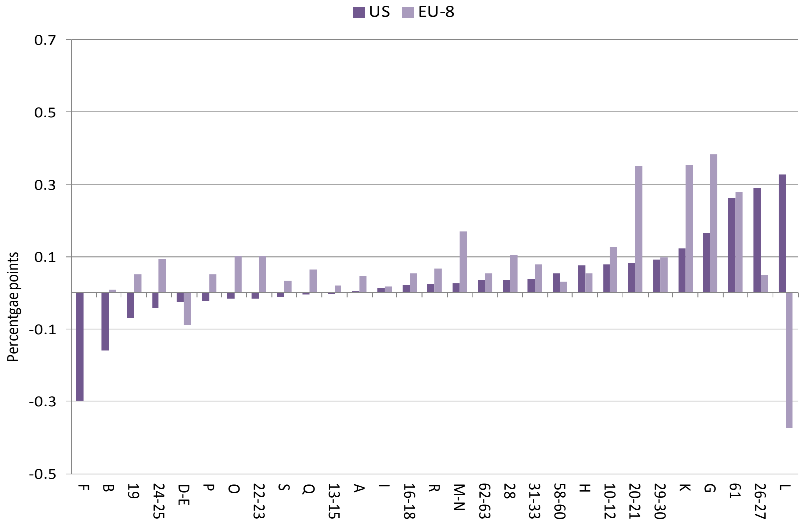
Figure 1.13 / Contributions by sector to labour productivity growth in the EU and the US, 1995-2004



Source: EUKLEMS and own calculations.

Figures 1.13-1.15 illustrate the contributions of each sector to labour productivity growth for the EU-8 in comparison to the US. Tables A.8 and A.9 in the appendix contains the detailed relative contributions of each sector to the total EU and US economies. In the right hand side of the panel of each figure, the sectors with a higher contribution to labour productivity growth in the US are shown, and in the left side, the sectors with the lowest contribution. During the period 1995-2004 (see Figure 1.13) the sectors that contributed the most to labour productivity growth in the US were the wholesale and retail sector, and the electrical and optical equipment, followed by the professional, scientific, technical, administrative and support services. These sectors explain most of the EU-US productivity growth differential. Another sector that had a significant contribution to labour productivity growth in the US during this period is finance and insurance activities; however it can be seen that the contribution of this sector to growth in the EU-8 was larger, therefore it helped to close the gap. Other sectors that that contributed to narrow the productivity gap relative to the US were: chemical and chemical products, rubber and plastic products, other manufacturing, electricity, gas and water supply.

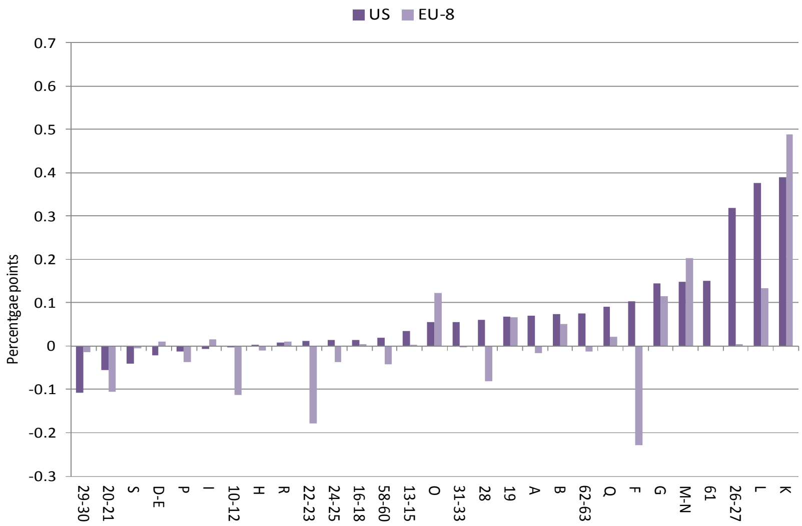
Figure 1.14 / Contributions by sector to labour productivity growth in the EU and the US, 2004-2007



Source: EUKLEMS and own calculations.

During the period 2004-2007, the EU experienced a phase of productivity convergence to the US productivity levels (see Figure 1.14). During this period the largest contributions to growth in the EU was due to wholesale and retail, finance and insurance, chemicals and chemical products, and the professional, scientific, technical, administrative and support services. The US experienced an important slowdown in productivity during this period; the sectors that contributed to this slowdown included construction, mining and quarrying and many manufacturing and services sectors. The electrical and optical equipment manufacturing sector in the US continued to outperform considerably that in the EU.

Figure 1.15 / Contributions by sector to labour productivity growth in the EU and the US, 2007-2010



Source: EUKLEMS and own calculations.1.3.2. Total factor productivity performance in production industries.

During the period 2007-2010 (see Figure 1.15) the majority of manufacturing sectors contributed negatively to productivity growth in the EU-8, while the performance of the US manufacturing sectors was considerably better. The performance of the manufacturing sector largely explains the widening gap between the EU and the US. The manufacturing sectors that fared worse relative to the US included: rubber and plastics, basic metals transport equipment, electrical and optical equipment. One of the few manufacturing sectors that helped closing the gap is the transport equipment sector. In contrast, the good performance of many EU services sectors has been a key factor in narrowing the gap relative to the US. This is the case of the finance and insurance activities sectors, the professional, scientific, sectors, public administration sector, and to a lesser extent the wholesale and retail sector.

1.3.1. GROWTH ACCOUNTING RESULTS AT INDUSTRY LEVEL.

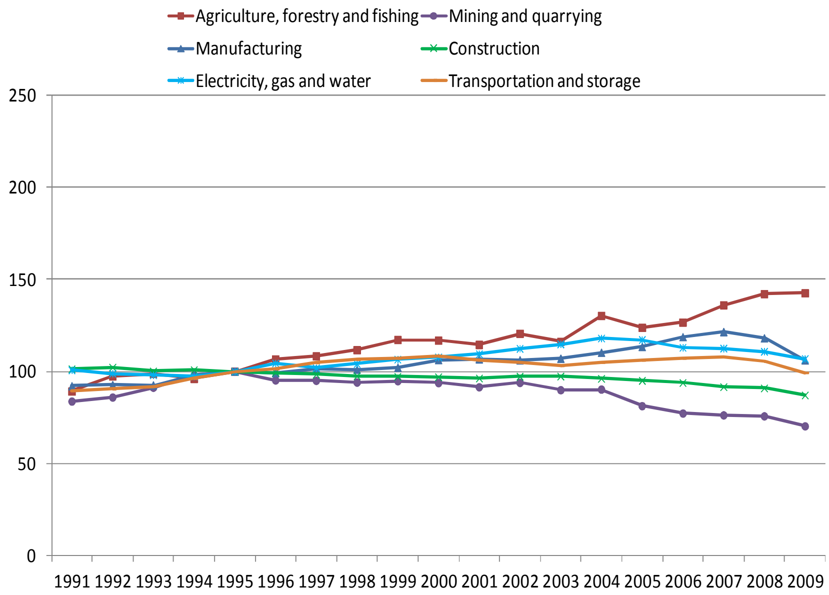
This section extends the overview of the recent industry labour productivity trends presented above by analysing the different components of productivity growth. This is based on growth accounting technique, which enables the empirical understanding of the extent to which each factor input and TFP contribute to the overall output per hour growth. Box 2 in the Appendix includes a detailed description of the growth accounting method.

The growth accounting technique is employed to assess the importance of each input as a sectoral output growth driver: hours, capital, labour composition and total factor productivity. The focus again is on the EU-8 group of countries (Austria, Belgium, Germany, Spain, France, Italy, Netherlands and United Kingdom) compared to the US in order to evaluate how the input use across the two regions has changed since the 1990s, in different parts of the economy. Figures in the appendix show the growth accounting exercise for the EU-8 in comparison to the US for all 1-digit NACE sectors and some key sectors at lower levels of industry disaggregation (NACE Rev. 2).

In the manufacturing sector, the contribution of hours to output growth decreased significantly in the mid 1990s and turned negative during the period 2007-2009. This is the case in both the EU-8 and the US. In the late 1990s and early 2000s total factor productivity gains were considerably larger in the US manufacturing sector than in the EU manufacturing sector. During the period 2007-2009, the contribution of TFP to growth turned negative in both regions, but to a larger extent in the EU. The contribution of capital to growth has remained more important in the US in the aftermath of the crisis, while the relative contribution of labour composition in the EU is higher.

In the US wholesale and retail sector, total factor productivity gains were outstanding in the late 1990, while the EU experienced faster TFP growth in the early to mid 2000s. Since the crisis, the US wholesale and retail sector fared worse than in the EU, showing an important TFP decline. The accommodation and food services sector in the US shows a similar pattern, with significant TFP declines during the period 2007-2009. The finance and insurance activities sector in the EU-8 has appeared more resilient to the crisis; while TFP growth was positive during the period 2007-2009 in the US it has turned negative. In the professional, scientific technical etc. activities sector accumulation of capital played a more important role for growth in the EU than in the US, despite a disappointing TFP performance that has worsened since the crisis. In the community, social, and personal services sectors, the largest in the economy, the US performed better until the crisis. Since the crisis, the US has experienced an important decline in total factor productivity.

Figure 1.16 / Multifactor productivity in the EU-8, 1991-2009, Production sectors (Index 1995=100)[10]



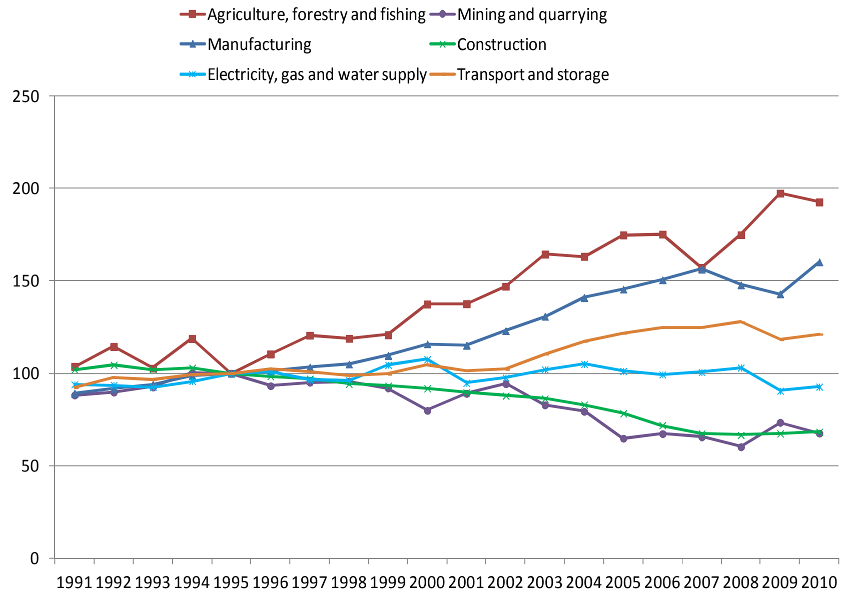
Source: EUKLEMS, rolling updates (2013) own calculations.

In this section, a more detailed description of total factor productivity performance for different groups of industries is provided. Figure 1.16 shows the evolution of total factor productivity performance for production industries in the EU-8. Across production industries, TFP performance has been heterogeneous. The best performing industry is agriculture forestry and fishing, where productivity increased throughout the period, with little cyclical variation. On the other hand, TFP decreased in mining and quarrying, particularly after 2004. With the exception of agriculture, forestry and fishing, productivity declined in all industries in 2007, with no sign of recovery in the following two years. The financial crisis reversed the positive productivity trend in manufacturing and in the network industries, as discussed in previous sections.

In the US (Figure 1.17) TFP was increasing particularly fast in agriculture, forestry and fishing, manufacturing and Transport and storage before 2007. When the crisis started, the agricultural industry was the first to experience a drop in TFP, followed by manufacturing, where TFP started to decrease in 2008, and transport and storage, which were particularly affected in 2009. In the other industries, the productivity slowdown started at an earlier stage. For example, mining and quarrying experienced a decrease in TFP since 1995, similarly to the EU-8, together with the construction industry. However, and differently from the UK experience, all industries started to recover in later years. The recovery was particularly strong in manufacturing and in agriculture.

[10] For seven of these countries data are available for up to 2010, while for UK is only available up to 2009.

Figure 1.17 / Multifactor productivity in the US, 1991-2010, Production sectors (Index 1995=100)

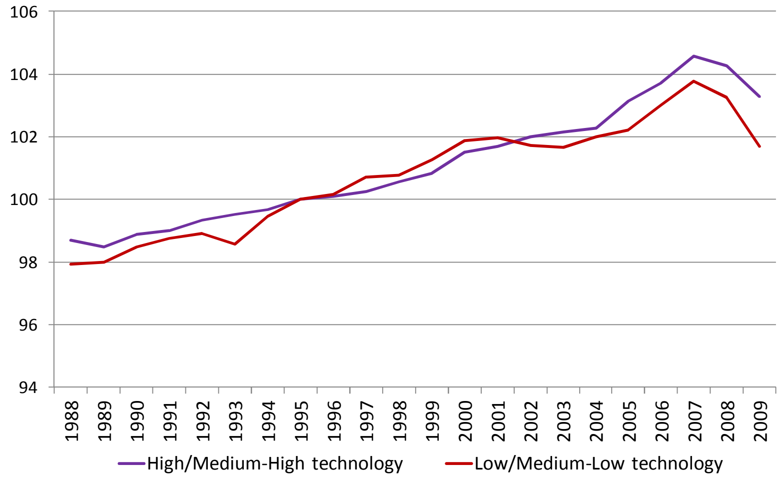


Source: EUKLEMS, rolling updates (2013) own calculations.

Figures 1.18 and 1.19 illustrate the TFP performance of manufacturing sectors in the EU and in the US, respectively. All manufacturing industries are divided into two groups, high/medium-high and low/medium-low technology intensive. In the EU, the performance across the two groups was not remarkably different. Both high and low tech industries were moving along an increasing trend, with TFP in the former overtaking the latter from the early 2000s. After the financial crisis TFP performance deteriorated in both groups, again with no sign of recovery until 2009.

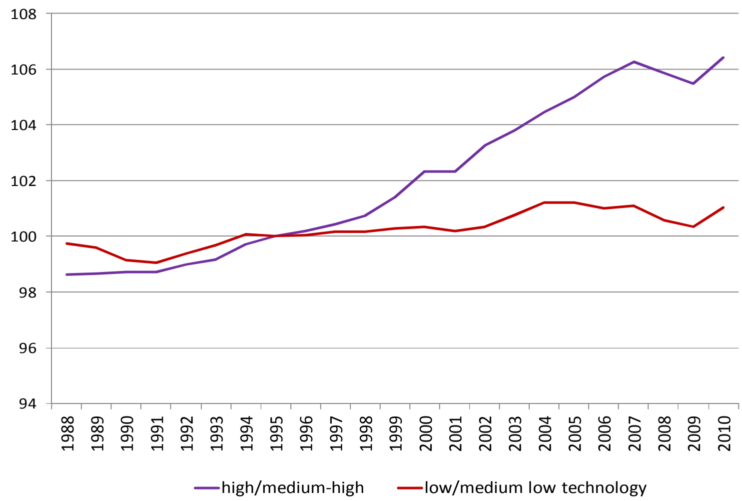
In the US TFP trends are quite different, particularly when looking at the high/medium ¬high technology sectors, where TFP started to increase very rapidly from the mid 1990s, displaying a remarkable performance until 2007. In 2008 TFP experienced a decrease but grow resumed again in 2010. These trends contrast with those in the low/medium-low tech industries, where TFP was on a fairly stable path throughout the whole period. Comparing the two regions, in the EU, low and medium-low technology sectors experienced a faster growth than in the US where TFP growth has been more stagnant. It is also apparent that all manufacturing sectors in the EU, whether they are of higher or lower technology content, have suffered deeper declines in TFP since the crisis than the manufacturing sectors in the US.

Figure 1.18 / Multifactor productivity growth by technological intensity, Manufacturing sectors, EU-8, 1995-2009 (1995=100)



Notes: High/Medium high technology sectors include (NACE Rev. 2, 2 digit): 20-21 (Chemicals), 26-27(Electrical and optical equipment), 28(Machinery and equipment n.e.c.) , 29-30 (Transport equipment). Low/Medium-Low technology sectors include ((NACE Rev. 2): 19 (Coke and refined petroleum products), 22-23 (Rubber and plastic products, and other metallic products) , 24-25 (Basic metals), 31-33 (Other manufacturing), 10-12 (Food products, beverages and tobacco), 13-15 (Textiles, wearing apparel, leather and related products), 16-18 (Wood and paper products, printing and reproduction of recorded media. The EU-8 aggregate includes the following countries: AT, BE, DE, ES, FR, IT, NL, UK.
Source: EUKLEMS database (2013), own calculations.

Figure 1.19 / Multifactor productivity growth by technological intensity, Manufacturing sectors, US, 1995-2009 (1995=100)

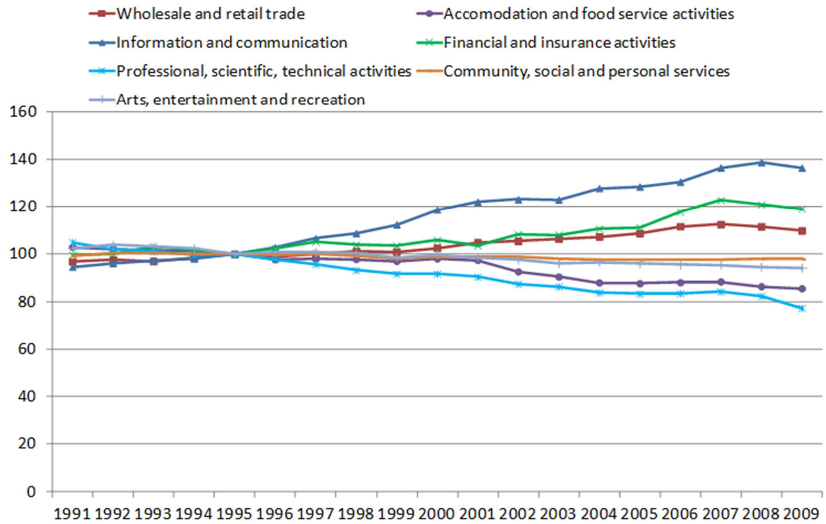


Notes: High/Medium high technology sectors include (NACE Rev. 2, 2 digit): 20-21 (Chemicals), 26-27(Electrical and optical equipment), 28(Machinery and equipment n.e.c.) , 29-30 (Transport equipment). Low/Medium-Low technology sectors include ((NACE Rev. 2): 19 (Coke and refined petroleum products), 22-23 (Rubber and plastic products, and other metallic products) , 24-25 (Basic metals), 31-33 (Other manufacturing), 10-12 (Food products, beverages and tobacco), 13-15 (Textiles, wearing apparel, leather and related products), 16-18 (Wood and paper products, printing and reproduction of recorded media. The EU-8 aggregate includes the following countries: AT, BE, DE, ES, FR, IT, NL, UK.
Source: EUKLEMS database, own calculations.

1.3.3. TOTAL FACTOR PRODUCTIVITY PERFORMANCE IN SERVICES INDUSTRIES.

Figures 1.20 and 1.21 illustrate TFP performance for 1-digit service sectors (NACE Rev. 2) for the EU-8 and the US. The information and communication sector experienced the strongest MFP performance across both regions. This sector encompasses economic activities such as publishing, audio-visual and broadcasting activities, telecommunications, IT and other information services. In the EU-8 the finance and insurance sectors sector experienced strong growth, especially from 2005 to 2007. After 2007, however, TFP started to decline. In fact, the largest decline in TFP since 2008 has been experienced by the financial Intermediation sector. Except in the case of the information and communication sector, TFP deteriorated across all services sectors since 2007. Those sectors where TFP deteriorated throughout the whole period include professional, scientific, technical activities and accommodation and food services. The poor performance of the professional, scientific, technical activities sector may be related to strict regulations that prevent across-border competition.

Figure 1.20 / Multifactor productivity In the EU-8, 1991-2009, Services sectors (Index 1995=100)[11]

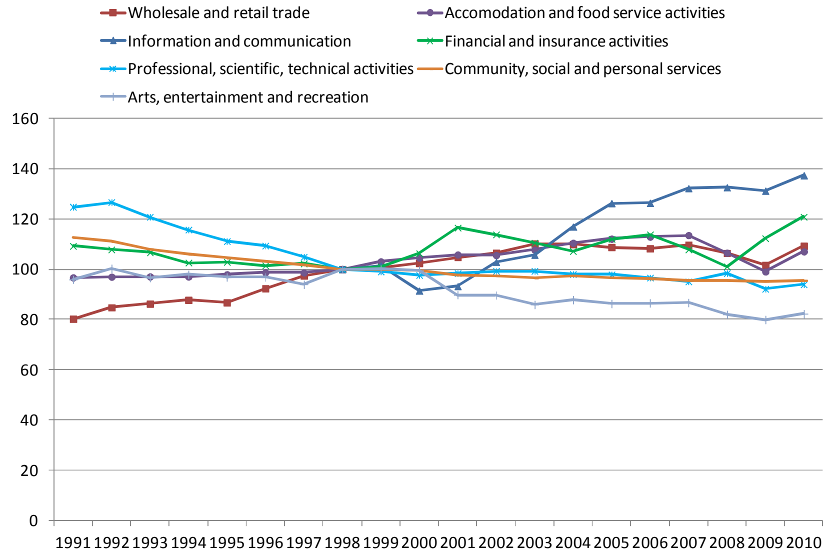


Source: EUKLEMS, rolling updates (2013) own calculations.

In the US market services, the information and communication sector has had an outstanding performance since the early 2000s, showing a greater resilience to the crisis. This is close to the performance of this sector in the EU-8. The rest of market services show a decline in TFP originated in the financial crisis of 2007-2008. It can be seen that TFP in Financial and Insurance activities decreased sharply in 2007 and improved quickly after in 2008. In the remaining sectors, the slow down took place from 2008 and recovery started from 2010, although mildly.

[11] For seven of these countries data are available for up to 2010, while for UK is only available up to 2009.

Figure 1.21 / Multifactor productivity in the US, 1991-2009, Services sectors (Index 1995=100)[12]



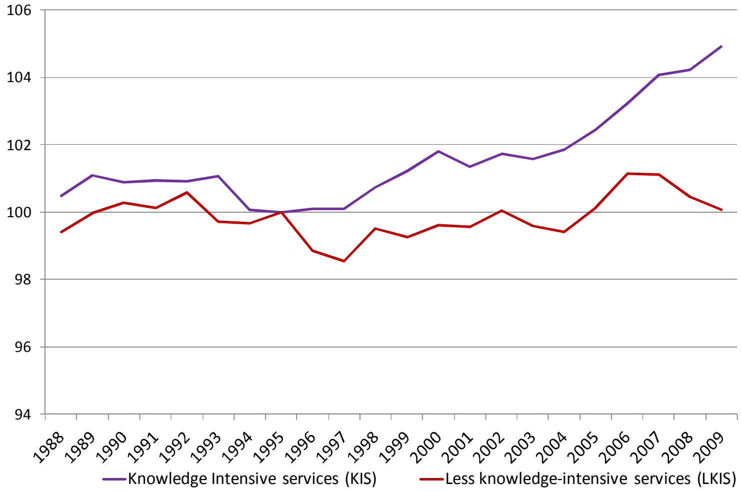
Source: EUKLEMS, rolling updates (2013) own calculations.

Figures 1.22 and 1.23 illustrate TFP growth performance of services sector according to their knowledge intensity (EUROSTAT classification). In the EU-8, TFP in the knowledge intensive industries (KIS) increased at considerably higher rates than in the less knowledge intensive industries (LKIS). Moreover, since 2008, TFP in the LKIS has fallen significantly. In the KIS, TFP stagnated in 2008 but continued to rise since 2009. In the US, TFP in the less knowledge intensive services industries followed an increasing trend since the early 1990s. Only after the crisis TFP declined, recovering again in 2010. The robust performance in the US is largely driven by the outstanding TFP performance in sectors that are heavy users of ICT technology (e.g. wholesale and retail.).

In contrast, in the knowledge intensive services industries in the US, TFP deteriorated until the early 2000s; since then they experienced a steady increase. After the crisis, TFP decline also in this group of sectors, but not as much as in the less knowledge intensive sectors.

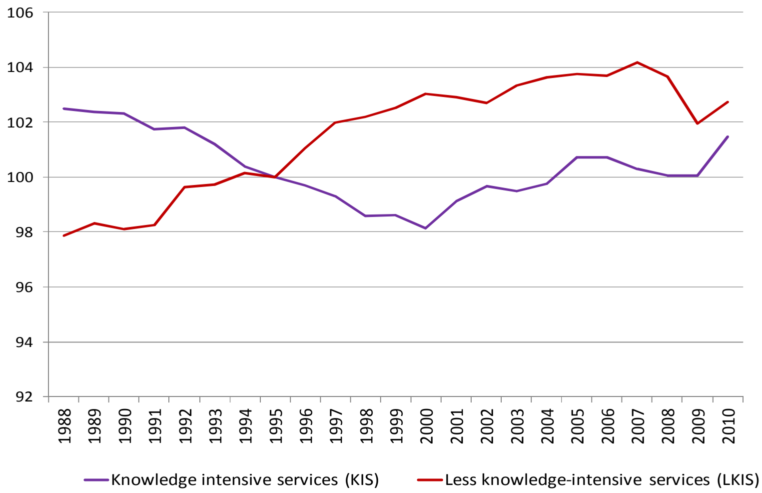
12 For seven of these countries data are available for up to 2010, while for UK is only available up to 2009.

Figure 1.22 / Multifactor productivity growth by knowledge intensity, Services sectors, EU-8, 1995-2009 (1995=100)



Notes: Knowledge intensive services industries (KIS): 58-60 (Publishing, audiovisual and broadcasting activities), 61 (Telecommunications), 62-63 (IT and other information services), K (Financial and insurance), M-N (Professional, scientific, technical, administrative and support services), R (Arts, entertainment and recreation). Less knowledge intensive services industries (LKIS): Wholesale and retail (G), Transport and storage (49-52), I (Accommodation and food service activities), 53 (Postal and courier activities), L (Real estate activities), S (Other service activities). The EU-8 aggregate includes the following countries: AT, BE, DE, ES, FR, IT, NL, UK.
Source: EUKLEMS database, own calculations.

Figure 1.23 / Multifactor productivity growth by knowledge intensity, Services sectors, US, 1995-2010. (1995=100)



Notes: Knowledge intensive services industries (KIS): 58-60 (Publishing, audiovisual and broadcasting activities), 61 (Telecommunications), 62-63 (IT and other information services), K (Financial and insurance), M-N (Professional, scientific, technical, administrative and support services), R (Arts, entertainment and recreation). Less knowledge intensive services industries (LKIS): Wholesale and retail (G), Transport and storage (49-52), I (Accommodation and food service activities), 53 (Postal and courier activities), L (Real estate activities), S (Other service activities). The EU-8 aggregate includes the following countries: AT, BE, DE, ES, FR, IT, NL, UK.
Source: EUKLEMS database, own calculations.

1.4. SUMMARY

Drawing on newly available data sources, this section has reviewed the productivity performance of the EU since 1995 to 2012, in relation to other major world economies, especially the US. The US experienced a significant labour productivity acceleration from 1995 to 2004, while productivity in Europe fell behind. As a consequence, the productivity gap between the US and the EU widened considerably, a phenomenon which has largely been attributed to a slower emergence of knowledge economy in Europe. If the EU was simply lagging behind the US in the adoption of the new technologies, a key question emerged to whether Europe would be able to resume the catching up process to the frontier economy, the US. This was in fact observed to some extent in the years leading up to crisis, from 2004 to 2007 when the EU productivity showed signs of catching-up towards the US productivity levels. Although this robust performance helped the EU close the gap with respect to the US, with the advent of the crisis since 2008 the EU competitiveness deteriorated again. To have a better understanding of what lies beneath the aggregate productivity divergence across the regions, the changing role of different drivers of productivity across different sub-periods has been considered here, highlighting the contribution of various industries and inputs to growth.

A large part of the widening productivity gap during the period 1995-2004 originated in the disparate performance of a few sectors, mainly those market service sectors that heavily invested in Information and Communications Technology (i.e. wholesale and retail, finance). Beyond the capital deepening effect from accumulating the new technologies, a significant surge in multifactor productivity was also observed in these ICT-using industries in the US. Consistent with the hypothesis of ‘delay’ in the adoption and diffusion of ICT which required a deep restructuring of production processes and organisational practices, a boost in total factor productivity in these industries was experienced by Europe some years later. This mirrored earlier US productivity developments but with less impressive TFP gains. During the period 2004-2007 the EU narrowed the gap relative to the US, as the latter area was experiencing slower growth due to a decrease in the speed of ICT capital accumulation and a moderation in the rate of total factor productivity growth.

The responses to the global downturn triggered by the financial crisis of 2007-2009 have varied across sectors in the EU. In Europe, the manufacturing sector suffered the consequences of the crisis to a larger extent than the services sectors taken as a whole. The poor productivity performance of the EU manufacturing sectors is one of the key factors explaining the current widening of the productivity gap relative to the US. It is also apparent that the majority of manufacturing sectors in the EU, irrespective of their technology base, have suffered deeper declines in TFP since the crisis, and considerably more than those in the US. Within the service sectors the picture is more heterogeneous. Overall, these industries in the EU appear to have relatively less affected by the global economic crisis than the manufacturing sectors. The finance and insurance service sectors have continued to show a robust productivity performance throughout the recession years. Other knowledge intensive service industries, such as information and communication activities, have shown a significant resilience to the crisis. The good performance of industries such as the professional, scientific, technical and administrative activities has also helped closing the gap with the US, but the ICT-related productivity growth experienced in these sectors is in contrast with the on -going deterioration of total factor productivity, possibly limited by the lack of domestic and international competition prevailing in these sectors.

2. Reducing productivity and efficiency gaps: the role of institutional factors in the empirical literature

In the last two decades, great research effort has been directed towards understanding the forces that drive economic growth (Aghion and Durleauf, 2009) and give rise to productivity and efficiency gaps across countries. Knowledge and intangible assets such as ICT, R&D and human capital, are considered key factors not only to maintain the technological lead but also to reduce the gap with the frontier countries (Griffith et al., 2004; Cameron, 2005; Vandenbussche et al., 2006). The ability of innovative factors to increase a country's competitiveness depends on how the rules of the marketplace are designed. This explains the large interest paid to the role of institutional factors in economic growth in recent years. The extant empirical evidence points quite extensively to the growth-enhancing effect of openness to market competition.

2.1. PRODUCT MARKET REGULATION

Several studies show that productivity growth is negatively correlated with product market regulations (PMR) and, consistently, that deregulation waves spur the speed of TFP growth and the catching up process of laggard countries/industries to the productivity frontier (Buccirossi et al., 2012; Conway and Nicoletti, 2006). Overall, restrictions on competition lower TFP growth especially in service industries, which are typically more regulated than manufacturing and less exposed to foreign competition. Measuring cross-country differences and changes in the regulation of non-manufacturing sectors is important for at least two reasons. First, these sectors represent around two thirds of the economic activity and are the most dynamic part of the economy (in terms of productivity growth and employment) in many OECD countries. Second, non-manufacturing is the area in which most economic regulation is concentrated. Given that import penetration is much more limited than in manufacturing sectors, final and intermediate consumers of non-manufacturing products have little alternative than to purchase these on the domestic market. Domestic regulation affects the quality, the variety and the price of such products in a number of ways (Conway and Nicoletti, 2006). This explains the increasing productivity gap between the service sector in Europe and in the US (Nicoletti and Scarpetta, 2003; Inklaar et al., 2008). In addition, the low competitiveness of the service sector can generate barriers to entry and curb competition in manufacturing industries (Bourlés et al., 2012). For example, Conway et al. (2006) inspect how the regulation impact is differentiated across asset types and industry groupings, finding that this factor is particularly detrimental for ICT investment. Rincon-Aznar and Robinson (2011) show that the effect of the regulatory framework of the service market on capital accumulation is not widespread as it mainly hampers non-ICT investment in network industries. Arnold et al. (2011) argue that the tight regulatory environment in the service sectors of EU countries has adversely affected the so-called ICT-using industries, as they intensively require inputs from these heavily regulated sectors – thus producing a 'knock-on' effect. Using firm-level data, the authors find that upstream (service) regulation reduces allocative efficiency, i.e. the movement of resources to more efficient uses. Moreover, the worst affected firms are the ones that are likely to mostly contribute to productivity growth – those that have the potential to reach the international technology frontier. This may in part explain the widening productivity and efficiency gaps between the EU countries and their major economic partners. Barone and Cingano (2011) have found that lower service regulation increases value added and productivity growth in downstream service-intensive industries; according to their estimates, the negative effect of upstream anti-competitive legislation on manufacturing performance is mainly driven by regulation in energy and professional services. The regulation impact may be not linear as there is evidence that is more stringent the smaller the gap with the productivity leader (Bourlés et al., 2012; Arnold et al., 2011). As an alternative possible channel of transmission of the effect of PMR on productivity, Barone and Cingano (2011) document that lower levels of regulation in upstream (service) markets significantly raise the rate of exports growth in downstream industries. Consistently, impediments to domestic product competition negatively affect inward FDI and related employment expansion: by raising barriers to entry, anti-competitive product market regulation discourages the establishment of foreign affiliates and their propensity to increase employment (Conway et al. 2006).

2.2. LABOUR MARKET INSTITUTIONS AND EMPLOYMENT PROTECTION

An increasing number of papers illustrates that the institutional design of the labour market affects productivity performance. For instance, employment protection regulation, by raising dismissals costs, reduces both employment flows and firm entry into the market. This distorts factor allocation and production choices, affecting TFP dynamics (Author et al. 2007). However, the impact of labour market institutions on productivity performance is far from being homogeneous. Sometime, labour market policies may have diverging effects, mutually offsetting each other. As a result, their net impact may contradict the initial motivation that originally inspired the policy intervention. For example, Cappellari et al. (2012) show that, in Italy, increased job turnover induced by the reform of apprenticeship contracts was productivity-enhancing; however, it was largely compensated by measures facilitating access to fixed-term contracts. In fact, these two policies have opposite effects in the degree of substitutability between temporary employees and external staff. In a similar vein, Bassanini et al. (2009) show that strict employment protection legislation (EPL) on regular workers depressed productivity growth in those industries where layoff restrictions were more binding, while deregulation of temporary contracts had no significant effect. Damiani et al. (2013) document that the deregulation of temporary contracts negatively influenced TFP growth in European industries and this effect was greater for those sectors that were more intensive of open (short-term) positions. Siebert and Rincon-Aznar (forthcoming) investigate productivity effects of EPL, in conjunction with wages and employment effects. They find that EPL lead TFP to fall, probably reflecting business costs of implementing EPL; however, effects on employment are not so clear-cut. The manufacturing sectors appear to be more hurt by strict employment laws than services sectors, as the latter rely more on voluntary worker turnover.

Interestingly, disparities in the effect of employment protection also emerge in innovation activity. Griffith and Macartney (2013) show that multinational enterprises patent more in countries with higher protection for regular contracts when relying upon incremental innovation (such as chemicals); this probably occurs as it favours investment in firm-specific human capital. Conversely, patenting is higher in countries where protection for temporary jobs is lower for firms specialised in more technologically advanced products; in these sectors, the rapid obsolescence of workforce skills imposes a rapid employment turnover. Cingano et al. (2010) assess the impact of EPL on firm’s investment, finding a significantly negative effect. EPL may also interplay with other dimensions of labour market regulation. For example, Scarpetta and Tressel (2004) document that strict employment protection negatively impacts on productivity growth only in countries with an intermediate degree of centralisation/coordination in wage bargaining.

Another important body of works studies the interaction between the regulatory framework of the labour market and that concerning the product market. It is documented that deregulation in the product market is more effective on employment dynamics when labour market regulation is high (Griffith et al., 2007, Fiori et al., 2012). Bassanini and Brunello (2011) look at the relationship between workforce training and product market regulations, showing that deregulation reduces the rents reaped by incumbents when training their employees. However, this effect is counter-balanced by the increase in output and profits achieved by new comers when product markets are liberalised. Therefore, this second group of firms has strong incentives to invest in training. At the aggregate level, the net effect of deregulation on training is positive.

2.3. FINANCIAL REGULATION AND LIBERALISATION

Since the pioneering work by Rajan and Zingales (1998) there is wide consensus that financial factors are crucial to economic development and growth. However, increasing the availability of external funds has a heterogeneous effect on growth depending on the structure of the economy, as firms and industries differ for the capacity to use internal funds (cash-flow). Levine (2005) provides a survey of the earlier literature. However, this body of studies has rapidly expanded in the last few years, as a result of the financial crisis and the associated credit crunch.

An early attempt to model the growth impact of financial factors is carried out by Aghion et al. (2005). More recent theoretical works have analysed the effect of financial development within multi-industry growth frameworks. For instance, Buera et al. (2011) design a model where the production sector (i.e., manufacturing) has more financing needs and it is therefore disproportionately more vulnerable to financial frictions which distort the allocation of capital and entrepreneurial talent across production units. Love (2003) shows that financial constraints are more binding when the financial market is scarcely developed and investment is distorted by a higher cost of capital. Ilyina and Samaniego (2011) find that financial development fuelled industry growth in the 1980s by attenuating investment lumpiness, and by facilitating R&D investments. In a related contribution, Ilyina and Samaniego (2012) show that financial development drives economic growth and structural change by enabling the reallocation of resources towards sectors with rapidly expanding technological frontiers.

According to the original interpretation of the Schumpeterian thought, access to finance is the main factor that promotes the implementation of innovative and highly risky projects. This issue has been examined by a very extensive body of studies at different level of data aggregation. Earlier works focused on the US and show that easy access to external finance triggered the R&D boom in the 1990s (Brown et al. 2009). Brown et al. (2012) look at European firms, finding evidence of binding finance constraints on R&D investments. A comparable industry-level study in this area is Maskus et al. (2012). These authors show that financial development, measured in different forms, fuels innovative investment; however, the strongest effects are found for private bond-market capitalisation, while the impact of FDI, private credit by banks, and stock-market capitalisation is smaller. Ang and Madsen

(2012) study the role of risk capital in knowledge production. They find that, despite the availability of external funds is a key factor for growth, the way to raise it may have a controversial effect on competitiveness, even in the long run. In essence, financial market reforms and financial liberalisation may induce lower innovation and growth when they have been implemented too rapidly. Ang (2011) argues that it may occur through discouraging savings, triggering financial instability and reallocating talents from the technology sector to the financial sector. Franco et al. (2013) show that excessive financial liberalisation may enlarge efficiency gaps with respect to the frontier in knowledge production.

3. The role of knowledge transfer, absorptive capacity and institutions for productivity growth

3.1. INTRODUCTION

The importance of technology for raising productivity and living standards has long been recognised. This is reflected in the modern literature on economic growth, in which technological progress is viewed as the prime determinant of long-run growth. In these models technological progress arises from the R&D activities of economic agents carried out in order to profit from the introduction of new products (Romer, 1990) or the improvement of existing ones (Aghion and Howitt, 1992). More broadly, technological progress encompasses changes in production processes, organisational structures, management techniques and the like that raise productivity. Resources for such innovation tend to be highly concentrated in a small number of advanced OECD countries [13], which have the requisite skills and institutions in place to undertake innovation and invest heavily in R&D. As a result firms in these countries register the bulk of patents. 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 also through follow-on innovation and adaptation (Evenson and Westphal, 1995). International technology transfer or diffusion refers to the process by which a firm in one country gains access to and employs technology developed in another country. Some transfers occur between willing partners in voluntary transactions, but much comes through non-market transactions or spillovers. Technology flows across borders via a number of formal and informal channels, making measurement difficult. Knowledge would be expected to flow across borders through a number of channels including international trade (both imports and exports), FDI, licensing, joint ventures, imitation and reverse engineering and through data published in patent applications.

Trade in goods and services is likely to be an important formal channel for international knowledge diffusion, with imports of goods having the potential to transfer knowledge through reverse engineering, but also through the cross-border learning of production methods, product design, organisational structure and market conditions. In particular, trade in capital and intermediate goods is likely to be an important source of technology diffusion, together with exports. For example, Grossman and Helpman (1991) argue that sellers gain from the knowledge base of their buyers, especially where buyers suggest ways to improve the product or the process of manufacture. A second formal channel of diffusion is FDI, and inward FDI in particular, with Multinational Companies (MNCs) expected to deploy advanced technology to their subsidiaries that may be diffused to host-country firms. Licensing, which involves the purchase of production and distribution rights for a product and the knowledge required to make effective use of these rights, is a further channel for technology diffusion. Joint ventures combine many of the properties of FDI and licensing and hence will also involve technology transfer. The movement of skilled workers across borders can also act as a channel for international technology diffusion. These

[13] 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% of OECD research scientists and engineers were employed in five countries (US, UK, Germany, Japan and France).

formal channels are likely to be interdependent, with firms making their decision on which channel(s) to serve foreign markets based on the expected return to their technological assets.

Informal channels of technology diffusion include imitation; the movement of personnel from one firm to another, taking with them specific knowledge of their original firm's technologies; data in patent applications and the temporary migration of people, such as scientists and students to universities and research institutes in advanced countries. What is specific to the informal channels, and is part of their attraction, is that there is no formal compensation to the original owner of the technology transferred. But there will still be costs. Imitation, for example, requires resources that may be drawn from local innovation [14]. The formal and informal channels are also related. For example, reverse engineering and the imitation of advanced technology might require some level of trade or temporary migration. The interdependence among formal channels and between formal and informal channels raises difficult issues for empirical studies.

While considered to be an important source of productivity growth, the measurement of technology is not straightforward given its nature as an intangible asset. A number of alternative measures have been employed in the empirical literature, though all have their disadvantages. Keller (2004) discusses the advantages and disadvantages of a number of these measures, including data on R&D expenditures, patent count data and measures of technological change based on Total Factor Productivity (TFP) data.

Since technology itself is difficult to measure, one also tends to find that measures of technology diffusion are imperfect. Several approaches have been employed [15]. One approach, following the seminal contribution of Coe and Helpman (1995), has been to examine whether R&D conducted in one country (and/or industry) impacts upon TFP in other countries (and industries). The starting point for this kind of analysis is to construct a stock of knowledge for each country (industry) using past R&D expenditures and then to weight these stocks by some variable indicating the access that other countries (industries) have to this knowledge. Weights used in the literature include imports (Coe and Helpman, 1995; Coe, Helpman and Hoffmaister, 1997), capital goods imports (Xu and Wang, 1999), inward and outward FDI (Xu and Wang, 2000), exports (Funk, 2001; Falvey, Foster and Greenaway, 2004), and intermediate input flows (Nishioka and Ripoll, 2012).

A second approach has been to use patent count data. While the decision to patent results in the publishing of the technical information relevant to the patent, as discussed above, Eaton and Kortum (1996) also argue that the decision of where to patent affords further information regarding where innovators see their ideas being used. Since patent laws are national in scope and since obtaining patent protection is costly, inventions are typically only patented in a small number of countries. Eaton and Kortum (1996) argue that this choice of where to patent is determined by market size and by where the invention is likely to be useful. They use a cross-section of 19 OECD countries to explain the number of patents taken out in one country (destination) by inventors in another country (source). The results suggest that technology diffusion is larger, the smaller the distance between two countries, the larger the ability of the destination to absorb technology (as measured by the level of human capital), and the

[14] Mansfield et al. (1981) show that the costs of imitation while lower than the cost of innovation are significant. Patenting innovations was found to raise the costs of imitation further, though even for products that were patented, 60% were imitated within four years.

[15] See Keller (2004) for a review of the evidence on international technology diffusion.

higher the relative productivity of the destination. A higher ratio of imports to GDP is not always found to facilitate the diffusion of knowledge.

A third approach that has proved popular in the growth literature more broadly, follows Nelson and Phelps (1966) who argue that the rate of technology absorption depends upon the 'technology gap', usually measured by the ratio of GDP per capita of a country to that of the technological leader (usually the US). Benhabib and Spiegel (1994), for example, regress the growth rate of GDP on standard variables including the interaction between the technology gap and a measure of human capital. They find a positive and significant coefficient on this interaction term and conclude that human capital speeds up the adoption of foreign technology.

3.2. EXISTING EMPIRICAL EVIDENCE

Given difficulties in measuring technology and technology diffusion, the majority of empirical work in this area concentrates on a particular channel of diffusion and examines the extent of interaction between countries via this channel and its impact upon measures of economic performance at either the aggregate or firm-level. While technology may diffuse through numerous channels, international trade has been emphasised in much of the empirical literature as being a particular important source.

Coe, Helpman and Hoffmaister (1997) identify four channels through which knowledge produced in one country and transmitted through imports can affect productivity and growth in others: Firstly, through the import of intermediate and capital goods which may enhance the productivity of domestic resources; Secondly, through the cross border learning of production methods, product design, organisational structures and market conditions that can result in a more efficient allocation of domestic resources; Thirdly, through the imitation of new products; and finally through the development of new technologies or the imitation of foreign technology. Exports are also likely to play an important role in international technology diffusion. Exports are likely to be an important channel of information flows with overseas buyers sharing knowledge of the latest design specifications and production techniques that might otherwise be unavailable, as well as providing a competitive environment, in which efficiency advantages can be obtained. Such effects may be observable at both the aggregate and firm/plant-level and this is reflected in the empirical work that has taken place. For the purposes of this study however, the emphasis will be on the literature at the aggregate level.

Coe and Helpman (1995) examine the impact of international R&D spillovers and the importance of imports in facilitating these spillovers for 22 OECD countries. They construct a stock of R&D for each country in their sample using past R&D expenditures. A measure of the stock of foreign knowledge that is available to each destination country is then constructed by weighting the R&D stocks of its source (exporting) trade partners by the bilateral import shares. TFP is then regressed on both the foreign and domestic stocks of knowledge. [16] The results suggest that both domestic and foreign knowledge stocks are important sources of productivity growth, although the former has a much larger impact in the larger

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[16] In their preferred specification the stock of foreign knowledge is interacted with the overall import share to take account of the level as well as the distribution of imports.

countries. Smaller countries it is argued tend to be more open and benefit to a greater extent from foreign knowledge spillovers[17].

The initial results of Coe and Helpman (1995) proved to be controversial. Keller (1998) compared the results of Coe and Helpman (1995) with those from assigning bilateral trade partners randomly and found that regressions based on simulated data generated on average larger estimated foreign knowledge spillovers and a better fit. Coe and Hoffmaister (1999) note however that Keller's bilateral import shares are similar to equal weights, or simple averages of trading partners' knowledge stocks, suggesting that Keller's weights are not in fact random. Using alternative random weights, Coe and Hoffmaister (1999) find that the estimated foreign knowledge spillovers are extremely small and present a poor fit. They conclude that using bilateral import weights or simple averages perform better than random weights suggesting that a country's productivity is related to its trading partners' knowledge stock, but concede that the actual intensity of the trading relationship may not be that important due to the public good nature of knowledge. In addition, while Coe and Helpman (1995) argue that there exists a cointegrating relationship between their variables, allowing them to consider the relationship in levels without having to transform the data they choose not to report t-statistics for their results since at the time of writing the paper the asymptotic distribution of the t-statistic was not known. Kao et al. (1999) argue that since the estimated coefficients are small it is not clear whether they are significant. They use non-stationary panel techniques examine whether there are indeed significant foreign knowledge spillovers. They find that while the coefficient on the spillover variable remains positive, it is not significant[18].

This type of analysis has been extended to consider North-South foreign knowledge spillovers by Coe, Helpman and Hoffmaister (1997) who find evidence that spillovers from the advanced North to the developing South are also an important source of productivity growth, with imports again being an important channel for such diffusion. The approach has also been extended to the industry level (e.g. Keller, 2000) with positive R&D spillovers again found at the industry level. Different trade weightings have also been used in the literature, with Xu and Wang (1999) using capital goods imports as weights rather than total imports and Funk (2001) and Falvey et al. (2004) employing export rather than import data. A further extension of the literature has been to consider the possibility of indirect spillovers through imports. This raises the possibility that country A can benefit from the R&D undertaken in country C even if it does not trade with this country. This would occur if country A imported from country B, which in turn imported from country C. Lumengo-Neso et al. (2005) capture this indirect effect and find that the results provide stronger evidence of trade-related R&D spillovers than found by Coe and Helpman (1995). Such results support the view that indirect spillovers are important. In a recent contribution Nishioka and Ripoll (2012) capture the direct and indirect effect of intermediate inputs using input-output tables (see below for more details).

Despite the controversy Keller (2004) concludes that overall the evidence points to a significant role for imports in the diffusion of foreign knowledge. This is particularly the case when one considers

[17] This outcome is not replicated when patent count data are employed, however. Eaton and Kortum (1996) find only limited evidence of a role for imports in facilitating technology diffusion among OECD countries as mentioned above.

[18] Engelbrecht (1997a) tests the robustness of the results on the R&D spillover variable to the inclusion of a general human capital variable and a catch-up term. He finds that their inclusion reduces the coefficient on the R&D spillover variable by around 30%. Lichtenberg and van Pottelsberghe de la Potterie (1998) argue that there is an aggregation bias in the construction of the R&D spillover variable and propose an alternative that removes this bias. Results using this alternative still find trade to be an important channel of R&D spillovers.

extensions to the literature such as Lumenga-Neso et al. (2005) and Xu and Wang (1999) who use capital goods imports rather than overall imports and find stronger evidence of foreign R&D spillovers than that reported by Coe and Helpman (1995).

An alternative method of capturing the effects of international technology diffusion is to use patent citation data. Sjöholm (1996) for example relates the citations of Swedish firms to patents owned by foreign inventors to a number of correlates including bilateral imports. The results suggest a positive correlation between patent citations and imports, a result consistent with imports contributing to international knowledge spillovers. Eaton and Kortum (1996) use information on where country's patent arguing that this is likely to convey information on where ideas are likely to be used. Relating bilateral patenting in OECD countries to a number of explanatory variables they find that imports are not a significant determinant of technology diffusion as measured by bilateral patenting.

3.3. CONTINGENT INTERNATIONAL TECHNOLOGY DIFFUSION

The notion that countries may gain from access to each other's knowledge or technology is not new. More than a generation ago Gerschenkron (1962) discussed the so-called 'advantage of backwardness', whereby countries positioned inside the world technological frontier obtain a nonreciprocal benefit by learning from the technological leaders. Gerschenkron observed that 'Industrialisation always seemed the more promising the greater the backlog of technological innovations which the backward country could take over from the more advanced country' (1962, p. 8). One implication of this statement is that the further a country is behind the leader the greater the backlog of knowledge available for diffusion and so the larger the potential knowledge spillovers.

Abramowitz (1986) accepts that being backward carries the potential for rapid advance, and that this should imply convergence over long periods of time. But backwardness in itself is unlikely to lead to greater knowledge diffusion and catch-up, unless certain preconditions exist that allow countries to absorb the inflow of foreign ideas and knowledge. These preconditions have been termed 'social capability' or 'absorptive capacity'. Abramovitz has a broad concept in mind, and identifies a large number of factors that could be considered important for a country's absorptive capacity, making measurement difficult. More recently, Cinera and van Pottelsberghe de la Potterie (2001) argue that 'in order to gauge the importance of international spillover effects, it may also be worth it to examine the factors improving the absorptive capabilities of foreign R&D such as education, training, mobility of the human capital or R&D collaborations'.

Despite theoretical arguments suggesting that the ability of a country to absorb and assimilate foreign knowledge is likely to be an important determinant of the extent of foreign knowledge spillovers, to date there has been relatively little work addressing this issue. Studies that have been undertaken tend to concentrate on two variables often associated with the idea that a firm or country needs to have a certain type of skill in order to be able to successfully adopt foreign technology, namely human capital (Nelson and Phelps, 1966) and R&D expenditures (Cohen and Levinthal, 1989).

Nelson and Phelps (1966) argue that the rate of technology absorption depends on the technology gap between the leading country and the follower. In this spirit, Benhabib and Spiegel (1994) and Engelbrecht (1997b) include a human capital/productivity catch-up interaction term in regressions on the growth of either TFP or GDP, which also include a separate human capital variable to account for domestic innovation. Benhabib and Spiegel (1994) find that the interaction term is significant and has the expected sign only for developing countries, while the domestic innovation rate for these countries is negative but insignificant. The opposite result is found for the wealthiest third of countries. In contrast Engelbrecht (1997b) finds that both variables enter significantly and with the expected sign for OECD countries. When including this interaction term, Engelbrecht (2002) finds for a sample of developing countries results similar to Benhabib and Spiegel (1994), namely a negative but insignificant coefficient on the education variable and a positive and significant coefficient on the interaction term. Falvey et al. (2007) use threshold regression methods to examine whether human capital and the technology gap impact upon trade-related knowledge spillovers. They find that higher levels of human capital are associated with larger knowledge spillovers, while spillovers have the strongest impact on productivity in countries with an intermediate technology gap. The results suggest that human capital can play a role in the international diffusion of technology, but that its role in encouraging domestic innovation is limited to the most advanced countries.

Cohen and Levinthal (1989) argue that in order to acquire outside technology a firm may itself need to invest in R&D. These authors argue that own R&D expenditures are critical for enabling the firm to understand and evaluate new technological trends and innovations. Empirical evidence exists to support these claims. Griffith et al. (2004) use industry-level data from twelve OECD countries to study the main determinants of productivity dynamics and find that conditional on a certain productivity gap to the leader country, subsequent productivity growth in an industry is higher, the higher are its R&D expenditures. This is consistent with R&D playing a similar role to human capital in facilitating technology diffusion. Dougherty (1997) also presents evidence to suggest that technology diffusion is positively related to the presence of domestic enterprise-level R&D programmes using data on Chinese enterprises. Using the Coe and Helpman framework, Crespo-Cuaresma et al. (2004) find that the benefits of foreign R&D spillovers are stronger in OECD countries that conduct significant R&D and that have relatively high levels of absorptive capacity as measured by education variables.

A further aspect of absorptive capacity mentioned by Abramowitz has also been emphasised in the recent literature, namely institutional barriers to the adoption of new technology. In a series of papers, Parente and Prescott (1994, 1999 and 2003) argue that absorptive capacity is to a large extent determined by institutional aspects that give rise to these so called absorption barriers, which in turn lead to the inefficient use of inferior technologies. This argument is based on the fact that many of these barriers are assumed to be put in place to protect the interests of groups vested in current production processes. Intuitively, as long as firms are not threatened by the prospect that their competitors might introduce more productive technologies, they may prefer to stick to their current technology, although better ones are available. This view that barriers may prevent technology adoption and may delay economic development is not new. Rosenberg and Burdzell (1986) and Mokyr (1990) also argue that lower barriers to the adoption of technology help explain why modern economic growth began in the West rather than the East.

Parente and Prescott (1994) argue that although the global pool of knowledge is readily accessible by each country, not all countries employ the best available technologies, because implementing new technologies and work practices involves costs. These costs are to some extent determined by institutional constraints such as the regulatory environment and competition policy. In their model, firms have to invest in order to increase the quality of their plants. However, the amount of investment required to achieve a certain level of quality depends on the institutional environment and therefore differs across countries. They find that even small variations in the costs imposed by the institutional environment give rise to large differences in income levels. In a related paper, Parente and Prescott (1999) focus on monopoly rights as the main institutional feature that acts as a barrier to the adoption of foreign technologies. If industry insiders have monopoly rights to the current technology they will resist the adoption of better production techniques. The greater the strength of protection granted to the insiders, the greater the amount of resources that potential entrants with superior technology have to spend in order to enter the industry. Thus, more competitive economies are likely to benefit from spillovers to a larger extent.

While barriers protecting industry insiders are likely to be considerable, labour market institutions are likely to be a further relevant barrier to technology adoption. Labour unions are another group with vested interests that may potentially oppose the introduction of possibly labour-saving technologies and could also be considered to be a group with vested interests in limiting technology adoption.

Empirically, Crespo-Cuaresma et al. (2004) in their paper also consider whether indicators of product and labour market regulations impact upon the extent of foreign knowledge spillovers. Their results indicate that measures of product market regulation, employment protection and the coordination of wage bargaining all impact upon the extent of foreign knowledge spillovers. In all cases higher barriers are associated with lower foreign knowledge spillovers. Coe et al. (2009) also search for conditions enhancing the benefits of R&D spillovers, concentrating on the importance of institutions. They find that countries where it is easier to do business, with higher quality tertiary education, with higher levels of patent protection, and with English and German legal systems benefit to a greater extent from foreign knowledge spillovers.

3.4. METHODOLOGY

The starting point is a Cobb-Douglas production function of the form:

$$Y = AK^{\alpha}L^{1-\alpha}, \quad A > 0,\ 0 < \alpha < 1$$

which can be written in intensive form as:

$$y = Ak^{\alpha}$$

where $y = Y/L$ and $k = K/L$. Expressing this equation in logs and taking first differences gives[19]:

(3.1) $$\boldsymbol{\Delta \ln y = \Delta \ln A + \alpha\, \Delta \ln k}$$

which expresses the (approximate) growth rate of output per worker to the growth rate of technology and the growth rate of the capital-labour ratio. What remains is to specify a form for technological progress. Here the following is assumed:

19 A major reason for focusing on this first-difference specification is that the levels of the variables included in the regression model tend to be non-stationary, while the first differences tend to be stationary. For more information on this see Appendix D.

(3.2) $$\Delta \ln \boldsymbol{A} = \boldsymbol{\gamma_1} \Delta \ln \boldsymbol{F}$$

where F is the R&D stock available. In the analysis below the R&D stock available is split into a domestic and a foreign component. Combining equations (1) and (2) gives

$$\Delta \ln y_{iht} = \gamma_1 \Delta \ln F_{iht} + \alpha \Delta \ln k_{iht}$$

where subscripts i, h and t refer to industry, country and time respectively. For purposes of estimation a number of modifications are made to this equation. In particular industry, country and time fixed effects are included, as is an error term and the initial logged value of output per worker to allow for conditional convergence. The basic estimating equation is therefore:

(3.3) $$\Delta \ln \boldsymbol{y_{iht}} = \boldsymbol{\gamma} \Delta \ln \boldsymbol{F_{iht}} + \boldsymbol{\beta_1} \Delta \ln \boldsymbol{k_{iht}} + \boldsymbol{\beta_2} \ln \boldsymbol{y_{ih1995}} + \boldsymbol{\alpha_i} + \boldsymbol{\delta_h} + \boldsymbol{\pi_t} + \boldsymbol{\varepsilon_{iht}}$$

The extent of knowledge flows from the donor countries and industries to the recipient countries and industries are captured following the approach of Nishioka and Ripoll (2012) by focusing on the concept of the R&D content of intermediates. Intermediate inputs are thus assumed to be the channel through which knowledge is diffused.

Following Nishioka and Ripoll (2012) the intermediate input weighted R&D stocks are calculated in the following manner. Let g and $h = 1, \dots, G$ be indexes for goods and i and $j = 1, \dots, N$ for countries. Assume that every good is consumed either as a final good or as an intermediate input. Let Q_i be a $G \times G$ diagonal matrix for country i's gross output, and $B_{ji}(g,h)$ be the amount of intermediate input g from country j used to produce one unit of gross output of country i's good h. If $i = j$, $B_{ji}(g,h)$ is the typical (g,h) element of the $G \times G$ matrix of domestic intermediate requirements B_{ii}. If $i \neq j$, $B_{ji}(g,h)$ is the typical (g,h) element of the $G \times G$ matrix of foreign intermediate requirements B_{ji}. Based on these definitions, the following global matrixes can be defined:

$$Q = \begin{bmatrix} Q_1 & 0 & \cdots & 0 \\ 0 & Q_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & Q_N \end{bmatrix} \text{ and } B = \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1N} \\ B_{21} & B_{22} & \cdots & B_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ B_{N1} & B_{N2} & \dots & B_{NN} \end{bmatrix}$$

where Q is an $NG \times NG$ diagonal matrix of gross output and B is an $NG \times NG$ matrix of global intermediate techniques whose typical element is $B_{ji}(g,h)$. It is then possible to distinguish between gross output (Q), net output or final demand ($Q - BQ$) or $(I - B)Q$, and intermediate demand for production (BQ). The term $(I - B)^{-1}Q$ represents total (direct and indirect inputs) needed to produce Q.

Let S_j be a $1 \times G$ row vector whose gth element is the business R&D stock used directly to produce good g in country j, and let D_j be a $1 \times G$ row vector whose gth element is the R&D stock per unit of good g. Then $D_j Q_j = S_j$ and one can define D to be a $1 \times NG$ global vector of direct R&D requirements, $D = [D_1, D_2, \dots, D_N]$ and S to be a $1 \times NG$ global vector of domestic R&D stocks $S = [S_1, S_2, \dots, S_N]$ where $S = DQ$

The R&D content of intermediates is defined as the total R&D stock embodied in intermediate inputs BQ. The total intermediate requirements needed to deliver BQ are given by $(I - B)^{-1}BQ$. The R&D content of intermediate inputs, F, is then defined as, (3.4) $$\boldsymbol{F} = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{B})^{-1}\boldsymbol{BQ}$$

with F being a $1 \times NG$ global vector of total R&D stock embodied in the production of intermediate inputs. A typical element F_{ih} from vector F corresponds to the measure of the domestic and foreign R&D embodied in the intermediate inputs sector h in country i purchases from all sectors and countries.

A measure including only the 'direct' R&D content of intermediates F^d is given by:

(3.5) $$\boldsymbol{F^d} = \boldsymbol{DBQ}$$

Nishioka and Ripoll (2012) discuss further how these measures can be disaggregated along a number of dimensions. Initially they separate the total effects of R&D by industry, separating own industry intermediates from intermediates from other industries. The R&D stock embodied in intermediate goods industry h in country i buys from its own industry in all countries (including itself) in time t is defined as:

(3.6) $$\sum_j \boldsymbol{D}_{jt}(\boldsymbol{h})\, \boldsymbol{A}_{jit}(\boldsymbol{h},\boldsymbol{h})\boldsymbol{Q}_{it}(\boldsymbol{h})$$

where $A = (I - B)^{-1}B$ so that the R&D content of intermediates can be defined as $F = DAQ$. The R&D stock embodied in intermediate goods industry h in country i buys from all other industries in all countries is defined as:

(3.7) $$\sum_j \sum_{g \neq h} \boldsymbol{D}_{jt}(\boldsymbol{g})\, \boldsymbol{A}_{jit}(\boldsymbol{g},\boldsymbol{h})\boldsymbol{Q}_{it}(\boldsymbol{h})$$

Of more relevance however is a disaggregation that involves separating the effects of R&D content from domestic and foreign source countries, which are respectively given by the following two equations:

(3.8) $$\boldsymbol{F_D} = \sum_g \boldsymbol{D}_{it}(\boldsymbol{g})\, \boldsymbol{A}_{iit}(\boldsymbol{g},\boldsymbol{h})\boldsymbol{Q}_{it}(\boldsymbol{h})$$

(3.9) $$\boldsymbol{F_F} = \sum_{j \neq i} \sum_g \boldsymbol{D}_{jt}(\boldsymbol{g})\, \boldsymbol{A}_{jit}(\boldsymbol{g},\boldsymbol{h})\boldsymbol{Q}_{it}(\boldsymbol{h})$$

In the analysis below this latter disaggregation is introduced into the regression analysis.

3.5. DATA AND DESCRIPTIVE ANALYSIS

3.5.1. R&D STOCKS

Data on R&D expenditure are obtained from the OECD ANBERD database. The OECD uses the implicit GDP deflator and PPP conversions to compute real R&D expenditures[20]. These deflators provide an approximate measure of the average real opportunity cost of carrying out R&D. The ANBERD dataset provides industry level R&D data according to the ISIC Revision 3.1 classification. To increase the number of available countries in the dataset some industries as available from the WIOD have to be combined which results in a set of R&D data for ten manufacturing industries as listed in Box 5. After

[20] Specifically, OECD reports R&D expenditure in 2000 prices and 2000 PPP dollars.

imputing a small number of values one is left with R&D data for these industries for 20 countries[21]: Australia, Belgium, Canada, Czech Republic, Germany, Spain, France, United Kingdom, Greece, Hungary, Ireland, Italy, Japan, Netherlands, Poland, Portugal, Singapore, Slovenia, Turkey and the USA. One thus is confined to examine knowledge spillovers from these manufacturing industries and countries. For the remaining countries and industries the approach suggested by Coe et al. (1997) is followed by assuming that the R&D stocks are zero. While not an ideal solution, given the high degree of concentration of R&D in a small number of developed countries and in a small number of manufacturing industries within these countries this assumption is unlikely to affect the results drastically.

Using data on R&D expenditures the domestic R&D stock for industry g in country j in time t is computed using the perpetual inventory method according to the following equation:

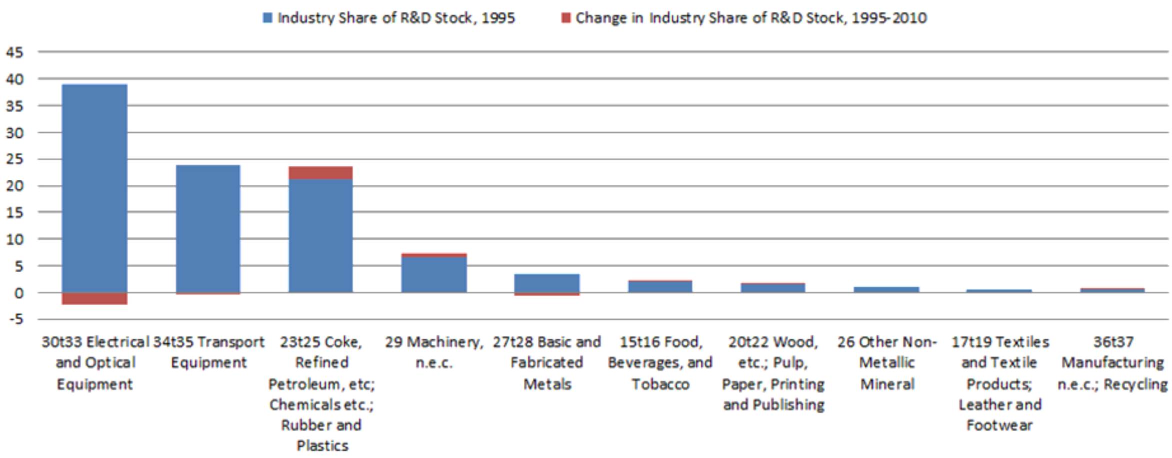
$$S_{gjt} = (1 - \delta)S_{gj,t-1} + R_{gjt}$$

where δ is the depreciation rate of knowledge obsolescence (set at 15%) and R_{gjt} is real business R&D expenditure. The initial value of the real business R&D stock is calculated according to the following equation:

$$S_{gj0} = \frac{R_{gj0}}{\delta + \pi_{gj}}$$

where π_{gj} is the average growth rate of real business R&D expenditures for industry g in country j over the whole period for which data are available. In general, the initial year in the dataset is 1994, which allows one to maximise the number of industries and countries used in the analysis.

Figure 3.1 / Industry shares of domestic R&D stocks, in %



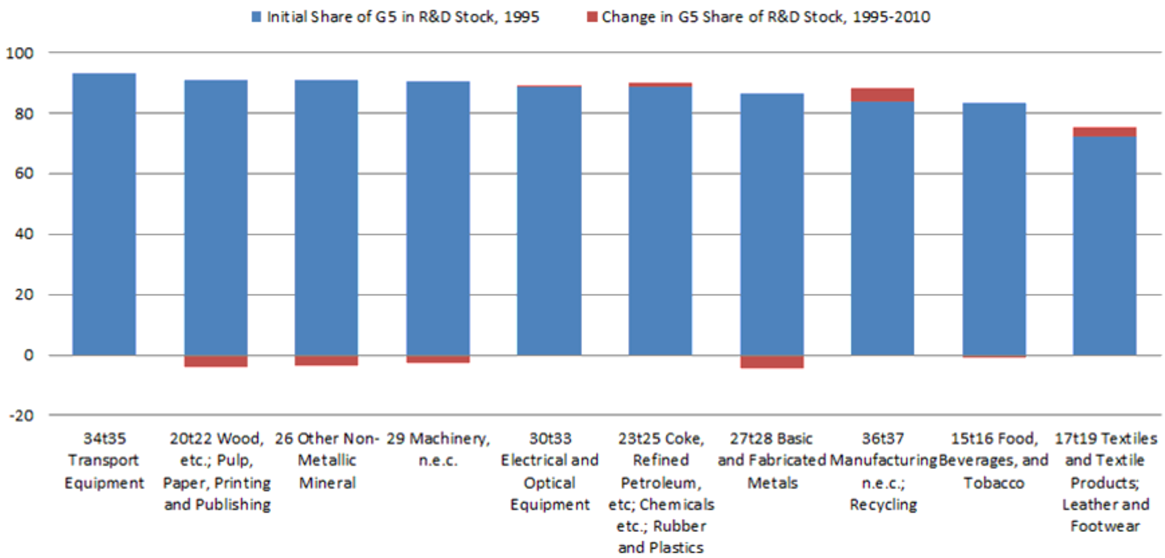
Source: wiiw calculations.

Figure 3.1 reports the shares of R&D stocks by industry in 1995 and the change between 1995 and 2010. As expected the R&D stocks of electrical and optical equipment, transport equipment and chemicals and chemical products make up the vast majority – over 80% – of the total R&D stock, with

21 Around 10% of observations had to be imputed due to missing values for particular years. Where data was not available linear interpolation was used to fill in the missing numbers.

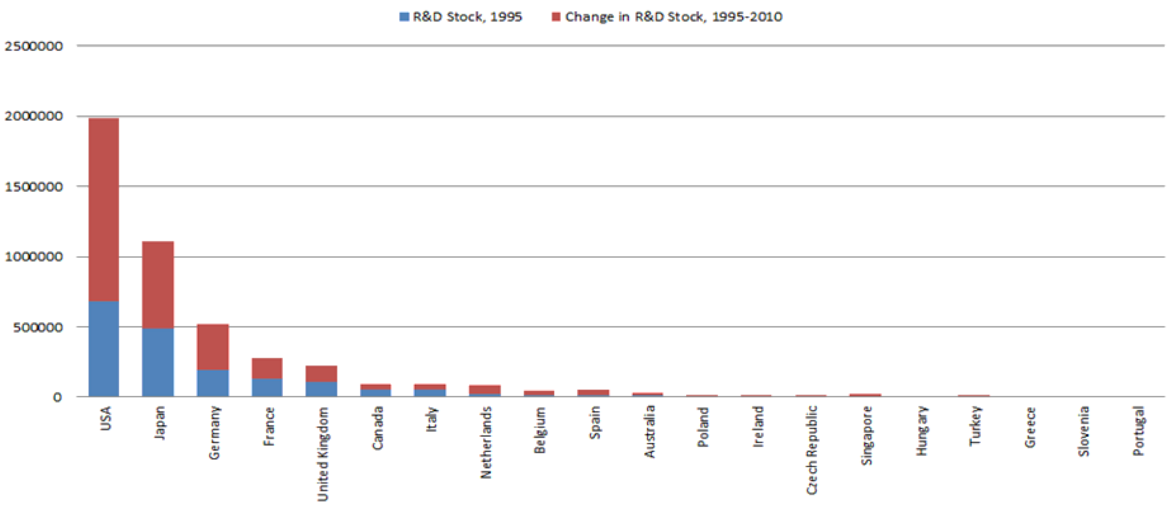
little change in this share over time. The shares of R&D stocks in the remaining industries are relatively low, and indicate the extent to which R&D is concentrated in a small number of industries.

Figure 3.2 / Shares of G5 countries in domestic R&D stocks by industry, in %



Source: OECD ANBERD Database; wiiw calculations

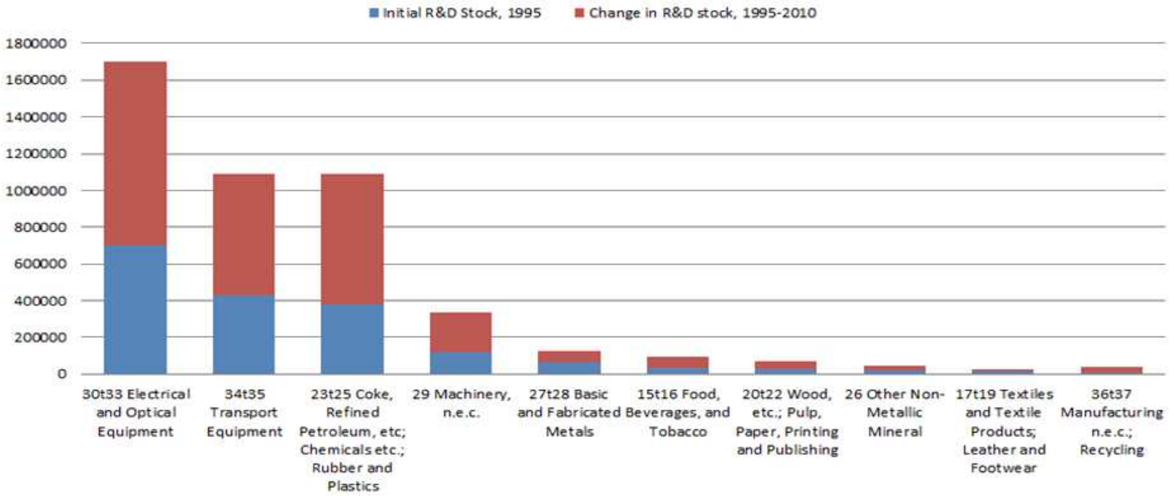
Figure 3.3 / Initial R&D stocks by country and changes between 1995 and 2010, in million USD



Source: OECD ANBERD Database; wiiw calculations

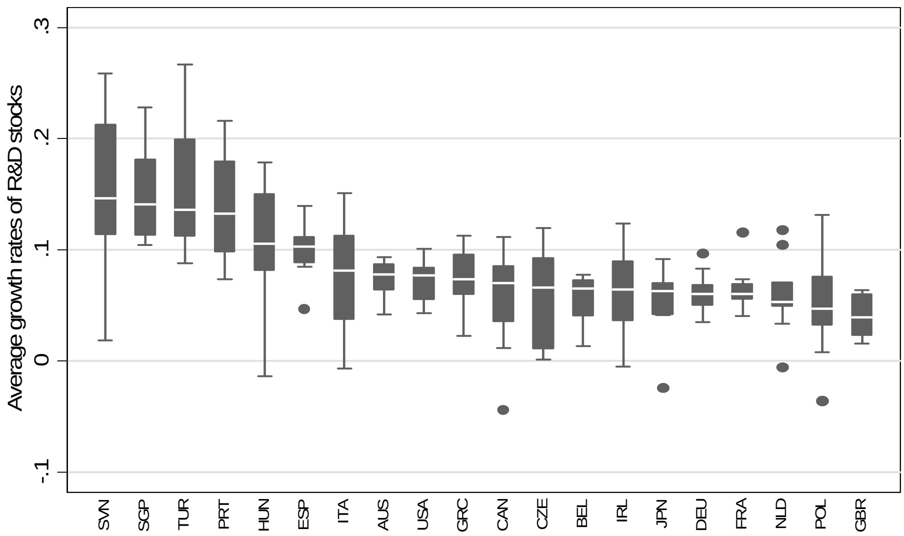
Figure 3.2 reports shares of G5 countries in the R&D stocks by industry. The figure indicates that these shares are very large and also tend to be above 80%, indicating the extent to which R&D is concentrated in a small number of countries. This can be further seen in Figure 3.3, which shows the values of the R&D stocks in 1995 and the change between 1995 and 2010 by country. The figure clearly shows that the USA and Japan dominate the R&D stocks the sample of countries considered, with Germany, France and the UK also showing relatively high R&D stocks. Figure 3.3 reports similar information by industry, which again documents the extent to which R&D is concentrated in electrical and optical equipment, transport equipment and chemicals and chemical products. It can also be observed that it is in these three industries that the R&D stocks have increased most rapidly, with relatively large increases also observed in machinery, nec (29).

Figure 3.4 / Initial R&D stocks by industry and changes between 1995 and 2010, in million USD



Source: OECD ANBERD Database; wiiw calculations

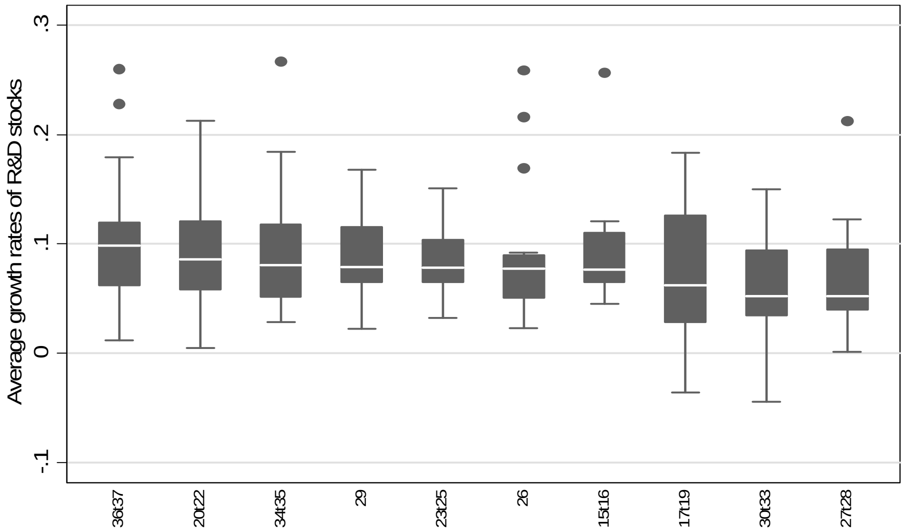
Figure 3.5 / Box plot of time-averaged growth rates of domestic R&D stocks by country



Source: OECD ANBERD Database; wiiw calculations

Since the model will be estimated in logged first differences (i.e. growth rates) it is also worth considering the growth rates of the R&D stocks in a descriptive way. In Figure 3.5 and Figure 3.6 the box plots of the time averaged growth rates of the constructed R&D stocks by country and industry respectively are reported. The figures reveal that R&D stocks have been growing relatively rapidly (albeit from a much lower starting value) in countries such as Turkey, Singapore, Slovenia and Portugal. Industry differences in average growth rates are much less pronounced.

Figure 3.6 / Box plot of time-averaged growth rates of domestic R&D stocks by industry



Source: OECD ANBERD Database; wiiw calculations

3.5.2. R&D STOCKS OF INTERMEDIATE INPUTS

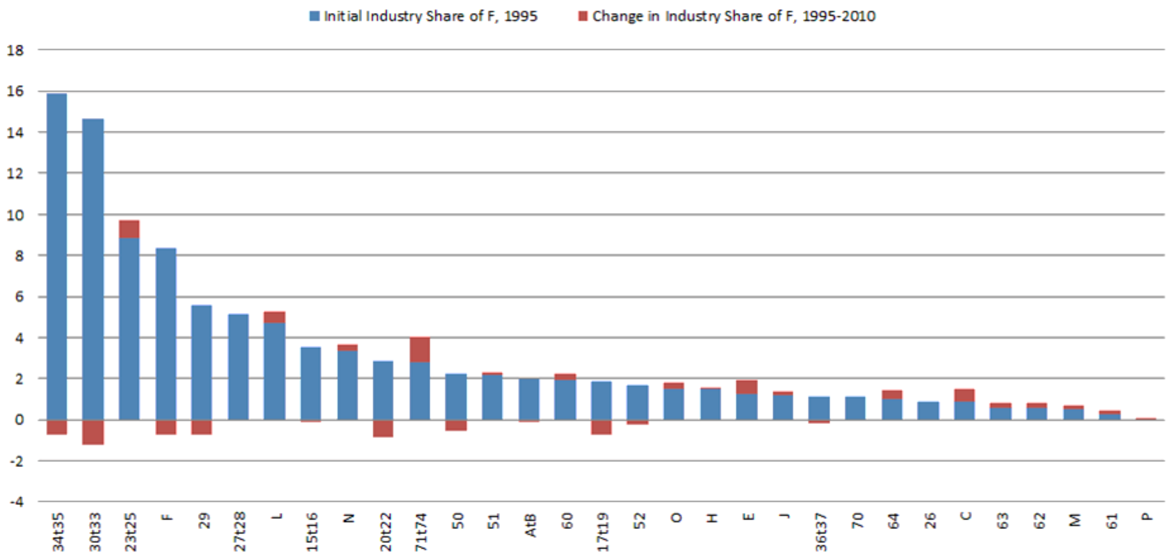
Information on intermediate flows required for the calculation of the R&D stock of intermediates are taken from the recently compiled World-Input-Output-Database (WIOD), which reports data on socio-economic accounts, international input-output tables and bilateral trade data across 35 industries and 40 countries over the period 1995-2009[22] These data result from an effort to bring together information from national accounts statistics, supply and use tables, data on trade in goods and services and corresponding data on factors of production (capital and labour by educational attainment categories). The starting point for the WIOD data are national supply and use tables (SUTs) which have been collected, harmonised and standardised for 40 countries (the 27 EU countries, Australia, Brazil, Canada, China, India, Indonesia, Japan, Korea, Mexico, Russia, Taiwan, Turkey and the US) over the period 1995-2009. These tables contain information on the supply and use of 59 products in 35 industries together with information on final use (consumption, investment) by product, value added and gross output by industry. These tables have further been benchmarked to time series of national accounts data on value added and gross output to allow for consistency over time and across countries. This approach allows one to provide information on the supply and use of a product by industry for each country. Using detailed trade data the use tables are then split up into domestic and imported sourcing components, with the latter further split by country of origin. Data on goods trade were collected from the UN COMTRADE database at the HS 6-digit level. These detailed bilateral trade data allow one to differentiate imports by use categories (intermediates, consumption and investment goods) by applying a modified categorisation based on broad end-use categories at the product classification. Bilateral trade in services data were collected from various sources. Services trade data are only available from

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

Balance of Payments (BoP) statistics providing information at a detailed level only in BoP categories. Using a correspondence these data were merged to the product level data provided in the supply and use tables. The differentiation into use categories of services imports was based on information from existing import use or import input-output tables. Combining this information from the bilateral trade data by product and use categories with the supply and use tables resulted in a set of 40 international use tables for each year. This set of international supply and use tables was then transformed into an international input-output table using standard procedures (model D in the Eurostat manual (Eurostat 2008). A rest-of-the-world was also estimated using available statistics from the UN and included in this table to account for world trade and production. This results in a world input-output database for 41 countries (including the rest-of-the-world) and 35 industries (for a detailed presentation of the database see Timmer, 2012).

The variables capturing the R&D content of intermediate inputs, F, as defined in equation (3.4) and the ‘direct’ R&D content of intermediates, F^d, as defined in equation (3.5), can be constructed for each year between 1995 and 2010 for all 40 countries included in the WIOD using R&D data for the 10 manufacturing industries as described above above. Due to inter-industry linkages one therefore ends up with direct and indirect R&D expenditures for all sectors as listed in Box 5. As mentioned above, for the industries and for countries for which no R&D stock data are calculated, the values of the R&D stock are set equal to zero when calculating F and F^d.

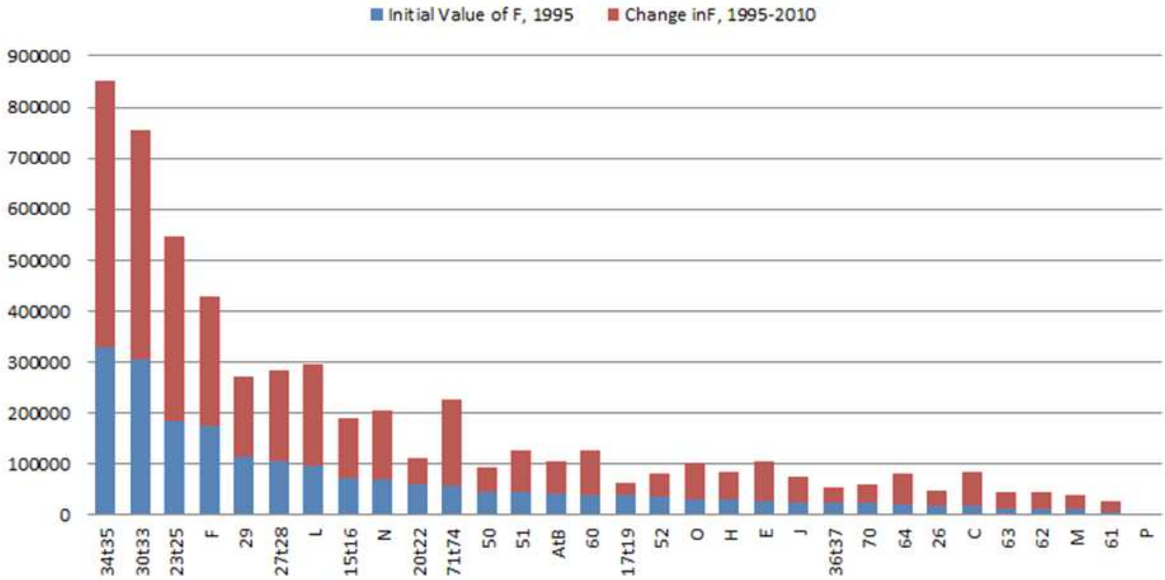
Figure 3.7 / Industry share of the R&D content of intermediate inputs F, in %



Source: OECD ANBERD and WIOD Data; wiiw calculations

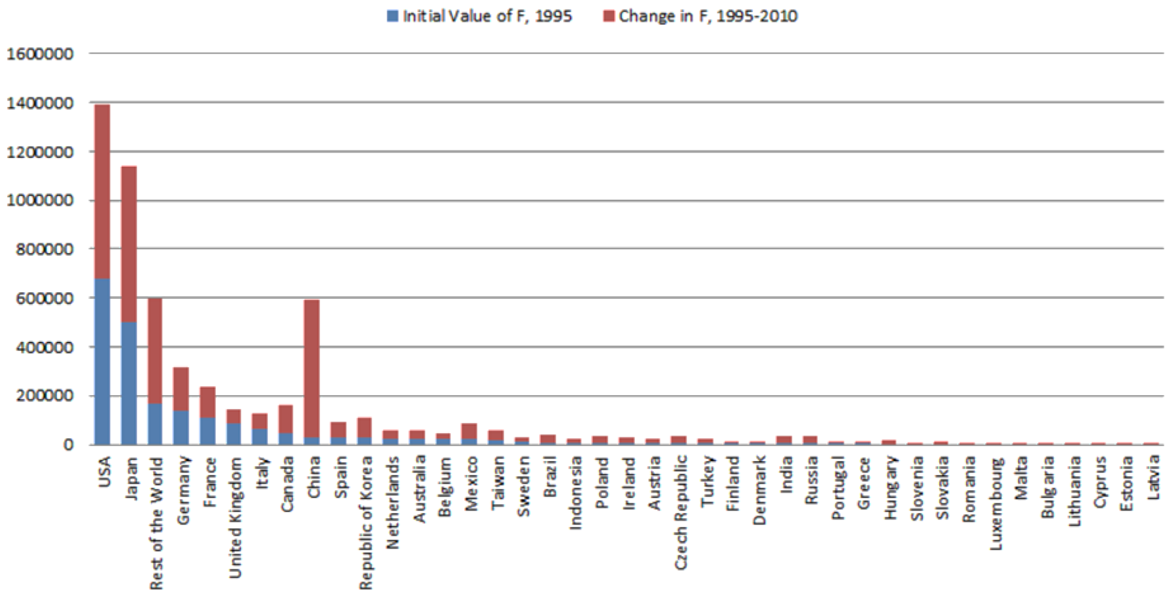
Figure 3.7 reports the industry shares of F in 1995 and the change between 1995 and 2010. As would be expected those industries for which R&D data are available tend to have the highest shares, and in particular industries 23t25, 30t33 and 34t35, which also dominate R&D expenditures (see Figure 3.1). Relatively large shares are also found for Construction, suggesting that there are strong linkages between manufacturing and this sector. These figures are mirrored in Figure 3.8, which reports the initial value of F by industry and its change to 2010.

Figure 3.8 / Initial value of the R&D content of intermediate inputs, F, and changes between 1995 and 2010 by Industry, in million USD



Source: OECD ANBERD and WIOD Data; wiiw calculations

Figure 3.9 / Initial value of R&D content of intermediate inputs F by country and changes between 1995 and 2010, in million USD

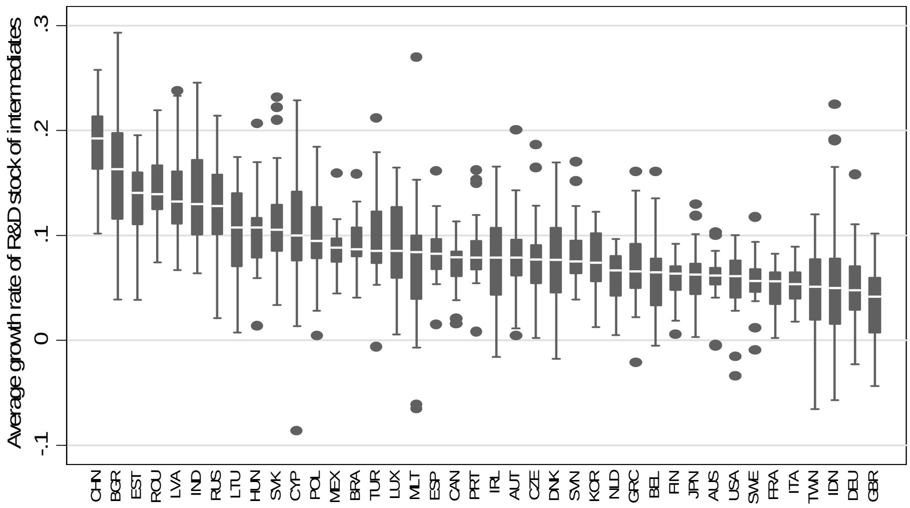


Source: OECD ANBERD and WIOD Data; wiiw calculations

Figure 3.9 reports the initial value of F by country and its change between 1995 and 2010. Here one observes that the initial values of F were particularly high in the USA and Japan, and to a lesser extent Germany, France, the UK and the rest of the world, consistent with above. While large increases in the value of F were reported for the USA, Japan and the rest of the world between 1995 and 2010, the most striking aspect of this figure is the large increase in the value of F for China in 2010. This increase is solely due to increased flows of R&D intensive intermediates into China over this period (since a lack of industry data for China it has to be excluded from the list of R&D source countries).

In principal, a more detailed analysis of R&D flows across countries and sectors would be interesting, particularly to which extent the EU is a provider (user) of R&D to (from) other countries. However, such an exercise is impossible by the lack of proper data on R&D stocks across industries for some countries and would therefore lead to misleading and implausible results. As detailed already above there are only a few countries (US, Japan, Germany, France, UK) and industries (Electrical and optical equipment, Transport equipment, and Chemical industry) which dominate R&D expenditures and stocks which are therefore also the most important countries and sectors as a source of technology diffusion. Unfortunately the lack of data does not allow to analyse the relative importance of foreign versus domestic R&D for smaller countries and therefore in the regression analysis below the focus will be on foreign R&D spillovers only.

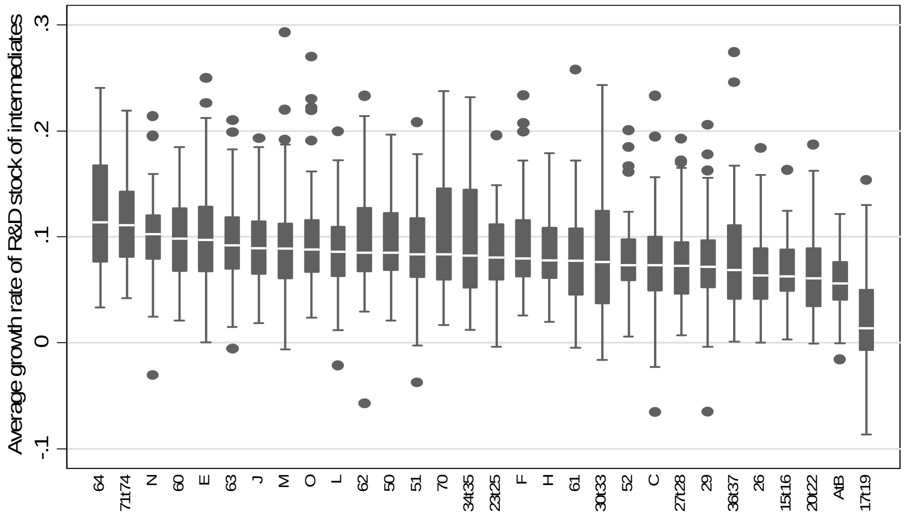
Figure 3.10 / Growth rate of R&D stock of intermediates by country



Source: OECD ANBERD and WIOD Data; wiiw calculations

Once again, it is instructive to consider information on the logged changes in these variables since a logged difference regression specification will be used below. Figure 3.10 and Figure 3.11 report box plots of the time-averaged growth rates of the R&D stock of intermediates by country and industry respectively. Figure 3.10 reveals large differences in the median growth rate of the R&D stock of intermediates. Growth rates are particularly large in countries such as China and India as well as new EU members such as Bulgaria, Estonia, Latvia and Romania. Since data on domestic R&D stocks for these countries are not available, the growth in their R&D stock of intermediates must represent either increased intermediate input flows from R&D source countries or a shift in demand towards intermediates from sources with higher domestic R&D stocks. Growth rates are much smaller in traditionally R&D intensive countries such as the UK, France, Japan and the USA. There are – again – fewer differences when considering the box plots by industry, though median growth rates are somewhat lower in industries AtB (agriculture, hunting, fishing and forestry) and 17t19 (textiles and textile products, leather and footwear), as may be expected.

Figure 3.11 / Growth rate of R&D stock of intermediates by industry



Source: OECD ANBERD and WIOD Data; wiiw calculations

3.5.4. ABSORPTIVE CAPACITY AND ABSORPTION BARRIERS

Finally, the question addressed requires information on a number of additional variables that capture absorptive capacity and absorption barriers. For measuring absorptive capacity information from the Barro and Lee dataset on the average years of secondary schooling in the population over 15 is used[23]. Further the approach of Cohen and Levinthal (1989) is followed which suggests to use the logged value of R&D (lnR&D) from the ANBERD dataset as an additional indicator of absorptive capacity. In this case R&D is set equal to a small number ($1,000) where data are not available, which then allows one to calculate the logged values.

The second set of variables used concentrates on indicators of absorption barriers (further details on the construction of these variables are found in Box 3) as also used when examining determinants of technical efficiency. In particular, the following variables that indicate the strength of labour market regulations from the OECD are used: the indicator for dismissal of employees on regular contracts (EPR), the indicator for strictness of regulations on temporary employment (EPT), and the indicator for additional regulation of 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) one would require that R&D spillovers are weaker in countries with higher values of these indices. To examine whether R&D spillovers are affected by the power of labour unions (Union) in limiting the take-up of potentially labour-saving technology further information on trade union density from the OECD is included.

A further indicator employed is the OECD indicator of product market regulation (PMR). The indicator represents the stringency of regulatory policy on a scale from 0 to 6 with higher numbers being

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

associated with policies that are more restrictive to competition[24]. 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. A further variable that is included is an indicator of the strength of Intellectual Property Rights (IPR). IPRs are a policy tool aimed at encouraging innovative activities. By preventing the copying and imitation of a patent however, IPRs may reduce technology diffusion. Alternatively, since the information on patents is made public, stronger IPRS may encourage technology diffusion (see Breitwieser and Foster, 2012 for a thorough discussion of the impacts of IPRs on innovation, technology diffusion and growth). The index of IPRs used is that developed by Ginarte and Park (1997) and updated by Park (2008). The index uses information on the coverage of patents, membership in international treaties, enforcement mechanisms, restrictions on patent rights and duration. The index takes on a value between zero and five, with higher numbers indicating stronger protection.

Finally, information from the Heritage Foundation's Index of Economic Freedom is used as additional variables. In particular, the sub-indices on investment freedom (invest) and financial freedom (finance) are included. Further details on the construction of these variables are relegated to Box 3. 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, such that higher numbers imply more restrictions[25].

3.6. RESULTS

3.6.1. LINEAR RESULTS

Table 3.1 reports results from estimating the linear model described by equation (3.3), including various different fixed effects. The results are fairly consistent across specifications. Results report the familiar negative and significant coefficient on initial output per worker, indicating conditional convergence. The coefficients on the capital-labour ratio are positive and significant coefficient in all specifications, indicating that greater capital intensities are associated with higher labour productivity growth. In terms of the R&D variables one obtains coefficients that are consistently positive and significant. The coefficients on the two R&D variables are similar, though the coefficient is larger in the case of the total R&D content of intermediates (F) than that on the direct R&D content only (F^d). Coefficients on the R&D variables also tend to fall somewhat when including additional fixed effects[26]. The coefficient estimates indicate that a 1% increase in the growth of the total R&D content of intermediates is associated with a higher growth rate of labour productivity of between 0.15% and 0.19%, with a similar increase for the direct R&D content of intermediates found to be associated with a 0.08 to 0.10 percentage higher growth rate of labour productivity. Such results are substantial and are consistent with results found elsewhere in the literature (see for example Falvey et al., 2007; Crespo-Cuaresma et al., 2008).

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24 For further details see Wölfl et al. (2009).

25 The variables included are those also seen relevant for technology spillovers in the literature (e.g. Parente and Prescott, 1994 and 1999). Some other indicators which are used in the technical efficiency analysis could not be included either due to lack of coverage over countries and time or limited cross-country or time variation.

26 The time, country and industry fixed effects are jointly significant.

Table 3.1 / Linear results I

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta \ln y$	$\Delta \ln y$	$\Delta \ln y$	$\Delta \ln y$	$\Delta \ln y$	$\Delta \ln y$
$\ln y_{1995}$	-0.0104***	-0.0106***	-0.0142***	-0.0110***	-0.0113***	-0.0143***
	(0.000742)	(0.000795)	(0.00289)	(0.000771)	(0.000815)	(0.00291)
$\Delta \ln k$	0.483***	0.423***	0.465***	0.488***	0.430***	0.474***
	(0.0278)	(0.0301)	(0.0333)	(0.0282)	(0.0305)	(0.0337)
$\Delta \ln F$	0.193***	0.180***	0.154***			
	(0.0188)	(0.0198)	(0.0209)			
$\Delta \ln F^d$				0.101***	0.0943***	0.0777***
				(0.0137)	(0.0142)	(0.0144)
Time F.E.	No	Yes	Yes	No	Yes	Yes
Country F.E.	No	No	Yes	No	No	Yes
Industry F.E.	No	No	Yes	No	No	Yes
Observations	15,850	15,850	15,850	15,850	15,850	15,850
R-squared	0.372	0.419	0.455	0.351	0.403	0.444
F-stat	285.0***	338.2***	87.10***	267.8***	330.2***	86.35***

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0

Table 3.2 / Linear results II

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta \ln y$	$\Delta \ln y$	$\Delta \ln y$	$\Delta \ln y$	$\Delta \ln y$	$\Delta \ln y$
$\ln y_{1995}$	-0.0104***	-0.0106***	-0.0142***	-0.0110***	-0.0113***	-0.0143***
	(0.000741)	(0.000797)	(0.00289)	(0.000770)	(0.000816)	(0.00291)
$\Delta \ln k$	0.482***	0.422***	0.465***	0.488***	0.430***	0.474***
	(0.0278)	(0.0301)	(0.0334)	(0.0282)	(0.0305)	(0.0336)
$\Delta \ln F_F$	0.190***	0.176***	0.150***			
	(0.0180)	(0.0192)	(0.0202)			
$\Delta \ln F_F^d$				0.0940***	0.0870***	0.0725***
				(0.0123)	(0.0130)	(0.0131)
Time F.E.	No	Yes	Yes	No	Yes	Yes
Country F.E.	No	No	Yes	No	No	Yes
Industry F.E.	No	No	Yes	No	No	Yes
Observations	15,850	15,850	15,850	15,850	15,850	15,850
R-squared	0.372	0.419	0.455	0.351	0.402	0.443
F-stat	289.2***	338.2***	87.04***	270.0***	330.3***	86.44***

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

While the above results suggest that the R&D stock of intermediates is positively associated with output per worker growth, the major interest in this report is to consider the impact of foreign R&D on labour productivity. As such, one would like to split up the total R&D stock into a domestic and foreign component as in equations (3.8) and (3.3.9). Here one encounters a problem because the domestic R&D stock is not defined for a number of countries and a number of industries, meaning that one cannot calculate the log of the domestic R&D stock. Coe et al. (1997) suggest to focus on the foreign R&D stocks only. Table 3.2 reports results when dropping the domestic R&D stock, including the foreign stock only. The results are very similar to those found when including the total stocks, which suggests that the inclusion of the measure of the domestic stocks does not affect the results on the foreign stock[27]. For this reason, the focus is now on results including only the foreign R&D stock. For reasons of brevity, the report further concentrates on results when including time, country and industry fixed effects, and on those results when using the total (foreign) R&D content of intermediate inputs rather than the direct effect only.

Table 3.3 / Linear results III

VARIABLES	(1) $\Delta \ln y$	(2) $\Delta \ln y$	(3) $\Delta \ln y$	(4) $\Delta \ln y$	(5) $\Delta \ln y$	(6) $\Delta \ln y$	(7) $\Delta \ln y$	(8) $\Delta \ln y$	(9) $\Delta \ln y$	(10) $\Delta \ln y$
$\ln y_{1995}$	-0.0142***	-0.0142***	-0.00500	-0.00497	-0.00422	-0.00486	-0.00404	-0.0134***	-0.0142***	-0.0143***
	(0.00289)	(0.00289)	(0.00409)	(0.00409)	(0.00454)	(0.00394)	(0.00396)	(0.00301)	(0.00289)	(0.00288)
$\Delta \ln k$	0.465***	0.465***	0.629***	0.632***	0.673***	0.636***	0.622***	0.472***	0.466***	0.461***
	(0.0335)	(0.0334)	(0.107)	(0.107)	(0.134)	(0.0955)	(0.103)	(0.0357)	(0.0336)	(0.0338)
$\Delta \ln F_F$	0.150***	0.150***	0.0806***	0.0778***	0.0635*	0.0894***	0.0749**	0.144***	0.150***	0.148***
	(0.0202)	(0.0202)	(0.0287)	(0.0290)	(0.0348)	(0.0228)	(0.0336)	(0.0227)	(0.0203)	(0.0201)
Syr	0.00650									
	(0.00636)									
$\ln R\&D$		0.000223								
		(0.000319)								
EPR			-0.0246**							
			(0.00983)							
EPT				-0.0190***						
				(0.00416)						
EPC					-0.0841***					
					(0.0308)					
Union						0.000170				
						(0.00109)				
PMR							0.0146			
							(0.0112)			
IPR								-0.00950**		
								(0.00419)		
Invest									-0.000327**	
									(0.000166)	
Finance										0.000777***
										(0.000171)
Observations	15,850	15,850	9,559	9,559	8,061	10,372	9,742	14,200	15,850	15,850
R-squared	0.455	0.455	0.445	0.446	0.468	0.456	0.471	0.455	0.455	0.456
F-stat	86.41***	86.05***	92.94***	94.22***	94.07***	108.8***	100.9***	82.53***	86.39***	95.54***

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; All models include unreported time, industry and country fixed effects.

[27] A second approach was tested as well by adding a relatively small number ($100,000) to the domestic R&D stocks of those countries and industries for which data are not available. This allows calculating the log of the domestic R&D stocks. While this assumption implies that the change in the log of the domestic R&D stocks will be zero for such observations, it does allow us to include the full sample of observations. The results when including the domestic stock of R&D are reported in Table 3.2. Results on the additional control variables are largely similar to those reported in the previous table, while the coefficients on the change in the domestic R&D stock are generally insignificant and often negative. This is likely to reflect the fact that a large number of observations had to be implemented for this variable, with the lack of variation in the resulting growth rates making insignificant coefficients likely. Coefficients on the foreign R&D stock are, however, consistently positive and significant, with the size of the coefficients being very similar to those for the total R&D stock reported in the previous table.

Table 3.3 introduces the indicators of absorptive capacity and absorption barriers linearly into the model. First, each of these variables is included separately in the model to avoid issues of multicollinearity. The results indicate that the initial output per worker term remains negative when including these additional variables (though the coefficient is often not significant), while coefficients on the capital-labour ratio remain positive and significant. The coefficients on the foreign R&D stock variable remain positive, and are usually significant. However, the coefficient on this variable tends to fall when the sample size is reduced (due to missing values on one of the institutional variables). Turning to the coefficients on the institutional variables themselves, a number of interesting results are found. The coefficients on the measures of human capital and the log of R&D expenditure are positive but insignificant[28]. The indicators of labour market regulation have a consistently negative and significant coefficient, suggesting that higher labour market regulations are associated with lower output per worker growth. Similar results are found for the index of IPR protection and the measure of investment freedom. For the remaining variables no significant coefficient are found, except in the case of financial freedom where less freedom is associated with higher growth[29].

3.6.2. HETEROGENEOUS EFFECTS OF FOREIGN R&D

This section examines whether the assumption of a common parameter on the foreign R&D stock of intermediates is a valid one, by searching for non-linear and contingent relationships between the growth of the foreign R&D stock and output per worker growth. The first step is to examine whether the association between the growth of foreign R&D and per worker output growth differs across country and industry groups. To do this the sample is split into different sub-groups. In the case of the country split, the sub-groups are the EU15, the EU12, other developed countries and other developing countries[30]. The sub-groups when considering industry splits are services industries, low-tech and medium/high-tech manufacturing[31]. Each of the right-hand side variables is interacted with a dummy for each sub-group.

Results from the single regression allowing for differential coefficients by country are reported in Table 3.4, while those allowing for industry differences are reported in Table 3.5. Results in Table 3.4 indicate that while there are few differences in the size of the coefficient on the growth of foreign R&D for the EU12, EU15 and other developed countries, the coefficient for other developing countries is considerably (and significantly) larger. In the EU15, EU12 and other developed countries the coefficient estimates suggest that a 1% increase in the growth of the foreign R&D stock is associated with increased per worker output growth of around 0.08%; a similar increase in other developing countries is associated with an increase of around 0.3%. Table 3.5 indicates that the estimated coefficients on the foreign R&D stock are similar for low- and medium/high tech manufacturing, and that these are significantly larger than the coefficient for services. In particular, results show that a 1% increase in the

28 In the case of R&D expenditure, this may again be due to the fact that the level of R&D expenditure is missing for a large number of observations, with the missing observations being replaced by $1,000. The lack of variation in this variable for such observations may lead to an insignificant coefficient on the variable. Many previous studies have found either an insignificant or even negative coefficient on indicators of schooling in growth regressions (e.g. Pritchett, 2001).

29 When including all institutional variables together all indicators with the exception of PMR and *finance* remain significant. Additionally the coefficient on product market regulation now also becomes negative and significant.

30 The sample of other developed countries includes Australia, Japan, Canada, Korea, Taiwan and the USA, while the sample of other developing countries includes Brazil, China, Indonesia, India, Mexico, Russia and Turkey.

31 The group of low-tech manufacturing industries are: AtB, 15t16, 17t19, 20t22, 26 and 27t28, with the medium/high-tech manufacturing industries being C, 23, 24, 25, 29, 30t33, 34t35 and 36t37.

growth rate of the foreign R&D stock is associated with an increase in labour productivity growth of around 0.27% in the case of low- and high-tech manufacturing, with a similar increase in foreign R&D being associated with an increase in labour productivity growth of around 0.11%. In general, these results suggest that there may well be significant differences in the association between foreign R&D and per worker output growth across countries or country groups and between manufacturing and services sectors.

Table 3.4 / Country splits

	(1) EU12	(2) EU15	(3) Developed	(4) Developing
$\ln y_{1995}$	-0.0210***	-0.0105***	-0.00669*	-0.0120***
	(0.00473)	(0.00337)	(0.00351)	(0.00303)
$\Delta\ln k$	0.371***	0.673***	0.708***	0.564***
	(0.0439)	(0.0248)	(0.0208)	(0.0178)
$\Delta\ln F_F$	0.0778**	0.0869***	0.0822***	0.294***
	(0.0324)	(0.0188)	(0.0198)	(0.0232)
Observations	15,850			
R-squared	0.483			
F-stat	136.0***			

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; All models include unreported time, industry and country fixed effects

Table 3.5 / Industry splits

	(1) High-Tech Man.	(2) Low-Tech Man.	(3) Services
$\ln y_{1995}$	-0.00664**	-0.00615**	-0.00974***
	(0.00329)	(0.00286)	(0.00293)
$\Delta\ln k$	0.420***	0.369***	0.483***
	(0.0462)	(0.0379)	(0.0507)
$\Delta\ln F_F$	0.271***	0.278***	0.112***
	(0.0293)	(0.0238)	(0.0308)
Observations	15,850		
R-squared	0.430		
F-stat	76.84***		

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; All models include unreported time, industry and country fixed effects

3.6.3. FOREIGN R&D AND ABSORPTIVE CAPACITY.

In this section, it is examined 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 applied econometric strategy involves estimating a model of the following form:

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

Here 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 and more details on how this is obtained can be found in Box 4[32]. When estimating this model the threshold variable, Z, is further included linearly. To the set of threshold variables capturing absorptive capacity and absorption barriers also the initial logged value of labour productivity ($\ln y_{1995}$) is included. Doing this, allows one to examine whether an indicator of relative backwardness impacts upon the relationship between foreign R&D and labour productivity[33]. While being further behind the technological leader means that there is more technology and knowledge to borrow and assimilate, it may also mean that a country or sector doesn't 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 3.6. Coefficients on initial output per worker and the growth of the capital-labour ratio are consistent with results above, with coefficients generally being significantly negative and significantly positive respectively. Before turning to the coefficients on the growth of the foreign R&D stock, it is worth mentioning that in 10 out of the 11 cases one finds evidence of a significant threshold (the exception being when the log of R&D is the threshold variable). This implies that the threshold model is preferred to the linear model, or in other words, that there are significant differences in the coefficients in the two regimes.

In terms of the threshold results, a variety of outcomes appear. In the case of the backwardness measure one finds that the lower the labour productivity, the larger are the spillover effects. The coefficient in the low regime (0.264) is more than double that 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.

Turning to the indicators of absorptive capacity (i.e. Syr and lnR&D), one finds 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 that are more R&D intensive. While the

32 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 this 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).

33 Falvey et al. (2007) present some evidence indicating that the impact of foreign R&D on labour productivity differs according to the degree of relative backwardness.

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.

Considering the case when labour market indicators are used as threshold variable one finds differences depending upon the indicator used. When using indicators of the strength of regulation on regular contracts and collective dismissal, one finds that spillover effects are larger in the low regime (i.e. in countries with lower regulations). The coefficients in the high regimes tend to be quite small, with those in the low regime larger and statistically significant. 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.

When considering the strength of regulation on temporary contracts one finds the reverse. In particular, one finds that 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 density as threshold variable one finds 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 $\mathrm{Finance}$ that 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 actually 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 $\mathrm{Finance}$ the differences are much larger (0.08 versus 0.237). Though this might be an unexpected result one should notice that these indicators could also reflect institutional quality in a broader sense. Thus, countries with higher institutional quality might attract more R&D intensive firms or have tighter co-operations in R&D activities, etc. which would be possible explanations of that finding.

3.7. SUMMARY

This report considers the extent of foreign R&D spillovers through intermediate inputs for a sample of up to 40 developed and developing countries. Results suggest that such foreign R&D spillovers are present and are economically important. A 1% increase in the growth rate of the R&D content of intermediates is associated with an increase in the growth rate of labour productivity of between 0.08% and 0.2%. Concentrating on the foreign R&D stock only leads to similar results, highlighting the importance of foreign R&D as a source of domestic productivity growth. Such results hide heterogeneity in outcomes however. The benefits of foreign R&D are found to be stronger in the lowest income countries in the sample, with few differences found between EU15 and EU12. One further finds significant differences in results when splitting the sample according to the value of measures of absorptive capacity and absorption barriers. To summarise the threshold results, one finds that countries and industries initially further behind the technological frontier enjoy stronger foreign R&D spillovers. In their study, Falvey et al. (2007) found that spillovers were strongest in countries with intermediate levels of relative backwardness. Their study included a broader range of countries than the current one. Given that the current study doesn't include countries at very low levels of development, the results one obtains are therefore not inconsistent with those of 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 one finds that stronger labour market regulation and greater union density is associated with lower foreign R&D spillovers, results again in line with Crespo-Cuaresma et al. (2008). Such results are also consistent with the arguments of Parente and Prescott (1994, 1999 and 2003). The evidence for other absorption barriers related to product market, financial and investment regulation provide no evidence of low regulation encouraging foreign R&D spillovers. Indeed, in these cases the reverse is found to be the case. Finally, one finds that stronger levels of IPR protection can limit the extent of foreign R&D spillovers, possibly by limiting the ability to copy and borrow technology from abroad.

Table 3.6 / Single threshold results

	(1) $\ln y_{1995}$	(2) *Syr*	(3) $\ln R\&D$	(4) *EPR*	(5) *EPT*	(6) *EPC*	(7) *Union*	(8) *PMR*	(9) *IPR*	(10) *Invest*	(11) *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: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; All models include unreported time, industry and country fixed effects

4. Efficiency analysis at the industry level

This section provides an integrated structural analysis of the determinants of technical efficiency in Europe, in the US and Japan. 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 framework and the regression analysis used in previous sections are based on the assumption that all resources, i.e. capital and labour inputs, are fully utilised. Technical efficiency analysis relaxes this assumption and assumes that only the top performing industries are able to use resources in the most efficient way. The other industries will lie below the frontier and will be characterised by a certain degree of inefficiency. The distance to the frontier output defines the efficiency gap. The first objective of this section is therefore to identify which industry/country is at the frontier and which ones are lagging behind, how efficiency levels have changed over time and how they compare with trends in TFP growth. This will lead to an understanding of whether there are discrepancies between productivity and efficiency. In fact, it is possible that the best performing industry in terms of productivity performance might not be the most efficient one. In this case, higher productivity could be achieved by improving the allocation and usage of the available resources. On the other hand, a high efficient industry might not be the most productive because of, for example, low investments in strategic assets such as ICT and R&D capital. Hence, the policy objective would be to promote investments in strategic assets.

The possibility that factor inputs are not fully utilised is discussed in the pioneering work by Leibenstein (1996), who states that ‘there is more to the determination of output than the obviously observable inputs’. In recent years, the development of non-parametric techniques for the analysis of inefficiencies in production, such as stochastic frontier, has contributed to an increasing research effort in this area (Kumbhakar and Lovell, 2000; Coelli et al., 2005)[34]. Existing contributions focus not only on the estimation of technical efficiency but also on the factors that can affect the efficient use of resources, such as intangible assets, ICT and the regulatory framework. For example, Kneller and Stevens (2006) examine whether differences in human capital and R&D explain inefficiency in manufacturing in nine OECD countries. Their results show that technical efficiency is positively influenced by human capital, whilst the effect of R&D is not relevant. Both human capital and R&D are considered as proxies for industry absorptive capacity, i.e. the ability to enjoy additional returns from the knowledge developed elsewhere. As for the role of ICT, there is substantial evidence showing the importance of new digital technologies, and related applications, in the re-organisation of production and in improving the efficiency of transactions among firms. For example, Rowlatt (2001) and Criscuolo and Waldron (2003) argue that the use of electronic data interchange, internet-based procurement systems and other inter-organisational information systems, produces a reduction in administrative and search costs and a better supply chain management. Milana and Zeli (2002) use frontier analysis to analyse the impact of ICT on the efficiency of Italian firms, finding a positive correlation in most industries with the exception of the highly R&D intensive ones. This result is justified by observing that such industries already operate at the frontier. Dimelis and Papaioannou (2012) address the issue of whether ICT capital has an impact on inefficiency in four service sector industries (wholesale and retail, hotels and restaurants, financial

[34] This field of research originated from in Aigner et al. (1977) and Meeusen and Van den Broeck (1977).

intermediation and real estate, renting and business activities) of nine European countries. Their results provide strong evidence on the ability of ICT to reduce inefficiencies.

Frontier analysis has also been used to investigate how different policies affect efficiency, although the evidence so far mainly concentrates on developing countries. For example, Henry et al. (2009) find that trade openness policies and technology transfers enhance production efficiency of developing economies. A similar result is also found in Thomson and Garbazc (2007), where measures of institutional freedom, together with telecommunication services, significantly improve productive efficiency in developing countries. Similarly, Su and He (2012) report micro-economic evidence for China showing that political interference reduces production efficiency. In developed countries Nakano and Managi (2008) provide evidence of the positive relationship between competitiveness and efficiency by showing that in Japan, the deregulation of the electricity market helped to improve efficiency in the steam power-generation sector. Using data for eighteen EU countries over the period 1970-2004, Mastromarco et al. (2012) document that imports and FDI improves efficiency and suggest that the recent slowdown in EU productivity can be related to the decline in FDI.

In this section, the analysis provides an important extension of the existing literature by looking at the role of ICT and the institutional framework in affecting efficiency using a large sample of manufacturing and service industries in Europe, the US and Japan. The study focuses on four types of regulations that affect competitiveness and are therefore potential candidates for policy interventions directed to the reduction of efficiency gaps: degree of competitiveness of the business environment, development of the financial system, strength of patent protection and regulatory restrictions to international operations. Based on the existing evidence, the main working hypotheses will be that ICT has a positive impact on production efficiency, while excessive regulation reduces it. The degree of openness to trade is also expected to positively influence efficiency, although the link between these variables may be quite complex, especially when the analysis focuses on a set of developed countries. Intellectual property rights (IPR) protection can have a dual role on productivity as it promotes knowledge creation by increasing the rents of innovators, but it can also hinder technology diffusion. The effects of this institutional factor on productive efficiency are largely unknown and have to be determined empirically, as part of this study.

The results show that there is heterogeneity in efficiency levels across industries and countries, but the general trends are not dissimilar from productivity trends. ICT investments are associated with higher efficiency levels, while regulations that severely constraint the competitiveness of the market reduce the efficient use of resources, contributing to the widening of the efficiency gap. The easy access to alternative sources of funding can also increase technical efficiency; however, excessive financial deregulation has a detrimental effect on the degree of efficiency with which industries manage production tasks.

The following section discusses the specification used to estimate the production frontier and to derive technical efficiency scores. The main efficiency trends are presented in Section 4.2, together with a comparison between efficiency and productivity performance. The main factors affecting technical efficiency are considered in Section 4.3, while Section 4.4 discusses the direction of their impact. Section 4.5 presents conclusions and policy implications.

4.1 TECHNICAL EFFICIENCY

This section extends the industry level analysis to account for the presence of technical inefficiencies in production, using stochastic frontier methods (SFA) – see Box 7. The most intuitive way of understanding frontier analysis is to think that the actual output produced can be lower than the maximum output that can be feasibly produced using the available resources. By defining actual output in industry i at time t as YAit and the maximum output as YFit, technical efficiency (TE) can be expressed as:

(4.1) $$TE_{it} = YA_{it}/YF_{it}$$

Efficiency levels in each industry range between 0 and 1, with higher scores indicating higher efficiency. Therefore, when TE<1, the industry lies within the frontier and it is not using its resources in the best possible way. Since output is strictly positive, the degree of technical efficiency is also assumed to be positive (TE>0).

By defining $TE_{it} = \exp(-u_{it})$ and re-arranging equation 4.1 it yields:

(4.2) $$YA_{it} = YF_{it} * TE_{it} = f(x_{it}, b) * \exp(-u_{it}),$$

where $u_{it} \geq 0$. This specification shows that actual output equals the frontier output minus a certain level of inefficiency. The latter is a typical measure of the efficiency gap existing between frontier and laggard industries. Equation (4.2) defines a deterministic frontier where all deviations from maximum output are caused by inefficiencies. Stochastic frontier analysis accounts for the fact that the gap between maximum and actual output could also be due to exogenous factors, which are likely to play an important part in a sample composed of different industries and countries. Hence, our measure of technical efficiency will generally be below 1 even for the top performing industries.

Exogenous factors are captured by a two-sided[35] error component, v_{it}:

(4.3) $$YA_{it} = YF_{it} * TE_{it} = f(x_{it}, b) * \exp(-u_{it}) * \exp(v_{it})$$

Assuming a Cobb-Douglas production function, and using logarithmic transformation, levels of technical efficiency are derived as a part of the residuals from the estimation of the following equation:

(4.4) $$\ln(YA_{it}) = b_0 + b_1 \ln(H_{it}) + b_2 \ln(K_{it}) + \ln(v_{it}) - \ln(u_{it})$$

Equation (4.4) expresses output, measured by value added, as a function of the total number of hours worked (H) and Total capital (K). This specification will be extended to include different types of capital (ICT and non-ICT capital) and intangible assets (labour quality and R&D capital). The inefficiency

[35] This component of the error term can take any positive or negative values.

component is assumed to follow the half normal distribution, while the idiosyncratic component follows the normal distribution, as it is commonly assumed in standard regression analysis[36].

The analysis is carried out using industry-level data, extracted from the EUKLEMS database. The total sample includes sixteen countries, namely fourteen European countries (AT, BE, CZ, DE, DK, ES, FI, FR, HU, IE, IT NL, SE and UK), Japan and the US. For each country, data are available for twenty-one industries, including manufacturing and services[37]. Industries in this analysis are classified according to the NACE rev. 1 classification, which differs from the one used in Section 1. However, whenever possible, results from the two sections will be compared for similar industry groupings. The analysis is conducted between 1995 and 2007 and, therefore, will provide a picture of industries' performance in the pre-financial crisis period. The exclusion of the financial crisis 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 exogenous shocks or cyclical factors.

4.2 RESULTS: ESTIMATION OF THE PRODUCTION FRONTIER

Results from the estimation of production function (eq. 3.4.4) are presented in Table 4.1[38] where, for comparison purposes, Ordinary Least Square (OLS) results are also shown[39]. The first part of the table presents estimates for the effect of tangible assets on value added, while the second part shows the coefficient estimates for intangible assets. The bottom section presents some diagnostic statistics.

The first column reports coefficient estimates for total capital services, while column (2) distinguishes between ICT and non-ICT capital services. The results are robust across the two specifications and, with the exception of ICT capital, all coefficient estimates are positive and statistically significant. The size of the coefficients for the labour and the capital variables are consistent with prior knowledge of factor shares. Human capital, measured by the labour quality variable, has a positive, albeit small, effect on productivity, which is consistent with the fact that the measure used accounts for the role of all

36 The econometric package 'STATA' allows choosing among three distributions for the inefficiency term: half normal, exponential and truncated normal. The results shown in this report are consistent with different distributional assumptions.

37 Industries included in the analysis, and their NACE rev. 1 codes, are: Food and Beverages (15t16), Textile and Leather (17t19), Wood & Cork (20), Pulp, Paper and Printing (21t22), Coke, refined petroleum and nuclear fuel (23), Chemicals (24), Rubber and Plastic (25), Other non-metallic minerals (26), Basic metals, fabricated metal products (27t28), Machinery NEC (29), Electrical Equipment (30t33), Transport Equipment (34t35), Manufacturing NEC (36t37), Transport and Storage (60t63), Post and Telecommunication (64), Business Services (71t74), Electricity, Gas and Water (40t41), Construction (45), Wholesale and Retail (50t52), Financial Intermediation (65t67), Other Community and Social Services (90t93).

38 The estimation of equation (3.13) in the panel dimension requires the introduction of fixed effects to control for cross-sectional heterogeneity. Hence, the specification used includes country and industry fixed effects, as well a set of time dummies to control for unknown or unobserved factors that are likely to affect all industries at different points in time.

39 OLS estimates are based on heteroskedasticity robust standards. The panel data set includes 12 yearly observations and around 350 cross-sectional observations. Although the time dimension is relatively short, a battery of four stationarity tests are performed to give full support to the use of the variables in levels (see Choi, 2001). Results from these tests are presented in Appendix Table A.10. Two of the tests (inverse chi-squared and modified inverse chi-squared) always reject the null of the presence of unit root in the data, while the other two (Inverse normal and inverse logit) do not reject the null at conventional significance levels. Therefore, cointegration tests were run on the residuals of the OLS regression, as these tests have not been devised for the composite error term underlying the SFA model. Inference presented in Appendix Table A.11 clearly supports the hypothesis of cointegration and, as a result, the appropriateness of using variables expressed in levels.

educational levels. Higher impact of human capital is normally estimated when the highest skilled workers are given a higher weight in the construction of the labour quality variable (Mason et al. 2012). In column (2), the impact of ICT is positive with an elasticity of approximately 0.02%. While the size of the effect is consistent with existing evidence[40], it is not statistically significant at conventional significance 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 coefficient improves (column 8). 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. Additionally, Section 4.4 will show that ICT plays an indirect effect on productivity, via the reduction of technical inefficiencies.

Results in Table 4.1 confirm the important role of R&D in increasing productivity: a 1% increase in R&D generates a 0.06% increase in value added and this effect is robust across different model specifications and estimation techniques. The size of the coefficient is in line with the reference literature where this value generally ranges between 0.04 (Griliches, 1979, 1984; Bloom et al., 2013) and 0.18 (Griliches and Mairesse, 1984), depending on the country and the time period analysed. 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 (column 3) and non-ICT capital (column 4). This is a consequence of the complementary relationship between R&D and capital assets. However, the impact of the total number of hours worked is significantly lower in columns 3 and 4, compared to the first two columns of Table 4.1. This is related to the fact that a large proportion of R&D costs is composed of the wages of employees involved in research activities. This 'double counting' is a well known phenomenon in productivity studies (Hall, 1992; Schankerman,1981; Guellec and van Pottelsberghe, 2004).

The Gamma parameter, presented after the SFA results, is the ratio of the variance of the inefficiency component to the variance of the composite error term. This parameter ranges between 0 and 1 and it measures how important inefficiencies are in each model, with a value of 1 indicating that all deviations from the frontier are due to inefficiency and a value of 0 implying that there are no inefficiencies; in the latter case, SFA does not provide any additional information compared to OLS. In this study, Gamma parameter is approximately equal to 0.4 which means that inefficiencies are important and explain 40% of the total residual variation. The presence of inefficiencies is also tested via the Likelihood Ratio test; it shows that inefficiencies are statistically significant.

The SFA modelling framework allows the derivation of technical efficiency for each industry/time period. Estimates of technical efficiency can be derived from any of the specifications presented in Table 4.1; 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 including R&D, as information on this asset is missing in several service industries. A typical example is the Hotels and Restaurants industry which typically does not invest in R&D. Given that the main objective of this part of the analysis is to understand efficiency trends across a large number of industries covering the full spectrum of manufacturing and services, the specification in column (2) is used to derive technical efficiency scores[41].

[40] Kretschmer (2012) compares estimates of the ICT elasticity in a large number of studies and reveals a clustering of values around the values of 0.05-0.06.

[41] 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 technical efficiency.

Panel A of Figure 4.1 presents the average, minimum and maximum levels of technical efficiency for the whole sample over the 1995-2007 period, while Panel B shows the distribution of the technical efficiency (TE) scores. TE levels tend to be fairly consistent over time, with the only exception of the lowest performing industries, which have experienced deterioration in their performance. This trend is however not particularly worrying as, by looking at the distribution of the TE scores, the number of highly inefficient industry is very low. The lowest TE scores, ranging between 0.23 and 0.40, are observed in the Coke, Refined Petroleum and Nuclear Fuel industry in the Czech Republic and in Denmark. Given that there are some methodological issues in measuring productivity in these industries (Inklaar et al., 2008), these figures need to be interpreted with caution, particularly when the same industry achieves the highest efficiency levels (0.91) in France (2001), Austria (2007) and in the UK (1995). The Chemical industry in Ireland and Machinery NEC in Hungary are also among the top performing industries.

Average efficiency is 0.78, which implies a gap of 13% between the most efficient (TE= 0.91) and the average unit, i.e. on average industries are 13% less efficient compared to the frontier industries and this difference has remained persistent over time. In fact, Figure 4.1 shows that there are no signs of convergence, consistently with a similar analysis carried out by Kneller and Stevens (2006) for the period 1970-1991.

Table 4.1 / Estimation of the production function. Dependent variable: value added

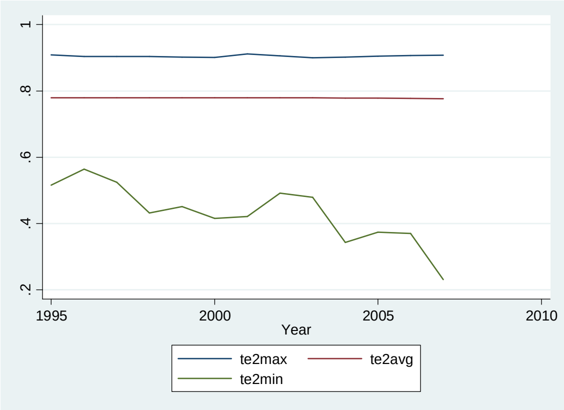
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Stochastic Frontier				OLS			
Total number of hours worked	0.790***	0.755***	0.632***	0.612***	0.808***	0.765***	0.642***	0.622***
	(0.031)	(0.031)	(0.036)	(0.037)	(0.043)	(0.041)	(0.045)	(0.045)
Total capital	0.351***		0.446***		0.341***		0.441***	
	(0.024)		(0.028)		(0.033)		(0.034)	
Non-ICT capital		0.394***		0.445***		0.387***		0.431***
		(0.024)		(0.029)		(0.027)		(0.032)
ICT capital		0.019		0.026		0.023		0.036
		(0.017)		(0.020)		(0.019)		(0.023)
Intangible assets								
Labour quality	0.011***	0.010***	0.008***	0.007***	0.012***	0.011***	0.009***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
R&D capital			0.061***	0.061***			0.059***	0.059***
			(0.008)	(0.008)			(0.009)	(0.009)
Constant	1.418***	1.154***	1.246***	1.248***	1.095***	0.875***	0.946***	0.968***
	(0.168)	(0.171)	(0.189)	(0.189)	(0.183)	(0.173)	(0.188)	(0.185)
R^2					0.926	0.926	0.923	0.923
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	4532	4519	3650	3488

Notes: ***,**, * = significant at 1, 5, and 10%. Robust standard errors in parentheses in the OLS regression. The cointegration test is a test of the stationarity of the residuals, based on the Pm test (Choi, 2001). The null hypothesis is that all panels contain a unit root. Gamma is the proportion of the total error variance due to inefficiency. The Likelihood ratio test is a test of the null hypothesis that there are no technical inefficiency in production.

Figure 4.1, although useful to get a glimpse of the general trends, hides differences across industries and countries. Trends in average TE in each country are presented in Figure A.6 of the Appendix to this study. These are quite stationary over time in Germany, Sweden, and the Netherlands, while countries such as Italy, Spain and Ireland have experienced decreasing levels of efficiency during the 1995-2007 period. Austria, Finland and France have been characterised by increasing efficiency since the late 1990s. Outside the EU, Japan has experienced declining efficiency trends over time.

Figure 4.1 / Trends in technical efficiency

Panel A



Panel B

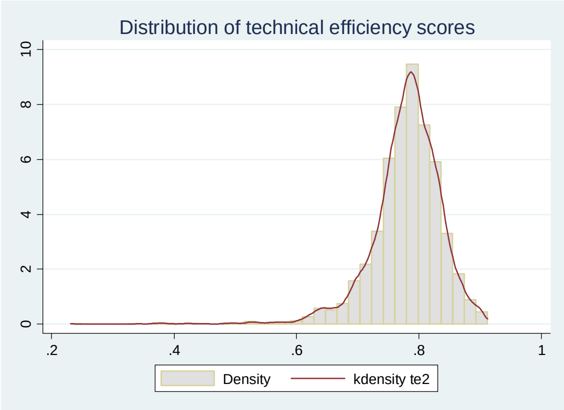


Figure 4.2 / Average technical efficiency in the EU, US and Japan

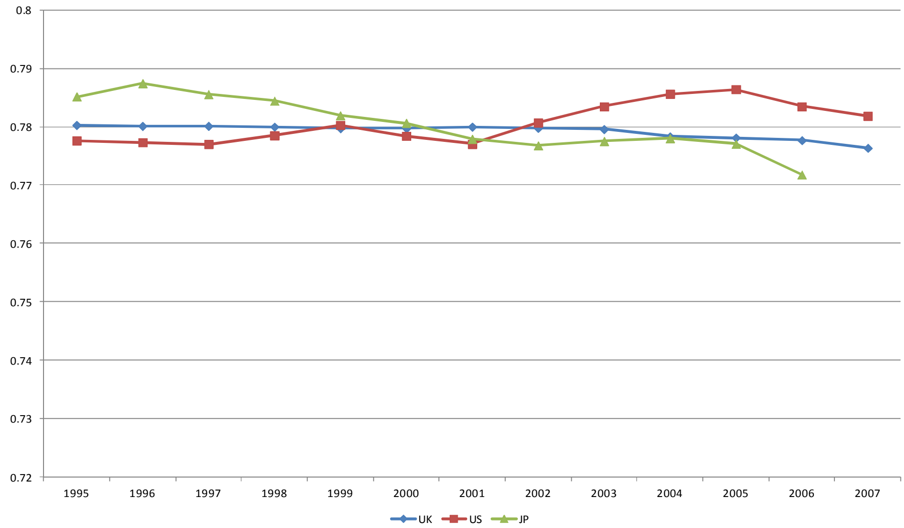


Figure 4.2 further investigates variations in efficiency over time presenting average efficiency scores for the EU, the US and Japan. Although actual efficiency levels do not differ greatly across economies, their variation over time shows some interesting patterns. In the mid-1990s, the US had lower efficiency

levels than Japan and Europe, but efficiency increased rapidly, placing the US at the frontier since 2002. Existing evidence dates the increase of US productivity in 1995 (see Figure 1.2 in Section 1[42]), around seven years before the aggregate increase in efficiency. This difference can be explained with 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 ICT. From 2002 to 2005 the efficiency gap between the US and the other two economies widens. However, from 2005 efficiency levels lowered in the US, while the EU trend remains virtually unchanged. Japan was the frontier country in 1995 but it experienced a decrease in efficiency from 1996, and since the year 2000 its efficiency has been below the European average. A further decrease took place after 2005. These trends are not dissimilar from trends in TFP levels, discussed in Jorgenson and Nomura (2007). Their contribution shows that until 1990 Japan outperformed several US industries, but in the 1990-2000 productivity stalled. Figure 4.2 shows that, similarly to the US, changes in efficiency follow changes in productivity with a lag, in the case of Japan, of about 5 years.

Table 4.2 provides a more detailed picture of industry/country differences in TE levels by presenting the mean score over the entire time span under examination. Individual industry scores have been underlined when they identify the frontier (double line) and the least efficient unit (single line). These show that there are large differences across industries. Looking first at the average scores, the Hotel industry has the lowest overall performance, with an average TE score of 0.66. This implies that this industry is 12% less efficient than the average industry. The UK and Ireland are the lowest performing countries when considering the overall sample. However, the UK is the efficiency leader in the Coke industry and in Manufacturing NEC and, among the service sector, has achieved high levels of efficiency in Post and Telecommunication. Ireland is the TE leader in the Chemical industry and in Pulp, Paper and Printing. Interestingly the US, although characterised by high efficiency levels in several industries such as Transportation Equipment (0.86), Coke (0.85) Electrical Equipment (0.82), are not the efficiency leader in any of the sectors of the sample. This is consistent with existing work by Kneller and Stevens (2006) and suggests that the US could further increase their productivity levels with a more efficient use of their resources. The Netherlands, on the other hand, have achieved the highest efficiency scores in several sectors, including Food, Textile, Basic Metals, Transport equipment and Hotels. It is also interesting to see that countries that have a competitive advantage in traditional sectors, do not achieve high levels of efficiency in their main industry of specialisation. For example, Italy classifies 8th in the ranking of the TE scores of the textile sector. Similarly Germany does not appear to be at the efficiency frontier in any industry; however, it is characterised by the highest mean score across all countries.

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42 Note that Figure 1.2 uses an EU-27 average, while Figure 4.2 is based on 14 European countries.

Table 4.2 / Technical efficiency scores by country and industry. Average over 1995-2007

	AT	BE	CZ	DE	DK	ES	FI	FR	HU	IE	IT	JP	NL	SE	UK	US	**AVERAGE**
Food	0.77	0.79	0.83	0.78	0.80	0.71	0.77	0.71	0.76	0.79	0.82	0.74	0.84	0.78	0.74	0.78	0.78
Textile	0.67	0.83	0.77	0.77	0.79	0.76	0.74	0.76	0.74	0.81	0.77	0.80	0.85	0.71	0.78	0.83	0.77
Wood	0.69	0.70	0.83	0.79	0.79	0.83	0.82	0.84	0.79	0.78	0.77	0.78	0.53	0.81	0.59	0.75	0.76
Paper	0.83	0.82	0.68	0.79	0.72	0.75	0.80	0.75	0.82	0.86	0.69	0.79	0.78	0.73	0.81	0.77	0.78
Coke	0.86	0.82	0.44	0.77	0.43	0.62	0.70	0.89	0.65		0.66	0.83	0.54	0.77	0.90	0.85	0.71
Chemicals	0.79	0.76	0.83	0.74	0.76	0.76	0.82	0.77	0.62	0.88	0.77	0.77	0.84	0.80	0.66	0.69	0.77
Rubber	0.83	0.86	0.85	0.79	0.74	0.76	0.74	0.84	0.79	0.78	0.79	0.61	0.80	0.71	0.78	0.65	0.77
Oth. NMM	0.80	0.81	0.86	0.81	0.78	0.80	0.76	0.77	0.81	0.74	0.84	0.74	0.77	0.66	0.74	0.72	0.78
Bas. Metals	0.72	0.78	0.77	0.79	0.78	0.75	0.78	0.76	0.75	0.82	0.81	0.79	0.83	0.80	0.73	0.77	0.78
Machinery NEC	0.73	0.78	0.75	0.79	0.77	0.77	0.78	0.81	0.89	0.74	0.75	0.80	0.73	0.75	0.80	0.75	0.77
Electrical Eq.	0.78	0.77	0.79	0.77	0.72	0.79	0.83	0.75	0.80	0.70	0.78	0.82	0.72	0.83	0.75	0.82	0.78
Transport Eq.	0.82	0.72	0.80	0.80	0.69	0.84	0.65	0.74	0.66	0.66	0.87	0.86	0.76	0.72	0.71	0.86	0.76
Manuf. NEC.	0.71	0.81	0.69	0.77	0.87	0.76	0.84	0.72	0.81	0.74	0.73	0.66	0.75	0.77	0.88	0.76	0.77
Transports	0.74	0.66	0.82	0.74	0.78	0.78	0.77	0.77	0.78	0.72	0.75	0.79	0.89	0.72	0.76	0.82	0.77
Post& Telecoms	0.79	0.70	0.60	0.82	0.80	0.75	0.74	0.80	0.70	0.67	0.78	0.79	0.79	0.88	0.85	0.75	0.76
Business Services	0.74	0.77	0.72	0.79	0.83	0.82	0.79	0.69	0.86	0.80	0.79	0.75	0.79	0.78	0.77	0.82	0.78
Energy	0.78	0.77	0.69	0.75	0.79	0.82	0.79	0.76	0.61	0.56	0.81	0.80	0.70	0.85	0.77	0.83	0.76
Construction	0.82	0.78	0.86	0.76	0.78	0.80	0.84	0.73	0.76	0.76	0.80	0.77	0.75	0.71	0.77	0.76	0.78
Wholes. Retail	0.78	0.80	0.79	0.84	0.85	0.78	0.82	0.79	0.69	0.80	0.72	0.72	0.83	0.77	0.73	0.76	0.78
Hotels	0.76	0.69	0.68	0.75	0.74	0.76	0.58	0.70	0.67	0.51	0.65	0.56	0.76	0.48	0.59	0.72	0.66
Financial Interm.	0.77	0.76	0.83	0.75	0.84	0.82	0.81	0.76	0.79	0.83	0.74	0.82	0.80	0.79	0.75	0.70	0.78
Other Services	0.74	0.77	0.83	0.78	0.80	0.80	0.71	0.75	0.85	0.79	0.78	0.75	0.79	0.77	0.66	0.78	0.77
AVERAGE	0.77	0.77	0.76	0.78	0.77	0.77	0.77	0.77	0.76	0.75	0.77	0.76	0.77	0.76	0.75	0.77	

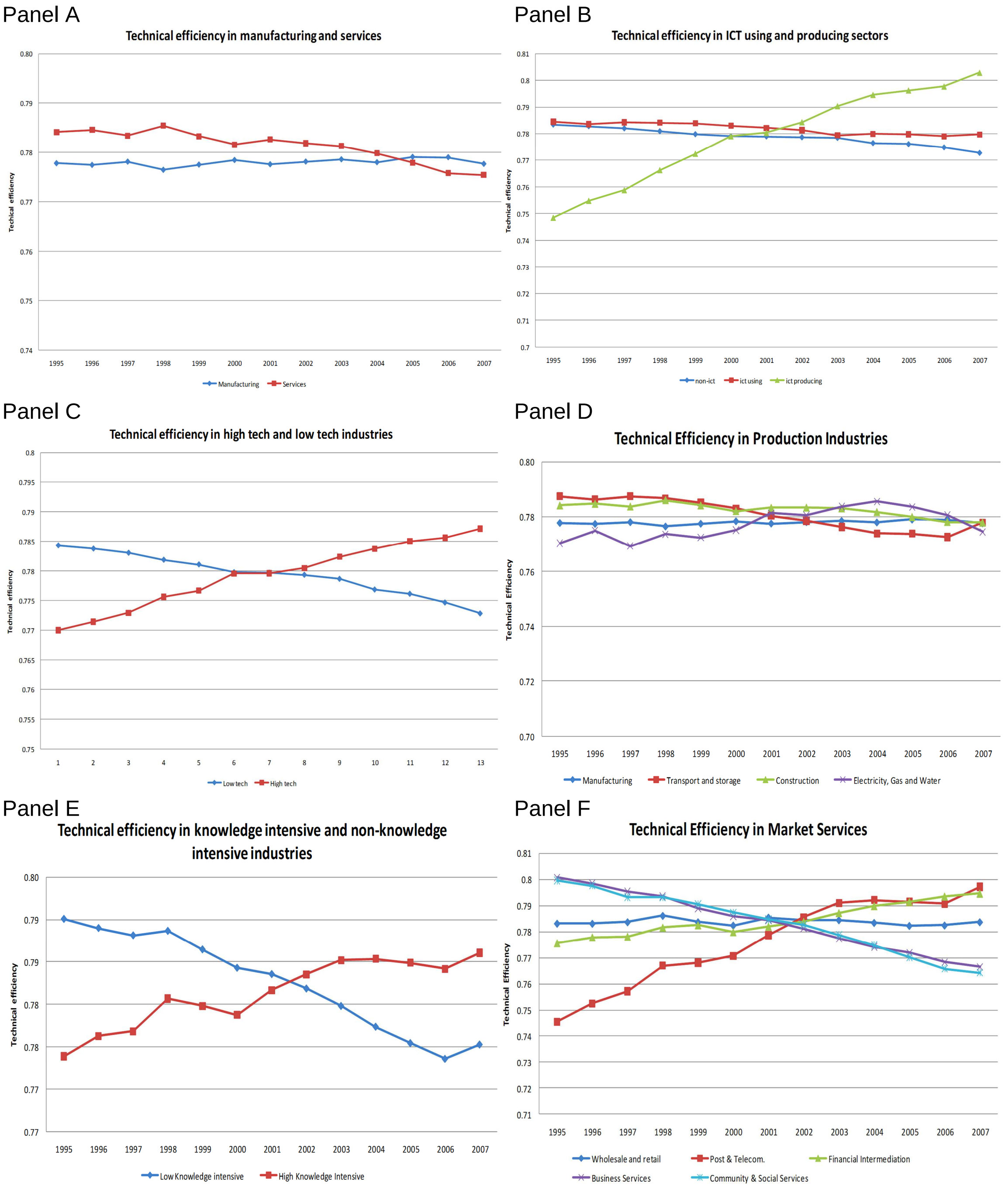
The analysis of average TE in selected groups of industries provides insights into the best performing sectors. Figure 4.3, panel A to F, presents mean efficiency trends for industry groupings comparable to those used in the analysis of average total factor productivity (Figure 1.18 - 1.19)[43]. Panel A compares TE in manufacturing and in services, showing that services have experienced a declining efficiency performance over time, while the manufacturing sector has remained fairly stable over the years. This trend is consistent with those presented in Figure 1.16 in Section 1.3 which shows that TFP growth in the EU-8 group of countries was quite flat in the pre-crisis period, while showing a negative trend in 2008-2009. Panels B and C reveal that the most innovative sectors, ICT producing and high tech industries, have also been the most dynamic in terms of TE and this result suggests that increases in productivity have gone hand in hand with increases in efficiency until 2007. In particular, the efficiency in the ICT producing sector has increased by 5%, from 0.75 in 1995 to 0.80 in 2007. On the other hand, the non-ICT and the ICT using industries have experienced a slight decline in efficiency levels. Increases in TE in the group of high-tech industries have been more modest (approximately 2%).

Figure 4.3 panel D compares performance in production and service industries showing, consistently with Figure 4.1, the steady performance of the manufacturing sector. The Construction industry has experienced a constant TE level, with a slight decline in recent years. Transport and Storage shows a declining TE trend for most of the period, with an improvement only in 2007. For Transport and Storage, there are some important differences between TFP and TE trends. Indeed, Figure 1.20 showed an increase in TFP growth up to 2007 while the TE figures reveal some more variations, with a decrease in efficiency levels from 1998 to 2005, and quite a sharp increase in the two years preceding the financial crisis. Electricity, Gas and Water is the most volatile sector in terms of TE. This clearly reflects changes in the world quotations of raw materials.

The last two panels, E and F, focus on the service sector. While the overall TE performance of the service sector has been declining over time, high knowledge intensive services have performance relatively well, with increasing efficiency throughout the period. This suggests that overall decline of service efficiency has been driven by the low knowledge intensive industries. Among market services (panel F), significant improvements in efficiency can be found for Financial Intermediation and in Post and Telecommunication. These trends match those underlined in the analysis of TFP growth in Section 1.3. On the other hand, in the Wholesale and Retail industry there is divergence between productivity and efficiency. Productivity is generally increasing (Figure 1.20) while efficiency has generally remained unchanged over the period.

43 A comparison across the two parts of the report must be done with some caution as Figures 1.18-1.19 are based on 8 EU countries, while figures in this section are based on an average across 14 EU countries, the US and Japan.

Figure 4.3 / Technical efficiency by industry groups[44]



44 ICT Producing Industries: Electrical and Optical Equipment (30t33), Post and Telecommunications (64). ICT Using Industries: Pulp, Paper, Paper Products, Printing and Publishing (21t22), Manufacturing NEC and Recycling (36t27), Wholesale and Retail (50t52), Financial Intermediation (45), Renting of Machinery and Equipment and other Business Activities (71t74). High Tech industries: Chemicals and Chemical Products (24), Machinery NEC (29), Electrical and Optical Equipment (30t33), Transport Equipment (34t35), Post and Telecommunications (64), Renting of Machinery and Equipment and other Business Activities (71t74). Knowledge Intensive Industries: Post and Telecommunications (64), Financial Intermediation (45) Renting of Machinery and Equipment and other Business Activities (71t74). Non-Knowledge Intensive Services: Wholesale and Retail (50-52), Transport and Storage (60t63), Other Community, Social and Personal Services (90t93).

4.3. REDUCING EFFICIENCY GAPS: DISCUSSION OF THE MAIN DETERMINANTS

The estimation of a stochastic production frontier provides a benchmark against which to estimate technical efficiency. However, to better understand why industries vary in the extent to which they use resources effectively, and what policies might be more suitable to foster efficiency performance, it is necessary to extend the frontier analysis and account for the factors that might cause industries to fall below the frontier, i.e. that might increase efficiency gaps. As anticipated in the introduction, this study focuses on the role played by ICT capital and the business environment where industries operate. The analysis uses a wide set of indicators that will be summarily described below according to their original range of variation; in the econometric analysis, all indicators have been rescaled so that they all vary between 0 and 1, with larger values indicating more stringent regulation.

As discussed earlier, the main reason for the inclusion of ICT derives from the substantial firm-level evidence suggesting the important role of ICT in improving the organisation of production and transaction across firms (Engelstätter, 2013). However, analyses at the industry level, which have sought to find a relationship between ICT and TFP, do not provide clear-cut results supporting the hypothesis that ICT generates excess returns and that it can be considered as a GPT (Stiroh, 2002; Basu et al., 2003; Basu and Fernald, 2007; Acharya and Basu, 2010). This study addresses such issues reporting new evidence on the relationship between ICT and technical efficiency.

Accounting for the impact of the business environment on efficiency requires considering a wide range of indicators that measure the regulatory setting of the market. This study uses industry and country level indicators that account for the impact of the product market regulation, employment legislation, intellectual property right regulations, financial development, financial liberalisation and restrictiveness of FDI inflows.

The impact of the **competitive environment** is accounted for by using the following indicators:

› Upstream Regulation Index (RI): this index is extracted from the OECD Product Market Regulation dataset 2011 (see Conway et al., 2006 for details) and provides information at the industry level. This indicator assesses the impact of anti-competitive legislation in the tertiary sector, namely energy transport and communications, and the retail and the professional services industries, on the performance of downstream sectors that use services as production inputs (see Box 3);

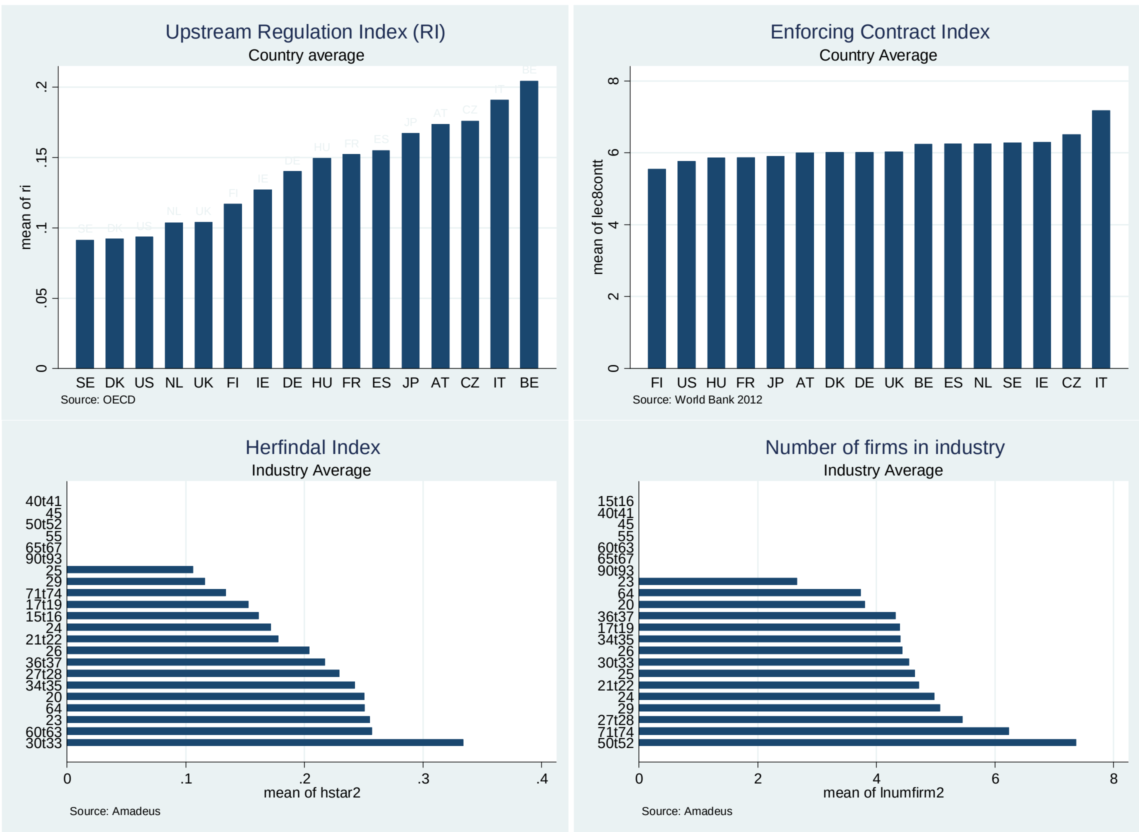
› Enforcing Contract Time (ECT): this index, developed by the World Bank Doing Business Report (2012), is based on the number of days needed to enforce a contract in each country and made available via the CANA dataset. High values indicate that more days (expressed in logarithms) are needed.

› Herfindal index (H): this measure the degree of competition between firms in an industry. It has been constructed using the Amadeus database and made available via the EUKLEMS dataset;

› Number of firms in the industry (Firms): this is a proxy for the impact of industry fragmentation on inefficiency gaps. A higher value means that the industry is more fragmented.

The RI index is our main measure of competitiveness as it has several advantages compared to traditional measures, such as the Herfindal index and industry fragmentation[45]. These advantages include the reduction of endogeneity problems and the direct link of the indicator with policy regulation (Bourlés et al., 2012). Additionally, the Herfindal index and the industry fragmentation index are not available for the US and Japan and for several industries in the service sector, hence they are mainly used to perform robustness checks. Figure 4.4 shows the variation of RI and ECT across countries, with higher values denoting more stringent regulations. SE, DK and the US have the most competitive environment measured by the regulatory impact indicator, while CZ, Italy and Belgium are the least competitive ones. Italy is also characterised by the highest ECT indicator, followed by CZ. The US is also among the three countries with the lowest ECT, together with Finland and Hungary. Figure 4.4 also shows the industry average of the Herfindal and the fragmentation index. Electrical and optical equipment (30t33) has the highest market power, followed by Transport and Storage (60t63) and Coke, Refined Petroleum and Nuclear Fuel (23). The latter is also characterised by the lowest degree of fragmentation, which is expected given the nature of the industry.

Figure 4.4 / Indicators of the competitive environment



[45] Schiantarelli (2010) discusses this issue in details.

The impact of **labour market regulation** on efficiency gap is captured by a set of well known indicators:

› EPL regular workers (EPL_r) and EPL temporary workers (EPL_t): these are the OECD employment regulation indices for regular and temporary workers, discussed in Venn (2009). From the same source, the analysis also considers the index of EPL for collective dismissal (EPL_c).

› Employment protection legislation (EPL burden indicator): this indicator follows the methodology proposed in Bassanini et al. (2009). This industry-level indicator is based on the notion that economy-wide level EPL, although it applies uniformly to all industries within a country, is more likely to be more binding in some industries than in others. That is, it is assumed that EPL is more harmful in those industries that rely on lay-offs than in those industries characterised by a higher degree of voluntary turnover. This indicator is the result of the product between the index of employment protection, which ranges between 0 and 6, and an indicator of lay-off propensity, which takes a maximum value of 8.

› National Minimum Wage (NMW): this variable is constructed as an index number ranging between zero (no National Minimum Wage) and 8 (National Minimum Wage set by Government without fixed rule). The availability of this variable is limited to those countries where the NMW is prescribed by law (Visser, 2011). These include the US, Japan and several EU countries. Considering the role of minimum wage is particularly interesting in the light of the political and economic debate, especially in the US, concerning the effects of this legislative intervention on employment outcomes and school enrolment (Neumark and Wascher, 1995; Card and Krueger, 1995; Neumark and Wascher, 2008).

Figure 4.5 / Indicators of labour market institutions

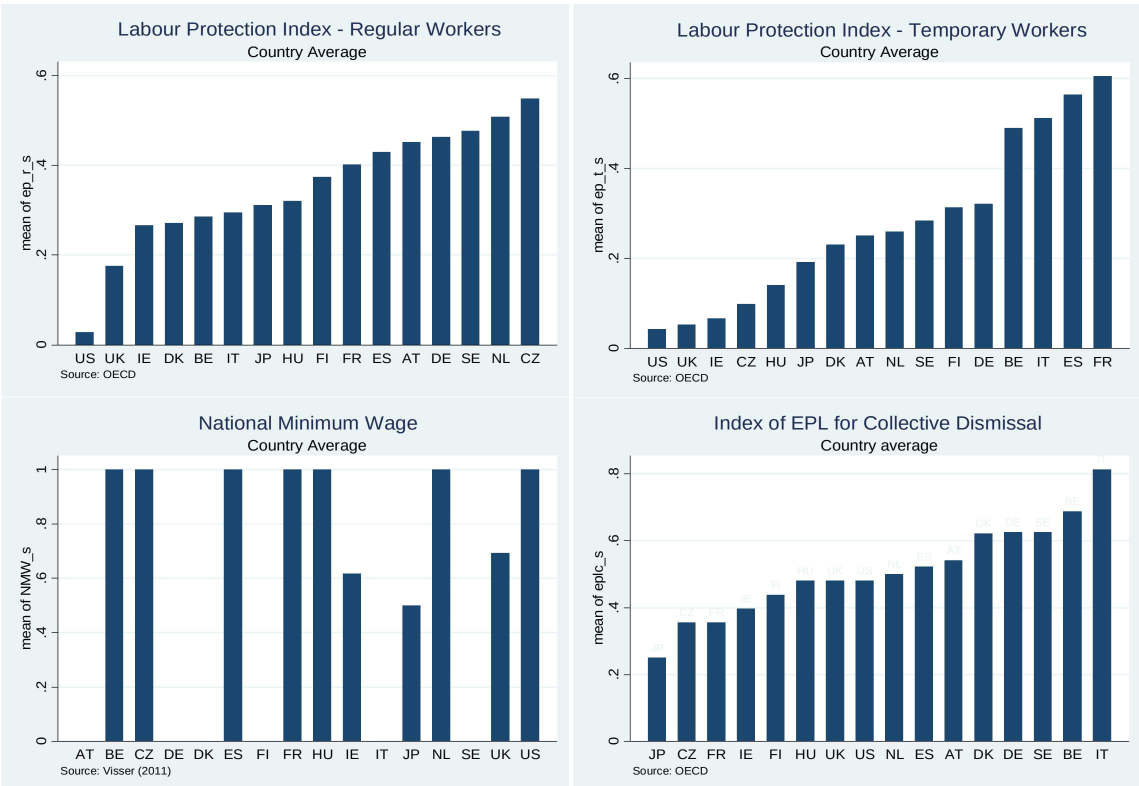


Figure 4.5 shows the country average for each indicator and the industry average for the EPL burden indicator. Overall, labour protection is more binding in continental Europe and in Japan, while it is particularly low in the US and UK. The US is the country with lower levels of EPL, both for regular and for temporary workers, testifying the high flexibility of the US labour market, recently discussed by Gordon (2011). The UK follows next, although protective measures towards regular workers are much stronger than in the US.

The impact of the **financial market development/regulation** are shown in Figure 4.6 and they include the following indicators:

- Financial reform index: this index, developed in Abiad et al. (2008), is constructed by combining liberalisation scores on seven different areas of the financial market (credit controls and reserve requirements, interest rate controls, entry barriers, state ownership, policies on securities markets, banking regulations and restrictions on capital accounts). The indicator also accounts for the different effort put by countries in reducing financial regulation and facilitating the access to the financial markets over the last two decades.

- Financial freedom: this is developed by the Heritage Foundation. It is intended to measure banking efficiency and the degree of independence from government control and interference in the financial sector. This indicator is described extensively in the Appendix.

- Private Bond Market Capitalisation over GDP (PBMC/GDP). The higher the ratios, the larger the external funds made available to the economy (Figure 4.6).

Figure 4.6 / Indicators of financial development and patent protection

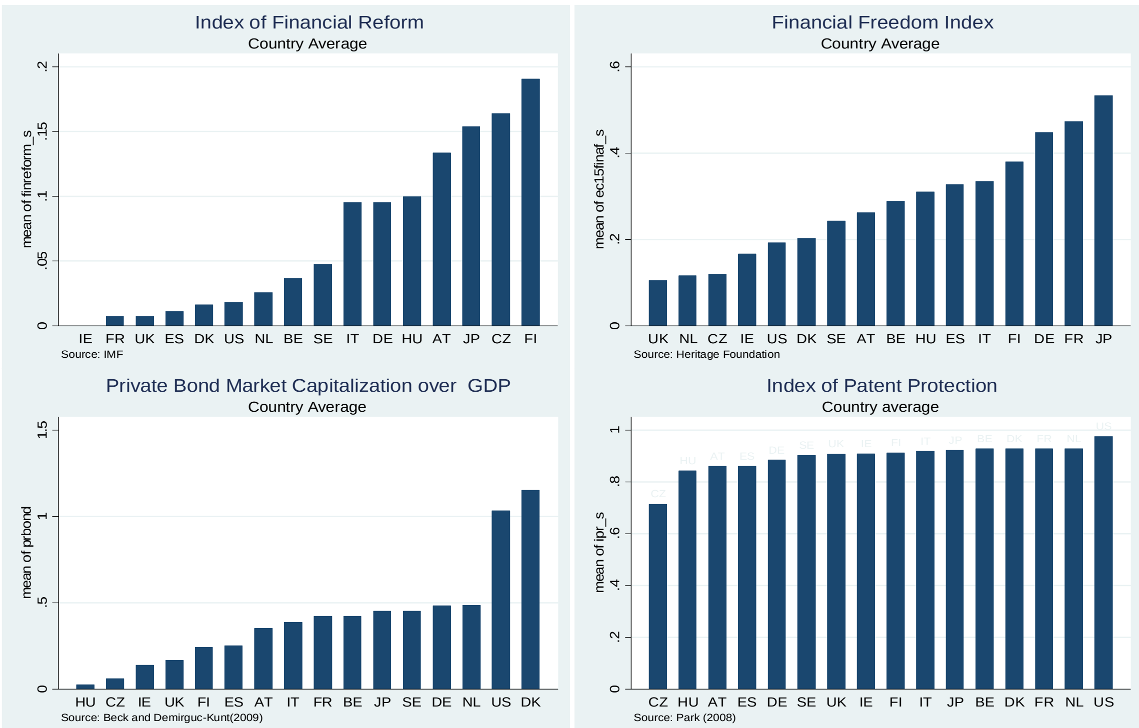
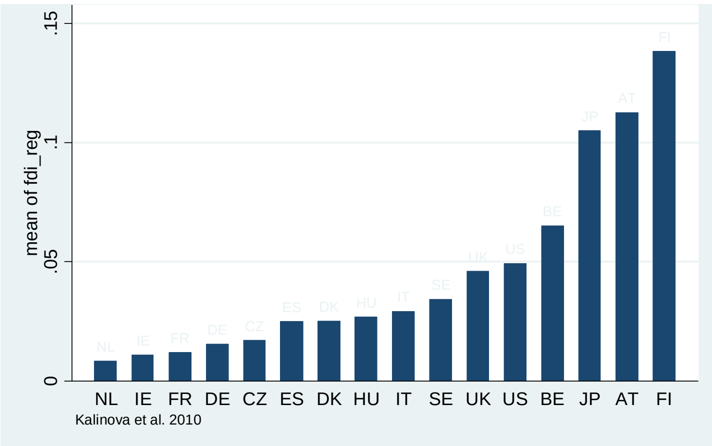


Figure 4.6 also displays the average value of the index of **Intellectual Property Rights protection** (Park, 2008). This reflects the assessment of national patent systems on the extent of the legal coverage of technological fields, the membership in international patent agreements, the duration of protection, enforcement mechanisms, and restrictions to patent rights. Therefore, higher scores mean a wider legal protection for innovation. As shown by the graph, patent protection is weaker in Austria and Spain, and stronger in the US. However, cross-country differences do not appear particularly large, suggesting that policies pursued to enforce intellectual property rights have been quite similar in Europe, US and Japan in the last two decades.

Figure 4.7 shows the FDI regulation index, which is included in the analysis to assess the impact of trade openness on the efficiency gap. This indicator, described in details in Kalinova et al. (2010), measures the extent of regulation concerning foreign direct investment, summarising information on four forms of legal intervention (equity restrictions, screening and approval requirements, restrictions on foreign key personnel, and other operational restrictions, such as limits on purchase of land or on repatriation of profits and capital). Equity restrictions limit the possibility for foreign companies or individuals to purchase property share of national firms. Screening regards the possibility that foreign property above a certain value, or a percentage of total equity, has to be approved by national authorities. Limitations to employment of foreigners may regard the entire workforce or some leading position, such as the board of directors; foreign employees may also be admitted with some time bound. The residual category to FDI impediments includes reciprocity requirement among countries, restrictions on profit/capital repatriation or on access to local finance, or limits to the acquisition or leasing of land for business purposes. The indicator ranges from zero to one, with higher values capturing higher levels of restrictiveness.

Figure 4.7 shows higher regulation in Finland, followed by Austria, Japan, Belgium and the US. Although the figure suggests quite a wide cross-country variation in FDI regulation, the size of the indicator is fairly small, ranging from 0.01 (the Netherlands) to 0.14 (Finland). This shows that FDI regulation is not particularly high in any of the countries considered in the present analysis.

Figure 4.7 / Regulation of FDI Country average



4.4. REDUCING THE EFFICIENCY GAP: MODEL SPECIFICATION AND RESULTS

The analysis of the impact of ICT capital and the regulatory system on technical efficiency is obtained by the empirical estimation of the following relationship:

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

The time variable is a simple time trend that captures how the efficiency gap is influenced by exogenous technological changes[46]. The inclusion of a large number of indicators naturally causes collinerarity 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 deal with this issue, the estimation will sequentially include different indicators, controlling for the presence of ICT and the competitiveness environment in all specifications[47]. The decision to include these two factors, in conjunction with other indicators, is also 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).[48]

Tables 4.3 and 4.4 present the sign of the impact for each of the factors affecting technical efficiency, and the related statistical significance. The full set of estimates is presented in Appendix Tables A.12 - A.14. It should be remarked that when an explanatory variable has a negative effect it means that it is contributing to reduce the efficiency gap. The reverse holds for a positive effect. Table 4.3 presents a summary of the results based on the indicators of product market regulation discussed above, next to ICT capital. The latter is negative and statistically significant in all specifications, indicating that this asset plays a very important role in decreasing 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 (Stiroh, 2002; Basu et al., 2003; Acharya and Basu, 2010). This implies that distinguishing between TFP and TE can provide important insights on the role of ICT. Although ICT does not appear to have significant excess returns in terms of productivity, its role on improving efficiency is substantial. Up to now, this issue has been unexplored by the economic literature.

Consistently with the existing evidence on the negative relationship between lack of competitiveness and productivity (see, among others, Buccirossi et al., 2012; Conway et al., 2006), higher values of the upstream regulation index significantly increase the efficiency gap. Given that larger values of RI are associated with more stringent product market regulations, this result indicates that administrative restrictions to competition in the service market have widespread negative effects on production efficiency. 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

[46] The estimation of the efficiency gap is carried out simultaneously with the estimation of the productivity frontier, using the Maximum Likelihood method. The one-step procedure used guarantees consistency in the coefficient estimates. The full set of results is presented in Appendix tables A.12 – A.14.

[47] The authors also tried to include intangible assets (R&D and labour quality) as determinants of both productivity and efficiency. However, results were highly unstable, hence intangibles were only included in the specification of the frontier production function (see Table 4.1).

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

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 4.3 provide strong support for the hypothesis that a more competitive business environment reduces the efficiency gap.

Table 4.3 / Reducing the efficiency gap: the role of product market competition

	(1)	(2)	(3)	(4)
ICT capital	Negative***	Negative***	Negative***	Negative
Upstream regulation (RI)	Positive ***	Positive***		
Enforcing contract time		Positive***		
Herfindal			Positive**	
Industry fragmentation				Negative***
Observations	3648	3648	2454	2256

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

Table 4.4 / Reducing the efficiency gap: the role of employment protection legislation

	(1)	(2)	(3)
ICT	Negative****	Negative****	Negative****
Upstream regulation (RI)	Positive***	Positive***	Positive***
EPL burden indicator	Positive***		
EPL regular		Positive***	Positive***
EPL temporary		Negative***	Negative***
EPL collective dismissal			Positive***
NMW			Positive***
Observations	3146	3648	3021

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

In line with the existing empirical evidence, results in Table 4.4 show that more stringent EPL for regular workers and collective dismissals significantly increase 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 result is not unexpected as existing evidence shows that legal discipline on regular and temporary workers can have opposite effects on performance. For example, Bassanini et al. (2009) show that employment protection of regular workers depresses productivity growth while deregulation of temporary contracts has no significant effect. Similarly, 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[49]. The novelty of this study is that of identifying the channel through which excessive deregulation of temporary workers' contracts translates into lower productivity performance, i.e. by increasing inefficiency in production. The introduction of minimum wage legislation also constraints the efficient use of the labour input by increasing the efficiency gap, through reducing

[49] This result is also consistent with those in section 3 of this study, where countries with higher employment protection for temporary workers enjoyed higher spillovers from foreign R&D stocks.

competitiveness in the labour market, a claim that is frequently used by those scholars that are against the introduction of the minimum wage (Currie and Fallick, 1996)[50].

Table 4.5 presents estimates of the effect of financial market indicators, property right protection and regulation of FDI on the efficiency gap. Both the Financial Reform and the Financial Freedom indicators consistently show that increasing regulation /decrease in freedom reduces the efficiency gap. This appears, at first look, to contradict the existing evidence on the positive relationship between financial development and growth (Rajan and Zingales, 1998; Levine, 2005). However, the financial crisis has drawn increasing attention to the dangers of a highly developed financial system. In a study on the role of risk capital in knowledge production, Ang and Madsen (2012) show that, despite the availability of external funds being a key factor for growth, the way to raise funding may have a controversial effect on competitiveness, even in the long run. Additionally, financial market reforms and financial liberalisation may induce lower innovation and growth when they have been implemented too rapidly. Ang (2011) argues that this may occur through discouraging savings, triggering financial instability and reallocating talents from the technology sector to the financial sector. The recent financial crisis has shown that excessive freedom in the financial market can have catastrophic consequences. Therefore it is not surprising to find that excessive freedom increases, rather than decreasing, the efficiency gap. On the other hand, access to alternative sources of finance, like the bond market, significantly reduces the efficiency gap. This is consistent with the findings provided by Maskus et al. (2012).

Table 4.5 / Reducing the efficiency gap: financial market regulation, property right protection and openness

	(1)	**(2)**	**(3)**	**(4)**
ICT capital	Negative***	Negative***	Negative***	Negative***
Upstream Regulation (RI)	Positive***	Positive***	Positive***	Positive***
Financial Reform Index	Negative	Negative***		
Private Bond Mkt Cap/GDP		Negative***	Negative***	Negative***
Financial Freedom			Negative***	Negative***
IPR				Negative
Regulation of FDI				Negative*
Observations	3648	3648	3648	3648

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

Table 4.5 also presents the effect of the index of intellectual property regulation which suggests that increasing protection reduces the efficiency gap. This support recent evidence in Ang and Madsen (2012), where stronger patent protection decreases innovative production. However, this effect is not statistically significant, implying that property right regulations are not too relevant for efficiency improvements. The measure of openness to external markets, summarised by the FDI regulation index, shows that stricter FDI rules decreases the efficiency gap. Although this outcome 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 this study. Firstly, Figure 4.7 shows that the overall restrictiveness of FDI is very low. It is worth reminding the reader that this indicator ranges

50 In the basic textbook model of labour demand, in which a downward sloping demand for labour curve represents the desired employment levels of numerous wage taking firms, 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).

between 0 (there are no regulatory impediments to FDI in the sector) and 1 (foreign investment in the sector is fully restricted). The highest score is observed in Finland where the indicator has a value of 0.15. This means that in the countries considered in the present study regulations constraining international trade are neither very stringent nor heterogeneous, 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 trade openness on growth differs from the impact of trade openness on technical efficiency, similarly to the relationship between productivity and ICT discussed above. 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 increasing globalisation. Hence, it is possible that an increasing openness to the international markets may lead to higher levels of production efficiency only 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.

4.7 SUMMARY

The analysis in this section has presented results on the factors affecting productivity at the frontier and the level of technical efficiency, identifying the drivers of efficiency gap among the EU industries relative to their counterparts in the US and Japan. The estimation of the production function has confirmed the positive and significant role of intangible factor inputs (R&D and labour quality) on productivity performance, yielding coefficient estimates that are consistent with the existing literature. Trends in technical efficiency provide an evaluation of industry and country performance based on the best use of resources, i.e. it indicates which industry/country can produce the most output with the given set of inputs. This has revealed the presence of heterogeneity within the EU. In particular, the most innovative sectors, both in manufacturing and in services, have experienced increases in efficiency over time, although efficiency gains in manufacturing have been larger than in services. In the light of these results, policies promoting investments in innovative assets are extremely important for increasing both productivity and efficiency levels.

Averaging TE scores across the main economic areas shows that, from 2002 onwards, there has been an increasing efficiency gap between the US and other major countries. The gap between the US and Europe narrowed between 2005 and 2007, mainly because of a reduction in US efficiency levels in the two year preceding the financial crisis. Japan, on the other hand, keeps on a downward sloping trend which started in 1996 and carried on until 2006, with no evidence of catching up with the US. Results also show that the increase in efficiency in the US follows the increase in productivity with a lag. Given that ICT is considered one of the main factors behind the US productivity acceleration in the mid-1990s, it is possible that it has also determined the increase in efficiency, albeit with a lag. One possible interpretation is that changes in technical efficiency typically take longer to manifest because they require changes in the structure of production. This interpretation is consistent with studies supporting the GPT nature of ICT.

The role of ICT in reducing inefficiencies is tested in the second part of the analysis, which focuses on the determinants of the efficiency gap. Next to ICT, whose positive effect is highly significant in all specifications, this study considers a set of institutional variables that aim to assess the role of different type of regulations on efficiency. The results are clear and often support those on the impact of regulations on productivity, i.e. more stringent regulations in the product and labour markets have a detrimental effect on efficiency. More complex is the relationship between financial development and technical efficiency. In this study, excessive financial liberalisation is associated with a larger efficiency gap. Similarly, trade regulation, measured by the index of restrictiveness of FDI, widens the efficiency differentials. This suggests that the link between trade openness and technical efficiency is more complex that usually envisaged, especially if compared to the effect of this factor on productivity. This is an issue needs that requires further investigation. Overall, results in this study reiterate the importance of ICT in achieving higher efficiency levels while, at the same time, support policies aimed at increasing the competitiveness of the product markets and adopting selected measures for the flexibility on the labour market.

5. EU firm performance at the outset of the financial crisis: evidence from EU EFIGE survey on manufacturing

The financial crisis of 2008-09 was a watershed for the European Union as it widened growth disparities among the Member States. If, for some countries, recent difficulties can be explained with the sovereign debt crisis and the risk of default, weak competitiveness before the crisis played a non-negligible role in the sluggish growth performance of 2008-2009. The EU Member States experienced low rates of GDP growth through the 2000s and this undermined the credibility of public debt sustainability with the arrival of the downturn.

While the previous sections of the report looked at the main productivity trends at the country and industry level, this section focuses on the firm and on how the financial crisis has affected performance and innovation strategies at the micro level. The main objective is to analyse the most recent productivity trends and unveil possible heterogeneity that remains masked when using industry-level data. This section relies upon a newly available dataset that collects information on a sample of manufacturing firms for seven EU countries (Austria, France, Germany, Hungary, Italy, Spain, UK) for the period 2007-2009. Details on the EU-EFIGE can be found in Altomonte and Aquilante (2012). For the purpose of this study, firms are primarily grouped by country and by size (small, medium and large). Confidentiality issues prevent the use of detailed industry information, hence the analysis will follow the Pavitt (1984) taxonomy to control for major industry characteristics (see Box 8 in the Appendix).

There is an increasing body of studies assessing how firms reacted to the financial turmoil and to the spreading of the recession world-wide. Overall, the main response was the adjustment of the labour force, either quantitatively or in terms of skill composition. Due to the financial nature of the downturn, the extent of the employment adjustment was heavily influenced by the credit crunch and the nature of the bank-firm relationship, particularly in SMEs, as they are more subject to asymmetric information issues (Chodorow-Reich, 2013). Cross-country differences were mainly determined by the different institutional settings and the set of rules governing the markets. Albeit scarcely explored, corporate governance was another important factor driving differentials in firm performance during the recession. For example, Allen et al. (2012) compare company behaviour at the earlier stages of the crisis in the US, UK, Germany and Japan. They find that US firms resorted to input adjustments, reduction of debt and dividend payout, as well as increase in cash holdings, more than companies in the other countries. These differences are, in general, explained by differences in financial leverage. For example, Clark et al. (2012) show that East European firms accessing external finance to fund investment were more likely to survive in the aftermath of the crisis. Levine and Warusawitharana (2013) investigate the debt-TFP growth nexus in a sample of EU companies during the 2000s, finding that those relying more on debt were considerably more productive. Their results suggest that the observed slowdown in debt growth from 2009 to 2011 explains the lower output growth performance, which was between 0.06 and 0.35 percentage points below the long-run trend. Békés et al. (2011) show that during the crisis, European manufacturing companies reduced employment proportionally less than sales, preserving particularly the employment of highly skilled workers. The decline in sales was more pronounced in firms relying on external finance or local banks, and for those that had experienced financial constraints in the past.

The following section presents a descriptive analysis of the data set and the main trends in companies' performance during the crisis, based on a large number of indicators. These include TFP growth, firm turnover and investments in physical assets, as well as firms' decisions to invest in intangibles (product/process innovation, R&D, patents). Next, this section will present a multivariate regression analysis of TFP growth and its determinants during the crisis, accounting for a large array of firms' characteristics.

5.1 EFIGE SURVEY AND SAMPLE COMPOSITION

The EFIGE dataset includes data on 14,759 manufacturing firms across seven EU countries: Austria (443 firms), France (2,973), Germany (2,935), Hungary (488), Italy (3,021), Spain (2,832), UK (2,067). The sample was originally designed to be representative of the manufacturing sector of these EU countries 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).

This data set is unique in its provision of detailed information on companies' competitiveness and their response to the financial crisis. It has however some limitations due to issues of representativeness of the sample. The sample composition by firm size is reported in Table 5.1. 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). In Austria and Hungary the total number of firms is noticeably smaller compared to the other countries; hence, results should be interpreted with caution, especially when grouping firms by country and industry categories.[51] Italy and Spain stand out for the largest share of small firms (over 80%), Germany for the medium and large classes of companies (27% and 10% of the total).

Table 5.1 / Sample composition by firm size

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total	No. firms
Small	67.7	72.4	62.6	66.6	81.0	80.5	69.7	73.0	10,779
Medium	21.9	20.5	27.0	24.2	14.2	14.3	25.1	20.1	2,970
Large	10.4	7.2	10.4	9.2	4.8	5.2	5.2	6.8	1,010
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	14,759
No. firms	443	2,973	2,935	488	3,021	2,832	2,067	14,759	

Source: EFIGE dataset

Table 5.2 shows the sample composition along the country and industry dimension. The different degrees of specialisation are assessed using the sectoral taxonomy proposed by Pavitt (1984). This

[51] It should also be noted that the EFIGE survey does not include data on firms exiting the market. Also, this dataset provides information in cross-sectional dimension and does not include the most recent trends in firm-level performance.

well-known classification groups industries on the basis of the nature of their innovation activities and inter-industry flows of knowledge. It distinguishes four groups of sectors (or firms): 1) Economies of scale producers (or scale intensive); 2) High-tech producers (or science-based); 3) Specialised producers (or specialised suppliers); Traditional producers (or supplier dominated). A brief description on the criteria followed and the industry groupings of the Pavitt taxonomy can be found in Box 8.

Table 5.2 shows that traditional sectors are dominant in the overall sample (50% of the firms), followed by scale intensive industries and specialised suppliers (26.5 and 18.9%). The share of high-tech companies is considerably smaller (4.6%) compared to the other industry groups. There is large heterogeneity across countries in the share of each type of industry. For example, traditional firms account for approximately 60% of the total sample in Spain, while they represent approximately 42% of the manufacturing sector in Austria. Economies of scales firms are pivotal in the UK (35%), while specialised suppliers are more relevant in Germany (25%). The share of high-tech firms is considerably higher in Germany and Austria where they account for almost 7% of the sample. This differs substantially from Hungary, Italy and Spain where the same type of firms accounts for just over 3% of the total.

Table 5.2 / Sample composition by Pavitt groups

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Economies of scale ind.	31.4	27.9	24.2	27.7	25.7	21.1	35.1	26.5
High-tech industries	6.9	4.4	6.9	3.1	3.5	3.5	4.9	4.6
Specialised suppliers	19.8	17.5	25.9	22.1	17.8	15.9	16.0	18.9
Traditional industries	41.9	50.3	43.0	47.1	53.1	59.6	44.1	50.0
Total	100	100	100	100	100	100	100	100

Source: EFIGE dataset

5.2 OVERVIEW OF PRODUCTIVITY PERFORMANCE BEFORE AND AFTER THE FINANCIAL CRISIS

Taken as a whole, the EU grew at moderate rates during the 2000s. Despite some common trends, there were large disparities across industries in the rate of expansion. As described in the previous section of this study, the growth performance not only differed between the Old and New Member States, but also within each of these groups. This pattern has been reinforced by the recent crisis, with some countries (so-called PIIGS[52]) struggling as a result of the fiscal compact policies pursued to consolidate public budgets, whilst others such as Germany, rebounding as a result of the good export performance (OECD, 2011).

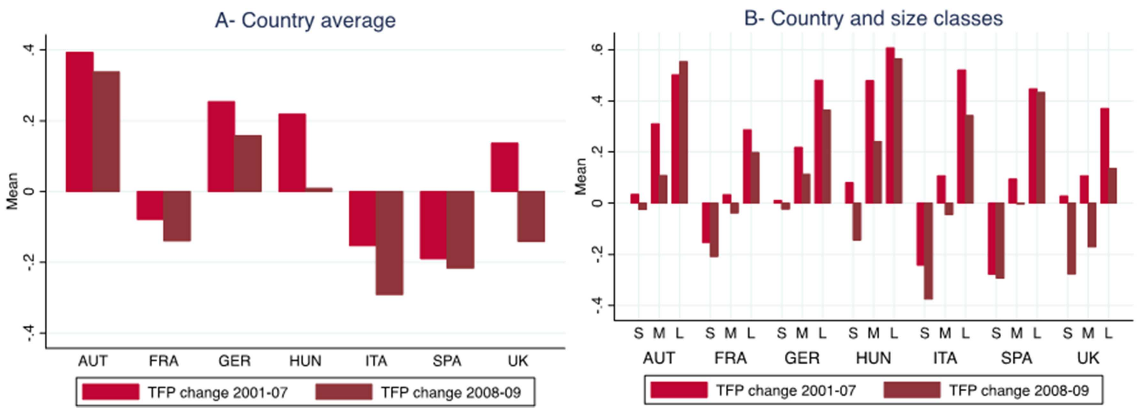
Figure 5.1 (panel A) describes TFP changes between 2008 and 2009 compared to the average annual rate of growth in the pre-crisis period (i.e. 2001-07). It is important to remark that the average rate of TFP growth was negative in the early 2000s, i.e. before the crisis, in France, Italy and Spain. With 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 more dramatic between the two sub-periods, falling from a positive rate of 6.5% to -15%. In absolute values, Italian firms registered the

52 Portugal, Ireland, Italy, Greece and Spain.

worst rates of TFP change in the downturn (-29%). This confirms the structural weakness of the manufacturing sector in this country, which lost competitiveness with respect to its major EU counterparts since the mid-1990s (Sterlacchini and Venturini, 2011a). A comparison of the productivity performance of Italy and Spain can be found in Mas et al. (2008) and Sterlacchini and Venturini (2011b).

Figure 5.1 (panel B) also outlines the extent of growth differences according to firms' size, highlighting three main facts. Firstly, large and medium sized firms experienced higher rates of TFP growth before and during the crisis. Secondly, productivity growth was positive for large companies even during the crisis; the gains were substantial and of comparable magnitude in all countries (except in France and the UK). Thirdly, small firms struggled throughout the EU in the 2000s and, in the case of France, Italy and Spain, they exhibited negative rates even before the crisis. As it will be discussed at more length below, the negative performance during the financial crisis was strongly related to such structural problems, along with the crisis itself (see also EC, 2012).

Figure 5.1 / TFP growth 2001-07 and 2008-09 (by country and size class)



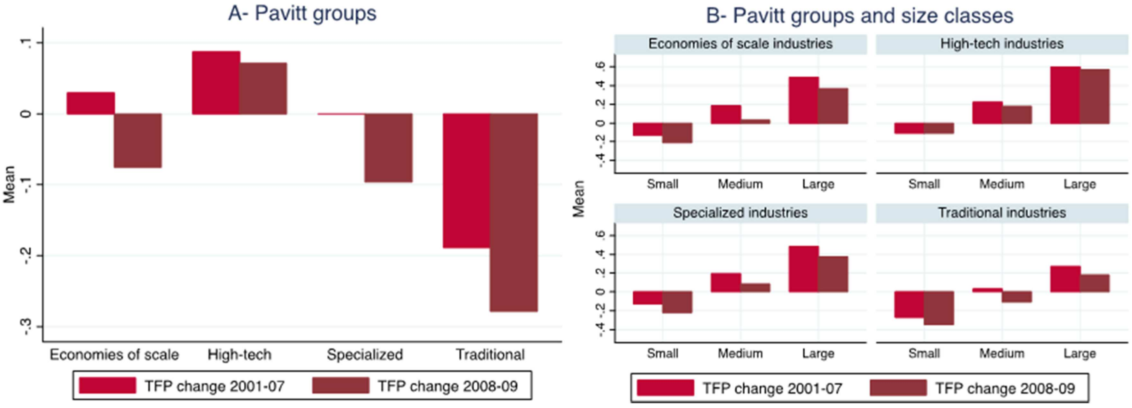
Notes: S=small firms. M=medium firms. L=large firms
Source: EFIGE dataset

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. Consistently, in the latter period, TFP growth rates were considerably higher for those firms with higher productivity levels at the beginning of the crisis. These findings hold irrespective of the country, the size and the nature of the economic activity of the firm. See Figures A.7-A.9 in the Appendix.

Panel A in Figure 5.2 provides an industry breakdown of TFP performance. Before the crisis, high-tech firms and scale intensive firms experienced important increases in productivity, while TFP growth was flat for specialised firms and extensively negative for companies manufacturing traditional goods. The collapse of the market in 2008-09 severely hit traditional industries, which experienced a fall in TFP levels by almost 30%. The rate of productivity growth was also negative for the economies of scale and specialised producers' groups. On the contrary, high-tech firms improved their productivity levels during the downturn, albeit at a slightly lower rate than in the first part of the decade.

Panel B of the same figure provides a more detailed picture by focusing on the type of firms that suffered the most within each industry group. The negative productivity dynamics described above for small-sized companies appears rather pervasive as it involves all industry groupings considered. Large companies outperformed other types of firms in all productions. After a period of moderately positive rates of TFP growth, medium-sized firms faced a severe drop during the crisis. A relevant exception is in the science-based firms whose productivity growth was positive although slightly downsized during the crisis with respect to the early 2000s.

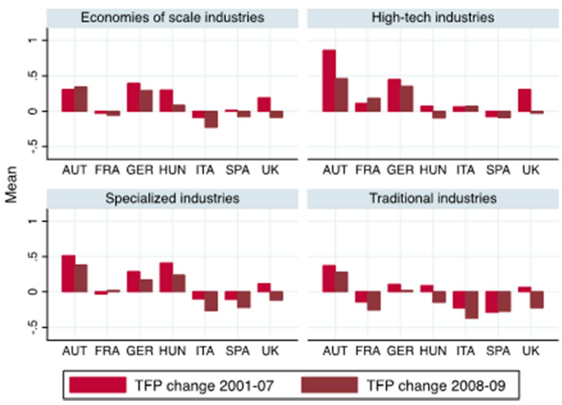
Figure 5.2 / TFP growth 2001-07 and 2008-09 (by Pavitt group and size class)



Source: EFIGE dataset

The inspection of productivity performance by industry group at country level (Figure 5.3) reveals that scale intensive firms suffered both before and after 2008 in France, Italy and Spain. In the latter two countries specialised suppliers and traditional producers experienced a similar productivity trend, while in high-tech companies productivity levels increased steadily between the 2001-07 and 2008-09. German and Austrian firms stand out with their positive productivity dynamics throughout the 2000s in each industry grouping.

Figure 5.3 / TFP growth, 2001-07 and 2008-09 (by Pavitt group and country)



Source: EFIGE dataset

5.3 FINANCIAL CRISIS: IMPACT ON TURNOVER

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 2008-09 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%. Table 5.3 shows that there is no difference in the proportion of the firms hurt by the crisis across size classes. In essence, the financial turmoil caused a real downturn that was very pervasive involving all types of firms.

Table 5.3 / Percentage of firms experiencing a turnover reduction in 2009 compared to 2008 (by size class)

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Small	60.3	69.6	61.6	75.4	74.3	82.2	66.7	71.5
Medium	72.2	73.4	68.9	82.2	80.0	80.8	64.7	72.9
Large	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 5.4 tracks reduction in firm turnover in the different industry groups. The category of specialised suppliers was sizably hit by the crisis as three fourths of the companies experienced a decrease in sales. From this perspective, the crisis looks more severe in Spain, Italy, and Hungary where the proportion of the firms facing a turnover reduction was higher than the EU average. Scale intensive firms were also considerably affected by the crisis; in particular, this category of companies turns out to be vulnerable in Spain where almost 90% of the total sample has reduced sales as a result of the 2008-09 crisis. On the other hand, the fall of turnover was less pervasive among high-tech firms, especially in France, Germany and UK, where sales diminished in only 50% of the sample.

Table 5.4 / 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

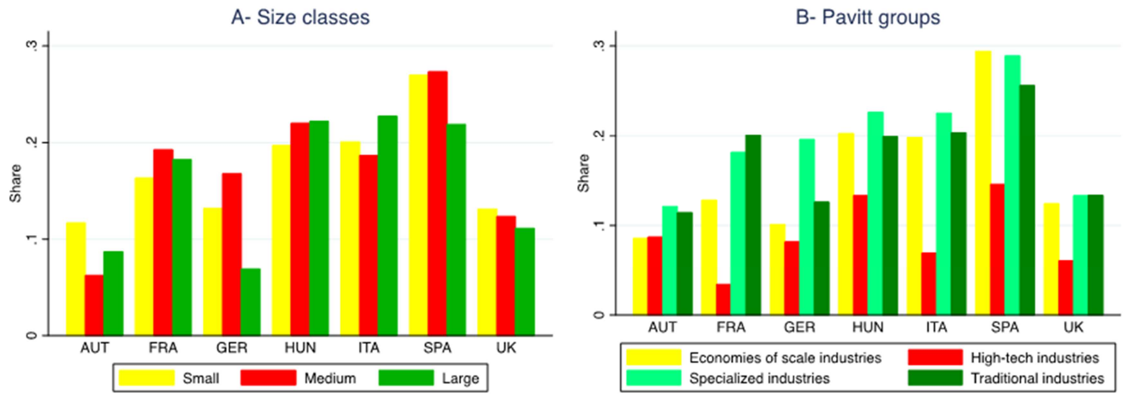
Source: EFIGE dataset

Panel A in Figure 5.4 provides a more detailed outline of the intensity of the turnover fall. For each country and size group, Panel A reports the percentage of firms with sales reduction larger than 30%. This proportion ranges from 10% in Austria and the UK to 30% in Spain. Italy is the country where large companies struggled most if compared to the different sized firms within the country and compared to the other economies in the sample. In Austria, only a modest fraction of medium-sized firms experienced a turnover reduction of 30% or more (just over 5% of the total sample). A similar performance can be found for large firms in Germany which outstripped SMEs for the capacity of sales' resistance to the crisis.

Panel B in Figure 5.4 also shows that there are important cross-sector disparities in the depth of the crisis. Indeed, when the focus of the analysis is on firms with turnover reduction of 30% or more, the downturn appears more sizeable in Spain, Italy and Hungary, where between one fifth and one third of the overall sample experienced a turnover reduction of such intensity. The only exception can be identified in high-tech firms whose performance looks similar to the EU partners. In the other countries (Austria, Germany, UK) the share of firms facing a collapse in demand accounts for 10% of the total.

The extent to which the financial turmoil translated into real macroeconomic effects mirrors how, from the microeconomic perspective, firms reacted to the fall in demand. This depends on an array of factors. In a recent work, Claessens et al. (2011) have sought to explain the real impact of the 2008-2009 crisis on the basis of the country-level linkages within the global markets, i.e. a financial channel, a domestic demand channel and a trade channel. Using a global sample of firms, they find that sales' drop was primarily driven by the degree of trade openness and by the sensitivity of domestic demand to the shock (inferred by the volatility of stock market quotations). By contrast, in the short term, no detrimental effect was found when considering the linkages with the financial market. Similar results are found by Bézék et al. (2011) for the EU firms; they show how the difference in the sales' decline between exporters and non-exporters was greatest in Austria, Germany and France.

Figure 5.4 / Firms experiencing a turnover reduction by over 30% in 2009 compared to 2008 (by country and size class)



Source: EFIGE dataset

5.4 DYNAMICS OF INVESTMENT ALONG THE DOWNTURN

Investment changes remarkably along the business cycle, reflecting firms' expectation on 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 the firm size, from 42% for small firms to 47.6% of large firms (see Table 5.5). However, there are important differences among countries, as large firms performed relatively better in Germany, Austria and, to some extent, in the UK.

Table 5.5 / Percentage of firms reducing investment in 2009 compared to 2008 (by size class)

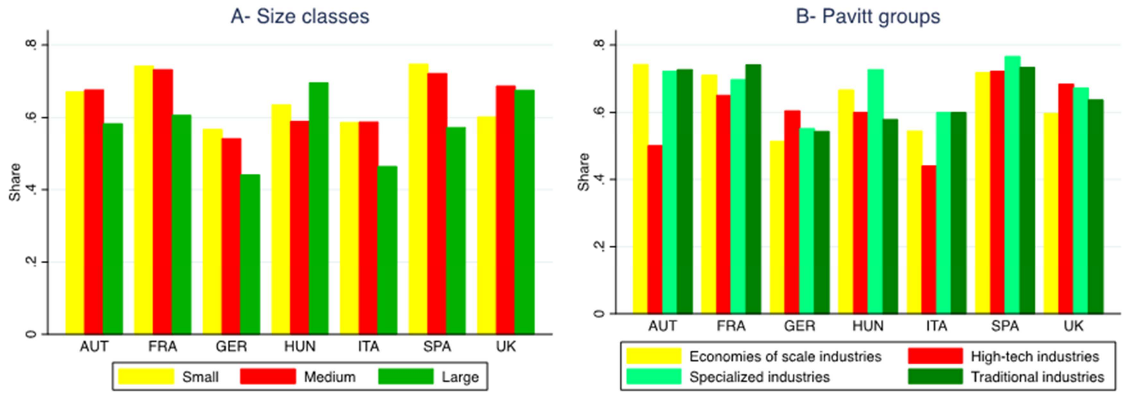
	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Small	32.3	55.1	26.8	46.4	35.8	52.0	39.5	42.0
Medium	45.5	54.9	36.0	41.5	36.0	55.5	43.2	44.2
Large	40.6	62.6	31.5	60.5	50.4	58.6	43.0	47.6
Total	35.8	55.7	29.8	46.6	36.7	52.9	40.6	42.9

Source: EFIGE dataset

The decrease of investment was quite diffuse throughout the economy in France and Spain, where between 55 and 60% of the sample reduced their engagement in such activities. 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. As mentioned above, large firms performed worse than the other categories, and this phenomenon was rather apparent in Italy. The larger sensitivity of investment in large-sized companies probably depends on a wider exposure to the international market, and therefore to the collapse of foreign demand.

When the focus is placed upon the intensity of capital formation reduction, as measured by the share of firms cutting investment plans by over 30%, cross-countries differences are narrower (Figure 5.5, panel A). This share ranges from 75% in France and Spain to about 50% in Italy and Germany. It should also be pointed out that, for large firms, this proportion is smaller than for the other size classes. Combining this with information coming from Table 5.5, it emerges that a larger number of big firms were involved by the turmoil, but they were able to limit the effect of the crisis on investment more than SMEs. Overall, the fall in investment looks clearly more pronounced than the turnover reduction, and largely more homogenous across countries and size classes.

Figure 5.5 / Firms reducing investment by over 30% in 2009 compared to 2008 (by size class and Pavitt group)



Source: EFIGE dataset

The inspection of investment dynamics along the downturn following the Pavitt groupings provides some interesting insights (Table 5.6). Although the overall average is similar for traditional, specialised suppliers and scale intensive industries, there is large heterogeneity across countries. Suppliers dominated (traditional) firms performed relatively better in Germany, Italy and Austria, but struggled in France where about 60% of the companies cut investment. 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 terms of investment reduction in specialised providers and scale intensive firms.

Table 5.6 / Percentage of firms reducing investment 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

The picture is relatively more homogenous when attention is paid to the depth of the crisis, as measured by the fraction of firms with a reduction of 30% or more in capital formation (Figure 5.5, panel B). From this point of view, there emerges a clear country-wide pattern, which is independent of industry categories. Firm performance in Austria is comparable to Spain and France where, as discussed above, the downturn pushed investment down more than elsewhere. On the opposite side, Germany and Italy exhibit a relatively low fraction of firms with a marked fall in investment. The figure also shows that, at least for planned investment in equipment, Italian high-tech companies performed better than any other group of firms within this sample of EU countries.

5.5 INNOVATION ACTIVITIES: PRODUCT/PROCESS INNOVATION, R&D AND PATENTING

Innovation performance of the 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 (see Table 5.7 and subsequent ones). As such, this indicator is representative of both informal and formal innovation carried out at firm level.

Table 5.7 / Firm innovation performance: summary of results (% of total)

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Product/process innovation in 2007-2009	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 in 2007-2009	55.5	50.7	54.6	26.8	55.0	46.0	53.2	51.2
R&D intensity on turnover in 2007-2009	6.5	6.2	7.8	5.7	7.3	7.1	6.9	7.0
Benefit R&D incentives	24.4	18.8	9.3	7.0	19.0	18.9	14.9	16.2
Patent an innovation in 2007-2009	19.4	11.7	15.8	4.3	14.2	11.2	14.0	13.2

Source: EFIGE dataset

In Europe, 65% of companies were engaged in such activities. This share amounts to 61% for small firms, 73% for the medium-sized firms and 79% for the largest ones. Austria is leading in terms of proportion of firms doing innovation especially among medium- and large-sized firms, followed by Spain and Italy (see Table 5.8). It is well known that such a qualitative indicator is more suited to describe the innovative capacity in less technologically advanced productions, and this explains why Germany falls to the bottom of the ranking. In France and Hungary, the fraction of innovating firms is particularly low among small firms, as those introducing a new product, or a new mode of production, accounts only for between 50 and 55% of the total. It should be nonetheless observed that, in Hungary, the share of innovators is rather low also among medium-sized firms but, conversely, is comparable to the other economies for large companies (78%).

Table 5.8 / Percentage of firms introducing product/process innovation in 2007-2009 (by size class)

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Small	69.0	52.7	58.5	51.7	64.9	67.1	62.8	61.3
Medium	89.7	62.2	76.0	58.5	78.3	76.9	76.7	73.5
Large	91.3	76.6	71.9	77.8	79.3	89.0	81.5	78.6
Total	75.9	56.3	64.6	55.7	67.5	69.6	67.3	64.9

Source: EFIGE dataset

Table 5.9 displays the firm propensity to product/process innovation on the basis of Pavitt taxonomy. This perspective of analysis yields findings perfectly consistent with expectations. High-tech firms are the most innovative, with 79% of firms introducing innovations, followed by specialised suppliers (70%) scale intensive firms (66%) and traditional firms (61.2%). Innovation patterns identified above at the economy-wide level remarkably shape cross-country differentials in industry groups. Indeed, for this indicator, Austria is confirmed to be the most innovative economy; in fact, the share of companies introducing innovations in the high-tech sector is 91.3%, the highest proportion among the countries included in the sample. In traditional industries, which are normally less prone to innovation, the share of innovating firms is comparable to that of high-tech industries in the other EU Member States. Hungary ranks at the bottom of the distribution in all industry categories apart from traditional sectors. For this kind of firm, France is lagging behind as only 48% of the interviewed companies introduced a product/process innovation.

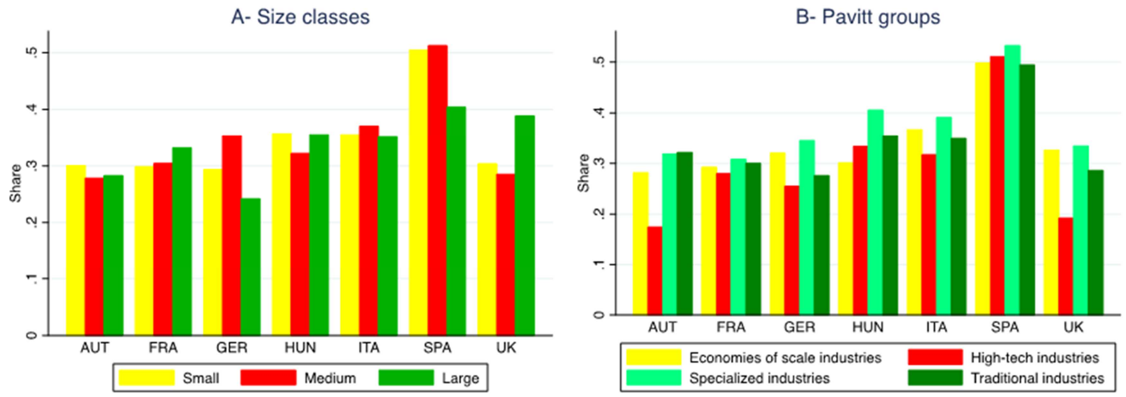
Table 5.9 / Percentage of firms introducing product/process innovation in 2007-2009 (by Pavitt group)

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Economies of scale	79.1	58.5	64.4	53.4	68.0	69.7	69.4	65.7
High-tech	91.3	79.7	74.0	73.3	74.3	86.5	83.8	79.0
Specialised	80.3	67.3	71.9	58.5	70.9	72.7	68.7	70.3
Traditional	77.9	48.5	59.4	54.4	65.4	67.9	62.9	61.2

Source: EFIGE dataset

The financial crisis and the consequent downturn caused a drop in the firm demand and severely clouded expectations on future sales. These issues, combined with tighter credit conditions, led one third of the EU firms to postpone their programmes of introducing a new product or/and process innovation (Figure 5.6, panel A). The share of firms reducing their engagement in innovation activities soars up to 50% among Spanish SMEs, and is also remarkable even among large firms in the UK (around 40%). The latter finding sharply contrasts with Germany, where the percentage of large companies postponing innovation amounts to one fourth of the total sample.

Figure 5.6 / Firms reducing product/ product innovation in 2009 (by size class and Pavitt group)



Source: EFIGE dataset

A larger heterogeneity emerges with respect to the picture thus far drawn when looking at how firms changed innovation programmes because of the deepening of the crisis across industry groupings (Figure 5.6, panel B). Half of the Spanish firms postponed product/process innovation; this proportion is similar among Pavitt category. These values are twice as large as those in Austria, Germany and UK. In Germany, the turmoil was particularly detrimental for the group of specialised suppliers and scale-intensive industries, as one third of these firms cut planned programmes of innovation. Apart from Spain, innovation activities of high-tech companies were less affected by the turmoil.

Table 5.10 / Percentage of firms doing R&D in 2007-2009 (by size classes)

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Small	43.3	43.6	45.5	20.9	50.3	41.7	48.8	45.0
Medium	79.4	65.8	66.8	33.1	72.5	61.3	63.4	65.2
Large	84.8	79.0	77.1	53.3	82.1	71.2	63.0	75.2
Total	55.5	50.7	54.6	26.8	55.0	46.0	53.2	51.2

Source: EFIGE dataset

Next, as a proxy for formal research, the proportion of the firms engaged in R&D is considered. These values are distinguished by size classes in Table 5.10 and by Pavitt categories in Table 5.11. One out of two EU firms declares to carry out R&D projects. This percentage considerably changes with the firm size, ranging between 45% (small firms) and 75% (large firms). Again, Austria shows the largest proportion of innovators (55% of total), closely followed by Germany and Italy. The latter country denotes a very high share of R&D-performers among small firms (50% against the EU mean of 45%). Engagement in formal research is rather low in Hungarian firms as, on average, only one fourth of them carried out R&D between 2007 and 2009. This country exhibits figures comparable to the EU levels only among high-tech firms; however, as discussed above, in absolute terms this type of firms is not numerically relevant in the sample. Similarly, Spain is characterised by a proportion of R&D-doing firms lower than the EU average in all Pavitt groups. Among high-tech firms, France has the highest proportion of companies doing R&D while Germany has the lowest.

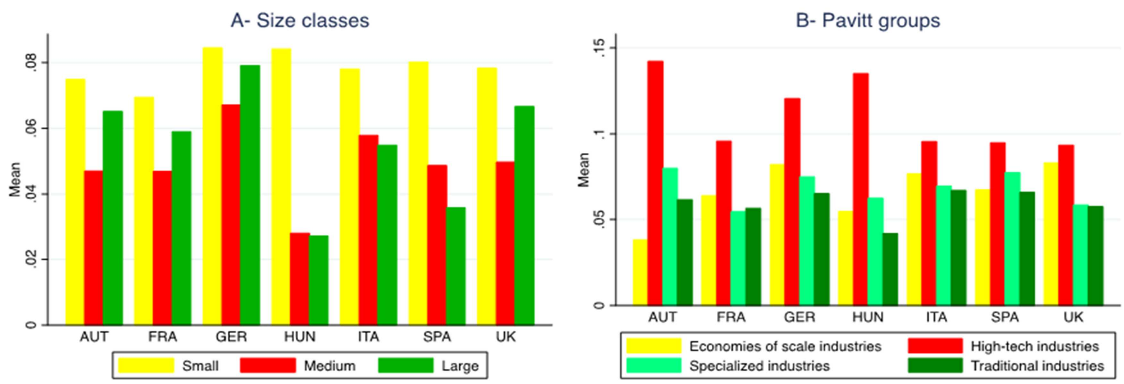
Table 5.11 / Percentage of firms doing R&D in 2007-2009 (by Pavitt groups)

	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
Economies of scale	54.3	53.6	54.3	27.1	54.5	49.5	54.6	52.5
High-tech	78.3	83.1	64.8	66.7	80.2	74.0	76.8	74.2
Specialised	66.7	67.9	67.3	28.3	61.9	58.0	61.6	62.6
Traditional	52.1	39.8	45.6	23.9	50.7	39.7	46.2	43.8

Source: EFIGE dataset

When examining the intensity of research engagement, expressed as percentage of total turnover allocated to R&D, small firms turn out to spend relatively more in all countries (Figure 5.7, panel A): the ratio between R&D expenses and sales ranges approximately from 7% in France to 8.5% in Germany and Hungary. Large firms rank at the bottom. However, there is a large heterogeneity among the EU Member States for this class of firms; indeed, R&D intensity spans from a bare 2.7% in Hungary to 8% in Germany. At the country level, Germany is leading in all size classes for research intensity. Moving to Pavitt categories (Figure 5.7, panel B), the outline is somewhat different as this country does not stand out in any particular group. Austrian and Hungarian firms operating in the science-based industries have the largest share of turnover devoted to R&D (14 and 13% respectively), while the lowest share is observed in the economies of scale group in Austria and the traditional group in Hungary. In the other industry types R&D intensity is not characterised by noticeable cross-country differences.

Figure 5.7 / R&D intensity on turnover in 2007-2009 (by size class and Pavitt group)

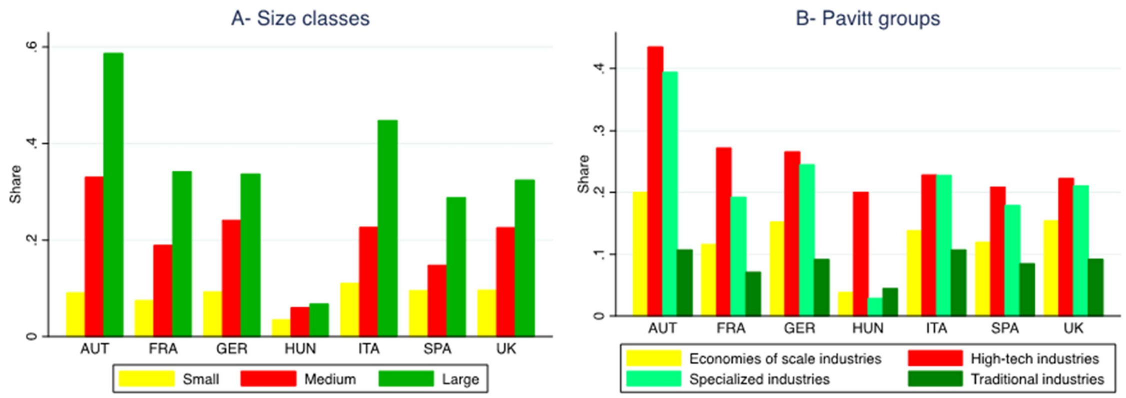


Source: EFIGE dataset

The last innovation indicator considered is the percentage of firms applying for patent protection for their innovations. In the EU manufacturing, the rate of patenting amounts to 13%. There is considerable variation among firms depending on their size as well as the nature of their economic activity. Figure 5.8 panel A shows that the proportion of patenting firms ranges from 9% among small-sized companies to 35% among the largest ones. Hungary proves to be an outlier, with a remarkably low proportion of patenting firms in all size classes. Large firms in Austria, on the other hand, are the more active in terms of patenting activities, followed by Italy, France and Germany. Austrian medium-sized firms are also particularly dynamic, while there are no major differences across the other countries.

Figure 5.8 panel B shows that the firm propensity to patent is higher among high-tech and specialised industries, as expected. In the former category, the share of patenting companies is very large in Austria, (over 40% of the total sample), whilst it fluctuates between 20 and 30% in the other countries. Specialised suppliers turn out to be particularly innovative in Italy, where their propensity to patent is comparable to that of high-tech firms. Traditional industries are on the other tail of the distribution as only one tenth of these companies apply for legal protection for their innovation outcomes. This proportion is quite similar across the EU countries under assessment. In scale intensive sectors, firms resort less to patenting as the main goal of their innovation activity is of reducing production costs and increasing the scale of production operations in order to exploit increasing returns. It should be nonetheless observed that, also for this industry group, cross-country variation in patenting is large, ranging from 20% of Austria to less than 5% of Hungary. However, for these countries, the caveats concerning the sample size apply. Overall, the outline drawn in this section is consistent with the patterns identified by Archibugi and Filippetti (2011) on the effect of the crisis on convergence in innovation performance across Member States.

Figure 5.8 / Proportion of patenting firms in 2007-2009 (by firm size and Pavitt group)



Source: EFIGE dataset

5.6 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. The cross-sectional regression model is estimated by OLS, using heteroskedasticity robust standard errors. The analysis is based on the following specification:

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

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 catching-up effect, whereby lower productivity firms fill the gap with the best performing ones. The first set of dummy variables (CRISIS) aims to control 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 impact negatively on TFP growth. A second set of dummies (INTANG) capture firms' decisions in relation to invest in intangible assets and provide information on whether the firm has conducted R&D investments over the period[53] (R&D), whether it employed a higher proportion of educated workers compared to the national average (human capital) and whether it implemented some relevant organisational changes (organisational change). There is large evidence that 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). These effects are stronger in the most knowledge intensive industries, where firms may benefit from important spillovers (O'Mahony and Vecchi, 2009)[54].

Another set of controls accounts 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 study. The information on the EFIGE data set allows to control for companies' adjustment to changes in labour market regulations throughout the 2000s[55] (LABOUR). The impact of such reforms is captured by a dummy variable which identifies companies resorting to flexible contracts, both in the form of temporary and part-time workers. Existing firm level evidence generally shows that a high share of temporary workers is associated with low innovation and productivity performance, probably due to the low experience and low endowments of firm-specific human capital of workers employed on a temporary basis (Daveri and Parisi, 2010).

Due to the financial nature of the downturn, it is also important to check whether and to what extent worsening conditions on the credit market affected firms' performance (FINANCE). This is captured by the inclusion of a dummy variable on credit rationing, which takes value of 1 if the firm required credit during the crisis but did not obtained it. There is considerable evidence that EU SMEs were severely hampered in access to credit in order to fund their investment (Holton et al., 2012), but the issue of whether this translated into lower rates of productivity growth is somewhat less explored and the results are not always clear cut. For example, Bricongne et al. (2010) show that the reduction in trade

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53 This is the preferred measure of innovation effort among those available (product/process innovation, R&D intensity, patent propensity) as its effect is more robust across specifications.

54 A cross-country comparison within the EU on intangible assets and measurement issues at firm level can be found in Piekkola (2011).

55 The cross-sectional nature of the data set inhibits the usage of the institutional indicators used in section 3.4 as perfectly collinear with the country dummies included into the regression.

experienced by French firms in the aftermath of the crisis was mainly due to the negative demand shock, although credit constraints acted as an aggravating factor.

Firms' decisions to invest in intangible assets and to compete on international markets are related to their managerial abilities (Castellani and Giovannetti, 2010). For this reason, this analysis accounts for the role of managerial practices 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 quality certification. An extensive discussion of cross-country differences in managerial practices, as well as their potential impact on aggregate productivity growth, can be found in Bloom and van Reenen (2007, 2010). These authors show that bad management is likely to persist in the presence of imperfectly competitive markets, family ownership of firms, regulations restricting management practices and informational barriers. Such managerial practices explain large variation in productivity growth at firm level, negatively reverberating on productivity performance at the economy-wide level.

Other control variables include the age of the firm, country, size and industry (Pavitt) dummies. The impact of firms' age on productivity is captured by a dummy variable taking the unit value if the firm is less than six year old[56]. This will help to understand the differential 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 give an important contribution to aggregate productivity growth in the US, whilst their role in the EU was more controversial (Bassanini and Scarpetta, 2002).

Results from the estimation of equation 5.1 are presented in Table 5.12 and Table 5.13. The first table compares estimates for the overall sample with those obtained by splitting companies into the three size classes used in the descriptive part of the analysis (small, medium and large). Table 5.13 presents estimates for companies belonging to the four Pavitt's categories. Overall, results corroborate most of the trends highlighted in the descriptive section. The positive coefficient on the level of TFP in 2008 suggests that there has been no productivity catch-up among companies during the crisis; on the contrary, firms with relatively higher level of TFP in 2008 experienced a faster growth during the crisis. This feature, that is common across size classes and industry groups, is not necessarily driven by nation-wide patterns, as country fixed effects are included into the specification. In other words, within any single country, those firms that were most productive at the outset of the downturn accommodated better the negative shock, outperforming in terms of TFP growth during the period 2008-09.

Firms that experienced a turnover and an investment reduction underperformed compared to those less affected by the crisis. This result confirms the cyclical nature of productivity. The significance of both variables indicates that the downturn impacted distinctly on these two dimensions of firm performance and this, in turn, reverberated on TFP growth. The effect of turnover reduction was relatively more severe among large and high-tech firms, while the decline in investment affected productivity particularly among medium-sized firms and those specialised in the manufacturing of specialised inputs.

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. The

[56] In the data set, firms are grouped in three broad categories (less than 6 year old, between 6 and 20 years, older than 20 years).

extant literature does not offer clear guidance on how this effect varies across different types of companies. Results in Tables 5.12-5.13 indicate that these factors 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 have 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[57], and/or the decision to postpone the full implementation of such changes with the explosion of the crisis.

As a whole, international firms were more productive with respect to those active solely on the domestic market. The main characteristic that appears to be systematically associated with a better TFP performance is the firm affiliation to a foreign group. This feature is common between 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, importers of service intermediate inputs experienced a faster productivity growth. Among scale intensive firms, TFP grew at a more rapid rate in those companies that, before the crisis, had carried out abroad some production tasks with their own affiliates or subsidiaries.

[57] See Rincon et al. (2012) for a discussion the delayed productivity effects of ICT and complementary investment in tangible assets.

Table 5.12 / Determinants of TFP growth 2008-09: OLS regression (total sample and by size classes)

	(1) Total sample	(2) Small firms	(3) Medium firms	(4) Large firms
Dependent variable: TFP change 2008-09				
Log TFP 2008	0.881***	0.880***	0.903***	0.843***
	(0.010)	(0.012)	(0.017)	(0.043)
Crisis effect				
Turnover reduction	-0.063***	-0.065***	-0.048***	-0.079***
	(0.005)	(0.005)	(0.010)	(0.021)
Investment reduction	-0.019***	-0.013**	-0.034***	-0.025
	(0.004)	(0.005)	(0.009)	(0.019)
Innovation reduction	-0.006	-0.008	-0.003	0.018
	(0.004)	(0.005)	(0.008)	(0.018)
Intangibles				
R&D-doing firm	0.011**	0.011**	0.009	0.014
	(0.005)	(0.005)	(0.009)	(0.021)
Human capital	0.008*	0.011**	-0.006	0.010
	(0.005)	(0.006)	(0.010)	(0.025)
Organisational change	0.003	-0.002	0.003	0.019
	(0.004)	(0.006)	(0.009)	(0.017)
Controls				
Openness				
Importer of materials	0.005	0.009	-0.009	0.005
	(0.004)	(0.005)	(0.009)	(0.020)
Importer of services	0.013**	0.011	0.013	0.020
	(0.005)	(0.007)	(0.009)	(0.019)
FDI active	0.012	0.009	0.019	0.010
	(0.011)	(0.031)	(0.015)	(0.019)
FDI passive (foreign group)	0.022***	0.032**	0.012	0.045**
	(0.008)	(0.016)	(0.011)	(0.020)
Labour input				
Flexible contracts	-0.003	0.002	-0.036**	0.018
	(0.006)	(0.007)	(0.017)	(0.028)
Financial input				
Rationed credit	-0.017	-0.027*	0.026	0.011
	(0.012)	(0.014)	(0.018)	(0.051)
Other firm characteristics				
Family management	-0.013***	-0.012**	-0.023	0.052
	(0.005)	(0.005)	(0.020)	(0.040)
Quality certification	0.009**	0.009*	0.007	0.007
	(0.004)	(0.005)	(0.009)	(0.021)
Young (less than 6 yrs)	-0.001	0.008	-0.026***	-0.032
	(0.004)	(0.005)	(0.009)	(0.025)
Constant	0.081***	-0.005	0.083**	0.150***
	(0.021)	(0.043)	(0.036)	(0.047)
Size dummies	Yes	No	No	No
Pavitt dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Observations	7,077	4,852	1,641	584
R-squared	0.878	0.844	0.882	0.867

Robust standard errors in parentheses.
***,**,* significant at 1, 5, 10%.
Source: EFIGE dataset

Table 5.13 / Determinants of TFP growth 2008-09: OLS regression (total sample and by Pavitt groups)

	(1) Total sample	(2) Scale intensive	(3) Hightech	(4) Specialised	(5) Traditional
Dependent variable: TFP change 2008-09					
Log TFP 2008	0.881***	0.898***	0.900***	0.886***	0.868***
	(0.010)	(0.017)	(0.054)	(0.019)	(0.016)
Crisis effect					
Turnover reduction	-0.063***	-0.063***	-0.074***	-0.055***	-0.063***
	(0.005)	(0.010)	(0.021)	(0.011)	(0.006)
Investment reduction	-0.019***	-0.019**	-0.013	-0.032***	-0.013**
	(0.004)	(0.009)	(0.026)	(0.011)	(0.006)
Innovation reduction	-0.006	-0.018**	0.030	0.008	-0.007
	(0.004)	(0.009)	(0.023)	(0.010)	(0.006)
Intangibles					
R&D-doing firm	0.011**	0.031***	-0.010	-0.004	0.005
	(0.005)	(0.010)	(0.024)	(0.010)	(0.006)
Human capital	0.008*	0.006	-0.034	-0.002	0.015**
	(0.005)	(0.010)	(0.021)	(0.010)	(0.007)
Organisational change	0.003	0.003	-0.016	-0.007	0.007
	(0.004)	(0.009)	(0.026)	(0.009)	(0.006)
Controls					
Openness					
Importer of materials	0.005	0.003	0.030	0.010	0.002
	(0.004)	(0.010)	(0.023)	(0.010)	(0.006)
Importer of services	0.013**	0.017	0.047**	-0.001	0.012
	(0.005)	(0.011)	(0.023)	(0.010)	(0.007)
FDI active	0.012	0.056**	0.006	0.003	-0.013
	(0.011)	(0.024)	(0.033)	(0.019)	(0.018)
FDI passive (foreign group)	0.022***	0.017	0.037	0.014	0.029*
	(0.008)	(0.014)	(0.033)	(0.015)	(0.016)
Labour input					
Flexible contracts	-0.003	0.006	0.001	-0.037***	0.002
	(0.006)	(0.014)	(0.034)	(0.012)	(0.008)
Financial input					
Rationed credit	-0.017	0.010	-0.028	-0.041	-0.020
	(0.012)	(0.023)	(0.045)	(0.032)	(0.015)
Other firm characteristics					
Family management	-0.013***	-0.004	-0.007	-0.031**	-0.013**
	(0.005)	(0.011)	(0.030)	(0.014)	(0.006)
Quality certification	0.009**	-0.005	0.032	0.032***	0.009
	(0.004)	(0.009)	(0.028)	(0.010)	(0.006)
Young (less than 6 yrs)	-0.001	-0.008	-0.057**	0.014	0.000
	(0.004)	(0.009)	(0.027)	(0.009)	(0.006)
Constant	0.081***	0.055*	0.123	0.126***	0.046*
	(0.021)	(0.031)	(0.082)	(0.031)	(0.025)
Size dummies	Yes	Yes	Yes	Yes	Yes
Pavitt dummies	Yes	No	No	No	No
Country dummies	Yes	Yes	Yes	Yes	Yes
Observations	7,077	1,844	273	1,349	3,611
R-squared	0.878	0.883	0.900	0.872	0.865

Robust standard errors in parentheses.
***,**,* significant at 1, 5, 10%.
Source: EFIGE

In accordance with the literature on the regulation governing the labour market, firms relying upon flexible contracts observed lower productivity growth; however, this effect is confined to some specific types of companies, namely medium firms and specialised suppliers. Finally, there is no evidence on the negative impact of worsening credit conditions on productivity for the overall sample. However, small firms experienced a 1.2% decrease in productivity following the credit rationing, consistently with the existing evidence (Holton et al. 2012).

Turning to other firm characteristics, results show that family management is another condition that was considerably detrimental to 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 gear among young firms; rather, they underperformed compared to medium-sized and high-tech firms. Probably, these 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 condition.

5.7 SUMMARY

This section has analysed firms' performance during the financial crisis, using a wide range of indicators drawn from the EFIGE data set. Identifying some common patterns is quite challenging as the countries included in the EFIGE survey are quite heterogeneous in several dimensions, such as international specialisation and regulatory environment. The analysis suggests that in terms of TFP growth, performance decreased in all countries in line with prior expectations. However, the fall in productivity was particularly large in countries that were underperforming before the crisis, pointing to the role of structural issues. The decrease in productivity was accompanied by a reduction in turnover and investments.

Within countries, the reduction of TFP growth was particularly strong among small firms, particularly those operating in traditional industries and in sectors producing specialised inputs. Conversely, companies in high-tech industries experienced higher rates of TFP growth before and during the crisis, as well as lower reduction in turnover and investments. Their innovative performance, measured either in terms of product/process innovations or R&D, was particularly dynamic even during the crisis.

At the country level, Spain emerges as a particularly weak economy when looking at different performance indicators, while Austria and Germany responded better to the financial crisis. Since the mid-1990, Spain had made important progress in productivity growth and knowledge accumulation, even within the most technologically advanced areas of the manufacturing sector[58]. Despite this, Spanish high-tech firms were rather vulnerable to the crisis compared to their EU competitors. This may be the consequence of a general institutional environment less favourable to innovation and input reallocation away from declining industries and towards the most productive ones.

The econometric analysis has shown that the collapse of the markets, and the associated decline in turnover and investment, pulled down productivity growth in the EU manufacturing. This trend was milder for firms investing in intangible assets (mainly R&D activities and human capital). The choice to

[58] See Sterlacchini and Venturini (2011b).

postpone innovation because of the slump did not produce any significant effect on firm productivity dynamics, at least in the relatively short-term horizon considered in the analysis. Being part of foreign group allowed firms to enjoy higher productivity even during the downturn, while firms strictly managed by the controlling family, specialised on traditional goods or supplying specialised inputs, suffered relatively more in terms of TFP growth.

Overall, this section of the study provides insights about which policies should be pursued to sustain firm performance. Supporting SMEs should be the milestone of the policy agenda in light of the marked weakness shown by these firms during the crisis (EC, 2012). To this aim, it would be primarily desirable to increase accumulation of intangible assets as, also for this category of firms, these factors have been proven to spur significantly TFP growth. To re-launch investment plans it appears indispensable to ease firm access to the credit market (EC, 2013). Another crucial condition to empower productivity performance of the EU SMEs is stimulating their engagement in international operations, as it extends both the set of available inputs and growth opportunities. From this perspective, hiring of high professional and independent managers may be a really important facilitating factor.

6. Overall summary and conclusions

This study has explored the main aggregate and industry productivity trends in the EU economy in comparison with main competitors, and provided empirical evidence on the key forces behind the widening productivity growth differentials with respect to the US. Identifying these factors is crucial to design policies aimed at closing the productivity gap and, more generally, to restore a sustained growth in Europe

Market services sectors were the main culprit of the EU productivity disadvantage during the uptake of ICT in the late 1990s. However, Section 1 has shown that, in the years leading to the financial crisis, the EU had experienced strong productivity growth in these sectors, driven by massive ICT investment, thus mirroring the earlier US experience. Service sectors, which are usually more sheltered from international competition, appear to have been less affected by the global economic crisis compared to manufacturing and, hence, have recently contributed to narrow the productivity growth gap of the EU with the US. This positive outlook, however, contrasts with the poor total factor productivity performance experienced by most service industries in the EU. It suggests that low levels of efficiency with which inputs are used in the production process may be the driving force behind the sluggish TFP performance of the EU services industries.

Important disparities still persist in Europe within the secondary and the tertiary sector. Indeed, whereas overall productivity in the manufacturing sector declined significantly since 2007, high- and medium-high technology industries have shown positive productivity growth, even though slower than prior to the financial crisis. In services, knowledge intensive sectors have been experiencing a strong productivity dynamics since the mid-1900s; while TFP growth slowed down in 2008, it continued to increase in 2009 in most industries.

The analysis developed in Section 1 has called for a more in-depth investigation of the factors affecting productivity performance as this is the main engine for increasing income levels in the long run and therefore responsible for the EU-US productivity gap. The existing empirical evidence, discussed in Section 2, points to the institutional design of the product and factor markets as one of the main factors preventing improvements in productivity performance in Europe, due to their negative impact on the adoption and implementation of new technologies. The institutional framework can decrease the competitiveness of the product and factor markets, reducing productivity and innovation and decreasing companies' ability to benefit from the innovation generated elsewhere, via spillover effects. These issues are specifically addressed in Section 3, which investigates the role of absorptive capacity and knowledge-base (intangible) assets -mainly R&D and human capital- in facilitating international technology transfers. This mechanism has been found in the literature to be highly conducive to total factor productivity growth through spillovers. However, its growth-enhancing effect is largely heterogeneous across industries and countries, and it requires the ability to accommodate the inflow of new technological knowledge by re-allocating factor inputs among tasks (or sectors) or by expanding new product lines. The regulatory setting governing the functioning of the markets is crucial in this process, as it may either mitigate or amplify the productivity effects of technology transfers.

The analysis in Section 3 shows that foreign R&D plays an important role in increasing productivity and the effect is stronger in developing countries and, in general, in countries/industries that are further away from the frontier. This implies that technology transfers can assist in the catching up process. The effects are also stronger in manufacturing industries, which typically invest more heavily in innovations, and in countries endowed with a highly skilled workforce. Hence, this study strongly supports the importance of technology transfers and absorptive capacity. The evidence regarding the role of the institutional environment is mixed. Two important absorption barriers have been identified. The legal system of IPRs protection has been found to limit the scope of spillovers as it probably discourages copying technology from abroad. Similarly, higher levels of employment protection for regular workers and for collective dismissals are also associated with lower trade-related R&D productivity benefits; this may signal that a certain degree of flexibility is necessary to adapt firm operations to the new productive opportunities offered by newly available technological knowledge acquired by foreign competitors. On the other hand, the relationship between foreign R&D and productivity is stronger in a regime with more stringent product market regulations, less investment and financial freedom. This suggests that countries with a more structured institutional setting were able to gain larger productivity benefits from international technology spillovers.

Section 4 has investigated another channel through which countries can achieve higher productivity and therefore close the productivity gap between the EU and the US, i.e. via the reduction of inefficiencies in the production process. The analysis has shown that ICT plays a very important role in decreasing inefficiencies, supporting the General Purpose Technology (GPT) nature of this investment asset. Productive efficiency is also significantly higher in countries with less restrictive product market regulations and employment protection laws, as well as in the presence of lower administrative burdens in running a business. Therefore, simplifying and reducing start-up regulations and administrative burdens can reduce barriers to entry, help emergence of most productive and efficient firms and diffuse the best efficient business practices (OECD 2010). However, lower restrictions in the use of temporary contracts increase the efficiency gap with respect to the frontier as these are likely to lead firms to adopt cost-cutting strategies rather than the most efficient methods of production. Similarly, excessive financial deregulation increases technical inefficiency, consistently with the analysis of technological transfers in Section 3.

Broadly consistent evidence also emerges from the assessment of firm-level performance at the outset of the financial crisis. The analysis undertaken for seven EU economies has provided strong micro foundations to the widening productivity differentials observed at a more aggregate level, showing that the most productive firms prior to the crisis experienced a faster total factor productivity growth afterwards. This finding confirms that, even within the EU, the recent downturn has reinforced the divergence in productivity trends that emerged in the earlier period. The econometric analysis has shown that the collapse of the markets, and the associated decline in turnover and investment, pulled down productivity growth in the EU manufacturing. This trend was milder for firms investing in intangible assets (mainly R&D activities and human capital). The choice to postpone innovation because of the slump did not produce any significant effect on firm productivity dynamics, at least in the relatively short-term horizon considered in the analysis.

Overall, the analysis carried out in this study has provided useful insights on which policies may be more effective to raise productivity performance within the EU and to close the gap with the US. A common finding throughout the study is that intangible assets (R&D, human capital, organisational changes) are an important source of TFP growth and sustained long-run competitiveness. From this perspective, initiatives aimed at stimulating such investments can be particularly useful. Concerning R&D, large evidence can be found in the literature about the effectiveness of generous tax credit to raise research effort. This policy instrument does not distort market incentives as reducing the cost of R&D without interfering with the firm choice concerning the projects to carry out (David et al., 2000).

Similar measures may also be put in force to increase firm endowment of qualified workers, for instance facilitating hiring of highly educated workers (such as professional managers), and/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 which can assist in the reorganisation of production such as ICT investments. 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 in formal R&D activities and need alternative ways of increasing their competitiveness (EC, 2012 and 2013). In this respect, another important condition to improve performance is to extend firm endowment of intangible assets that raise reputation, such as branding and advertising. This condition appears useful to make firms more recognisable both in production and innovation activities, reducing their vulnerability to competition from low-income countries. Note that, albeit R&D still remains the main source of technological advancements in many fields, complementary non-technological innovations play a crucial role for smaller firms, which rely on derivative innovations obtained as incremental improvements of existing products or production modes. This would benefit from measures encouraging alliances, joint ventures with external parties and the acquisition of external knowledge by contract R&D or patent licensing of patents (OECD 2010).

Concerning ICT assets, this factor spurs productivity performance by increasing efficiency in production tasks and this effect may take time to materialise. Therefore, such measures targeted to increase this kind of investment may be accompanied with further policies targeted to an array of facilitating factors. Of particular effectiveness may be those aimed at improving the functioning of the product and factor markets. 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, consequently, the adoption of the best production and managerial practices.

Changes in the regulatory setting of the labour market should be tailored to avoid counter-balancing effects between the measures pertaining to the regular and temporary workers. Excessive liberalisation of the latter type of contracts has in fact been proven detrimental to productivity and efficiency. Corroborating econometric evidence has also been found at firm level in the analysis focused on productivity performance at the outset of the crisis (see Section 5). This area of policy intervention therefore asks for measures that can account for both the productivity spillovers and technical efficiency impact and consider that these may be self-enforcing. Overall, the results of Sections 3 and 4 suggest that differentiating the regulation of temporary labour contracts from that on permanent contracts may be useful to close the growth gap of the EU with respect to the US. The interplay between employment protection legislation and productivity performance, broadly intended, will be certainly a fertile area of economic research in the next years.

Access to financial instruments has been acknowledged to be pivotal for improving productivity and efficiency performance. However, it is important to distinguish between easier access to external finance and less regulations in channelling funds by financial institutions. Easier access to financial resources, which are particularly important for funding innovation activities such as R&D, has been confirmed to significantly raise productivity. Sound policies could be therefore directed towards facilitating bank credit to SMEs or firms' access to more developed forms of financial instruments, such as private bonds. These measures should be conceived without forcing deregulation of the financial market; in fact, the recent downturn has shown that excessive financial freedom may be a source of instability and can lead to wider productivity and efficiency gaps.

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Appendix tables and figures

Table A.1 / Growth in GDP per person, average annual growth by sub-period (%), 1995-2012

	1995-2000	2000-2007	2007-2009	2009-2012
AT	2.19	1.29	-1.83	0.85
BE	1.61	1.01	-1.71	0.63
BG	1.88	3.60	0.21	4.60
CY	2.47	0.68	0.04	0.17
CZ	2.82	3.96	-1.02	1.33
DE	1.03	1.23	-2.73	1.59
DK	1.80	0.87	-2.95	1.93
EE	8.53	5.69	-4.51	3.77
EL	2.82	2.35	-2.01	-1.79
ES	0.23	0.03	1.97	2.16
FI	2.47	2.06	-4.27	1.71
FR	1.13	1.04	-1.22	0.89
HU	1.80	3.53	-0.89	-0.11
IE	4.23	1.79	0.90	2.70
IT	0.92	-0.09	-2.71	0.38
LT	5.68	6.50	-2.74	4.24
LU	1.91	0.78	-5.42	-0.57
LV	5.95	6.02	-4.83	7.10
MT	2.32	0.62	-0.57	-0.05
NL	1.45	1.12	-1.35	0.69
PL	5.64	3.34	1.22	2.89
PT	2.07	0.86	-0.40	1.27
RO	1.41	7.93	1.14	0.78
SE	2.65	2.24	-2.11	2.52
SI	4.43	3.37	-2.78	1.68
SK	4.14	4.96	-0.33	2.93
UK	2.11	2.08	-2.04	0.36

Source: The Conference Board Total Economy Database, January 2013, own calculations.

Table A.2 / Growth in total employment by sub-period, average annual growth (%), 1995-2012

	1995-2000	2000-2007	2007-2009	2009-2012
AT	0.92	0.93	0.62	0.98
BE	1.21	0.90	0.79	0.69
BG	-1.65	2.00	-0.02	-3.67
CY	1.24	2.87	0.79	-0.34
CZ	-1.00	0.67	0.24	-0.30
DE	0.82	0.17	0.64	1.00
DK	1.01	0.72	-0.36	-0.85
EE	-2.06	1.65	-5.19	0.80
EL	0.57	1.74	0.31	-4.44
ES	3.80	3.33	-3.44	-2.61
FI	2.22	1.15	-0.04	0.31
FR	1.55	0.77	-0.41	0.28
HU	1.10	-0.05	-2.17	0.70
IE	5.55	3.21	-4.77	-2.33
IT	0.97	1.34	-0.70	-0.41
LT	-1.12	1.27	-3.86	-0.87
LU	4.04	3.33	2.97	2.19
LV	-0.60	2.44	-6.60	-4.22
MT	0.64	1.22	1.15	1.79
NL	2.52	0.84	0.37	0.09
PL	-0.37	0.63	2.09	0.58
PT	2.09	0.26	-1.08	-2.15
RO	-2.55	-2.00	-0.99	-0.20
SE	0.81	0.72	-0.78	1.19
SI	-0.18	0.94	0.36	-1.83
SK	-0.80	1.04	0.60	0.41
UK	1.25	0.88	-0.47	0.39
US	1.66	0.91	-2.12	0.55
JP	-0.42	-0.18	-0.99	-0.37

Source: The Conference Board Total Economy Database, January 2013 own calculations.

Table A.3 / Growth in hours by sub-period, average annual growth (%), 1995-2012

	1995-2000	2000-2007	2007-2009	2009-2012
AT	1.20	0.40	-1.35	0.79
BE	0.77	1.05	0.35	0.75
BG	-2.50	2.13	0.00	-3.74
CY	1.51	2.34	0.38	-0.40
CZ	-0.56	-0.18	-0.19	0.57
DE	0.05	-0.31	-0.76	1.32
DK	1.72	0.62	-1.16	-0.78
EE	-1.62	1.73	-9.51	2.42
EL	-0.57	1.16	-0.68	-3.76
ES	3.78	2.71	-3.07	-2.33
FI	1.93	0.79	-1.05	0.48
FR	0.69	0.41	-0.83	0.33
HU	1.38	-0.52	-2.50	-0.05
IE	4.14	2.70	-6.33	-2.27
IT	1.00	0.99	-1.95	-0.88
LT	0.14	1.50	-4.22	-0.97
LU	3.37	2.48	1.44	2.15
LV	0.97	1.70	-10.25	-4.19
MT	0.62	0.68	-0.29	1.79
NL	2.23	0.37	0.20	0.18
PL	-0.09	1.77	1.53	0.42
PT	2.83	0.07	-1.51	-2.11
RO	-0.94	-1.81	-0.78	-0.25
SE	0.84	0.46	-0.85	1.69
SI	-0.56	0.47	0.82	-1.73
SK	-1.21	0.84	0.29	0.57
UK	0.89	0.55	-1.24	0.65
US	1.73	0.64	-2.86	1.10
JP	-0.98	-0.48	-2.66	-0.92

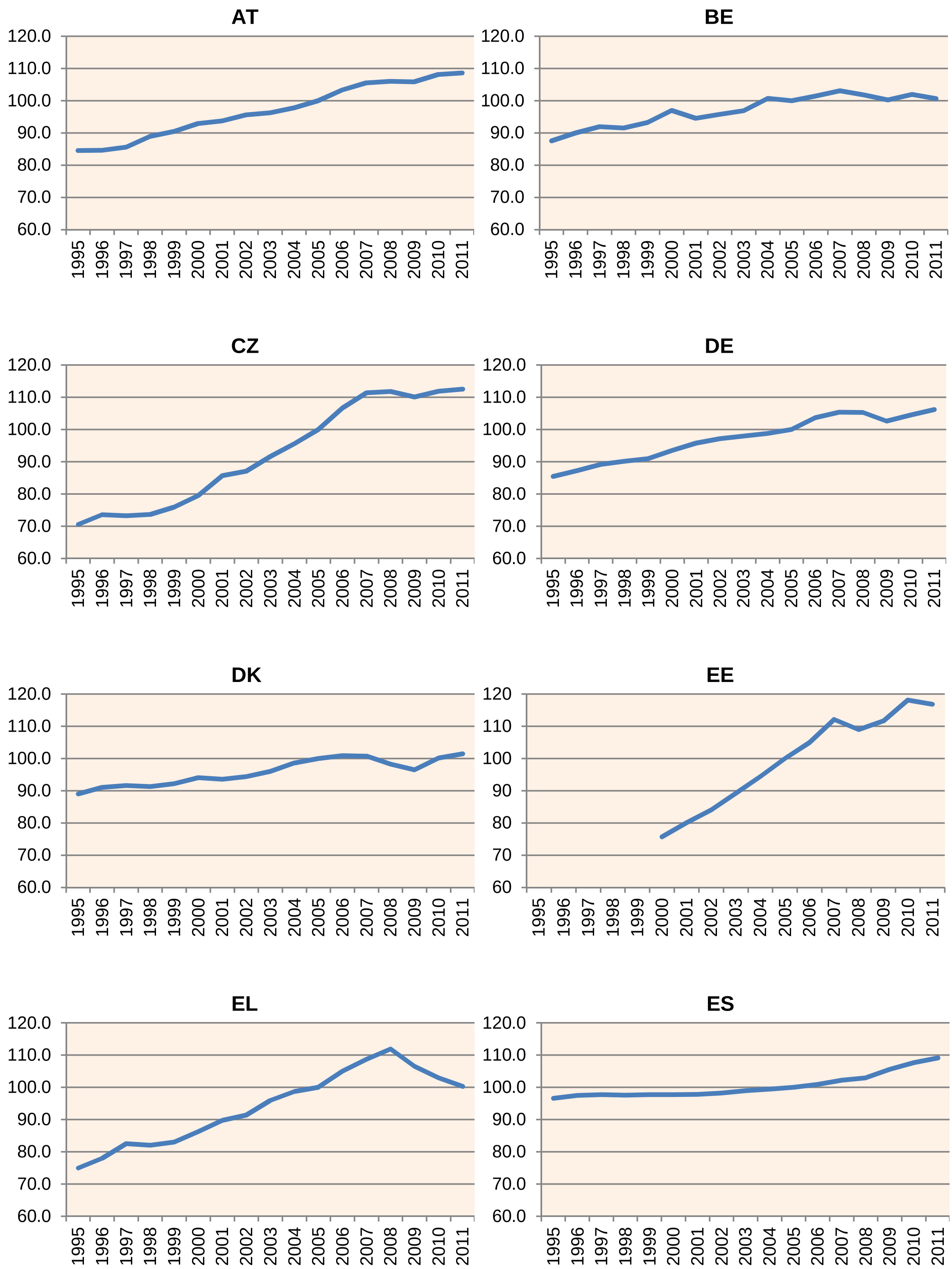
Source: The Conference Board Total Economy Database, January 2013; own calculations.

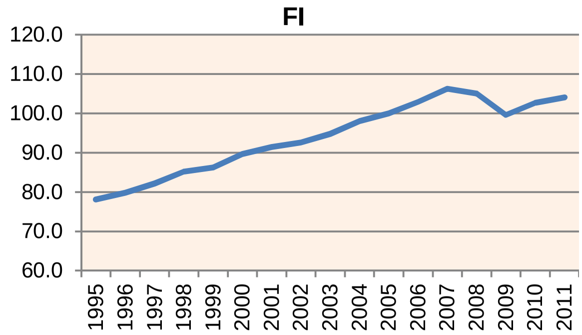
Table A.4 / Growth in GDP per hour by sub-period, average annual growth (%), 1995-2012

	1995-2000	2000-2007	2007-2009	2009-2012
AT	1.90	1.82	0.13	1.04
BE	2.05	0.87	-1.27	0.57
BG	2.72	3.48	0.19	4.68
CY	2.20	1.21	0.45	0.22
CZ	2.39	4.81	-0.59	0.45
DE	1.80	1.71	-1.33	1.26
DK	1.10	0.98	-2.15	1.86
EE	8.10	5.62	-0.19	2.16
EL	3.96	2.93	-1.03	-2.46
ES	0.26	0.64	1.61	1.88
FI	2.76	2.43	-3.27	1.54
FR	1.99	1.40	-0.81	0.84
HU	1.52	3.99	-0.56	0.64
IE	5.64	2.30	2.46	2.63
IT	0.89	0.26	-1.46	0.86
LT	4.42	6.27	-2.38	4.34
LU	2.58	1.63	-3.89	-0.53
LV	4.38	6.77	-1.17	7.07
MT	2.35	1.16	0.87	-0.05
NL	1.74	1.59	-1.18	0.59
PL	5.36	2.21	1.77	3.04
PT	1.33	1.06	0.03	1.23
RO	-0.20	7.74	0.92	0.84
SE	2.62	2.51	-2.04	2.02
SI	4.81	3.84	-3.24	1.58
SK	4.55	5.15	-0.03	2.78
UK	2.47	2.41	-1.27	0.09

Source: The Conference Board Total Economy Database, January 2013, own calculations.

Figure A.1 / Labour productivity growth, country average (1995=100)

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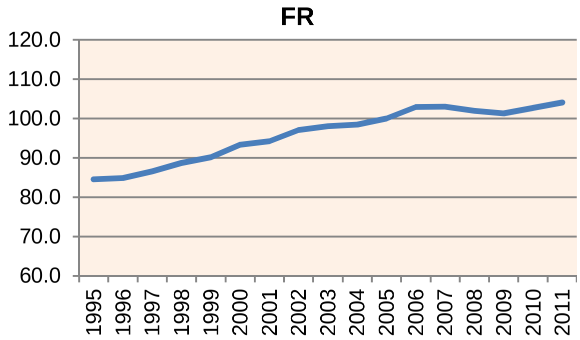
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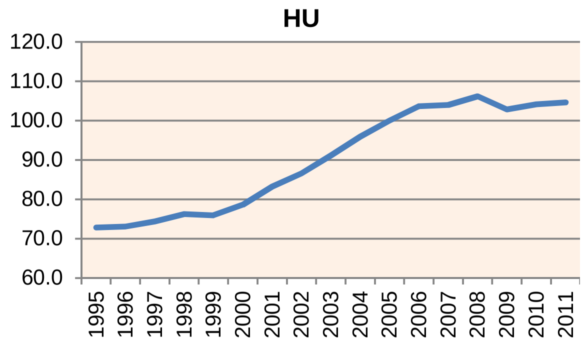
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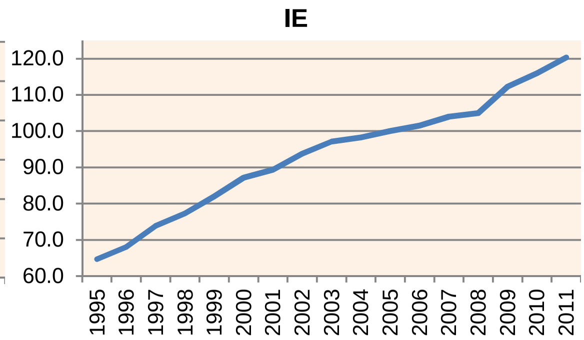
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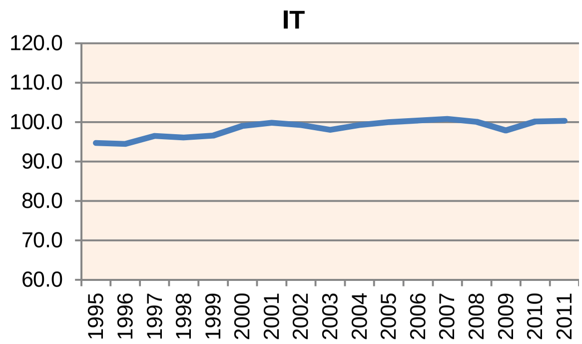
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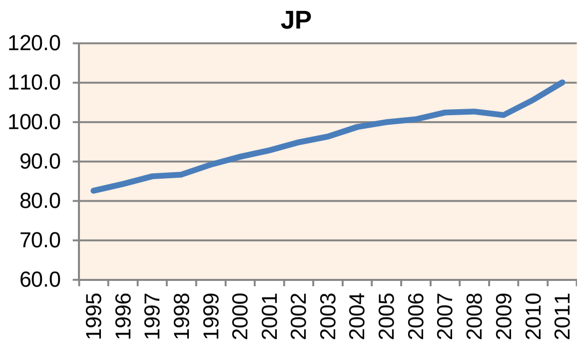
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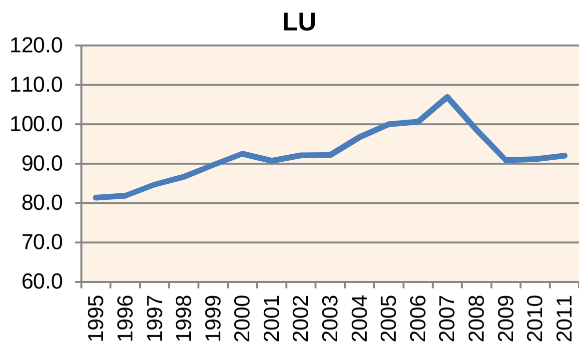
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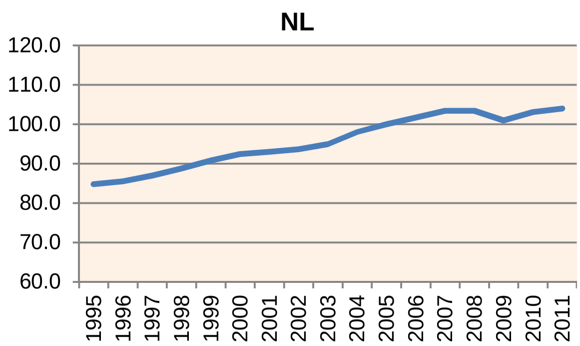
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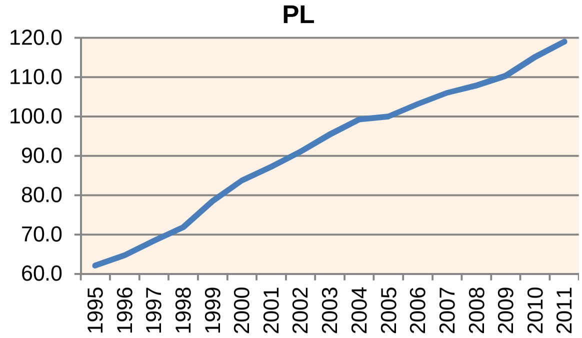
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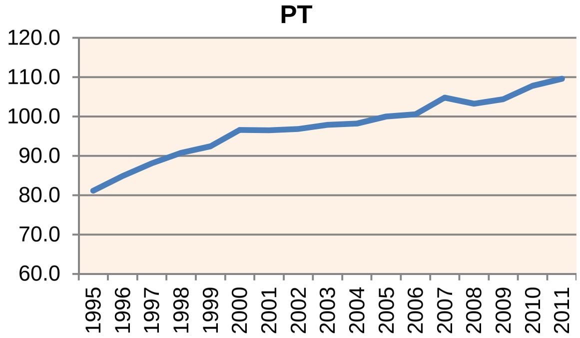
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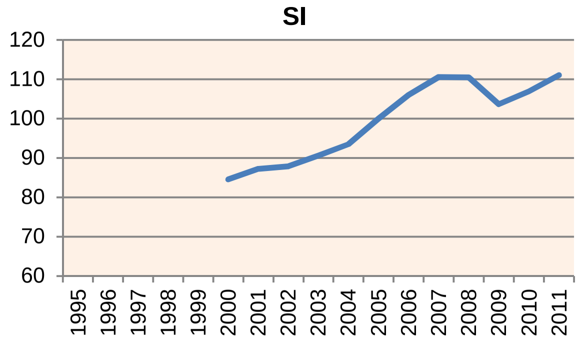
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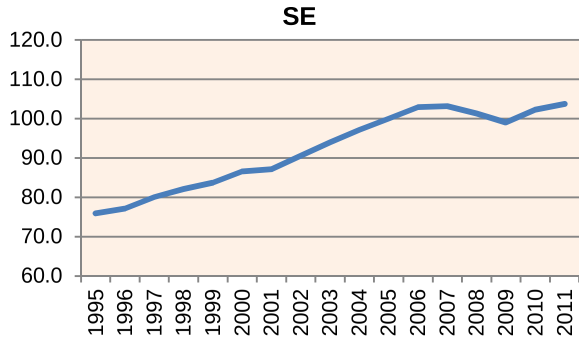
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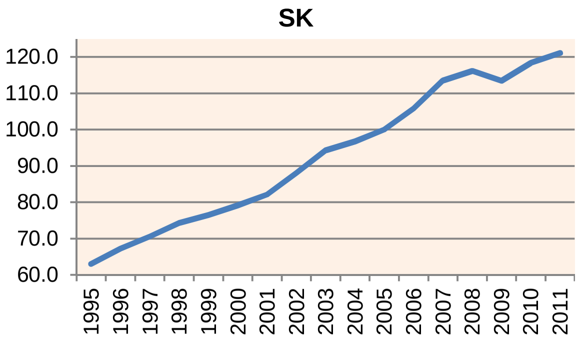
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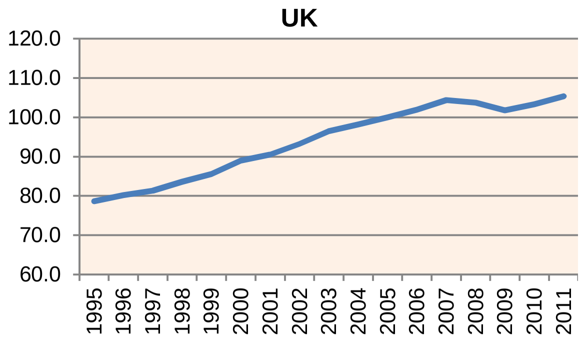
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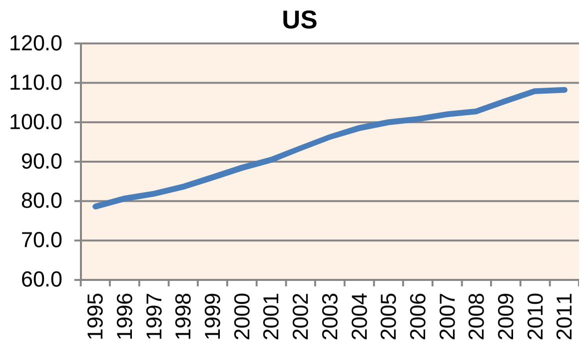
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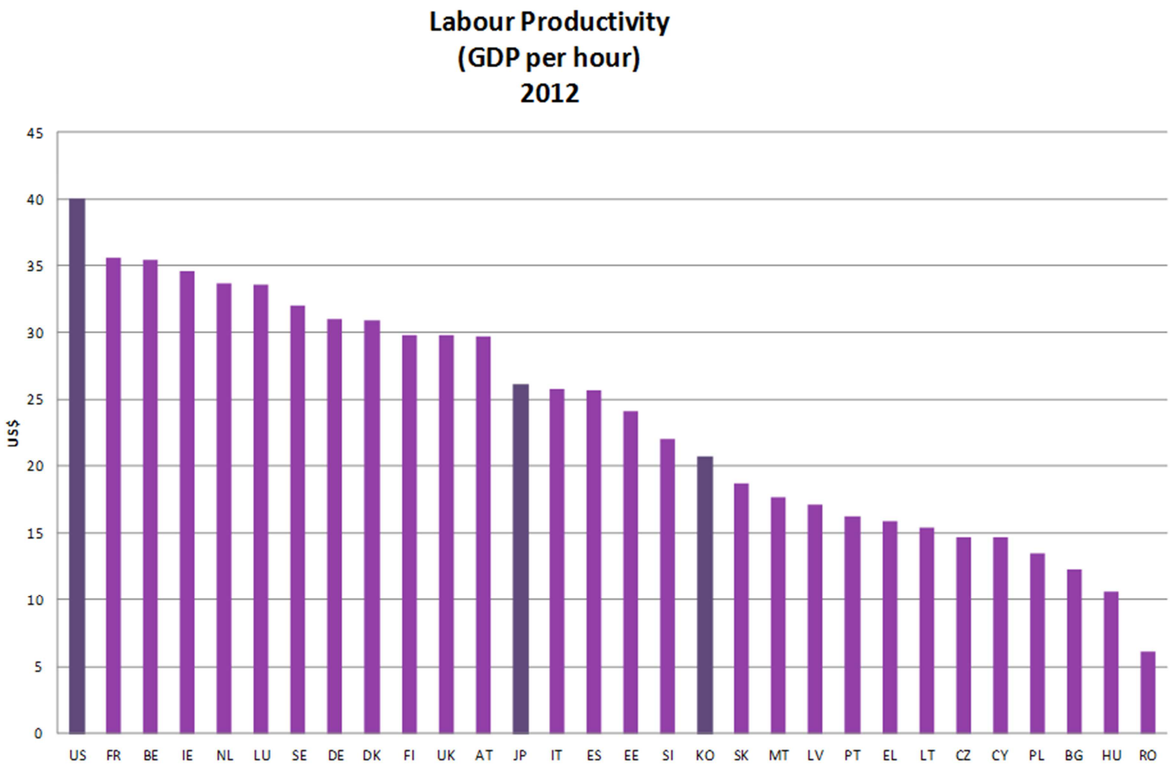
Figure A.2 / Labour productivity levels. GDP per hour (US dollars, Geary Khamis 1990 price levels)



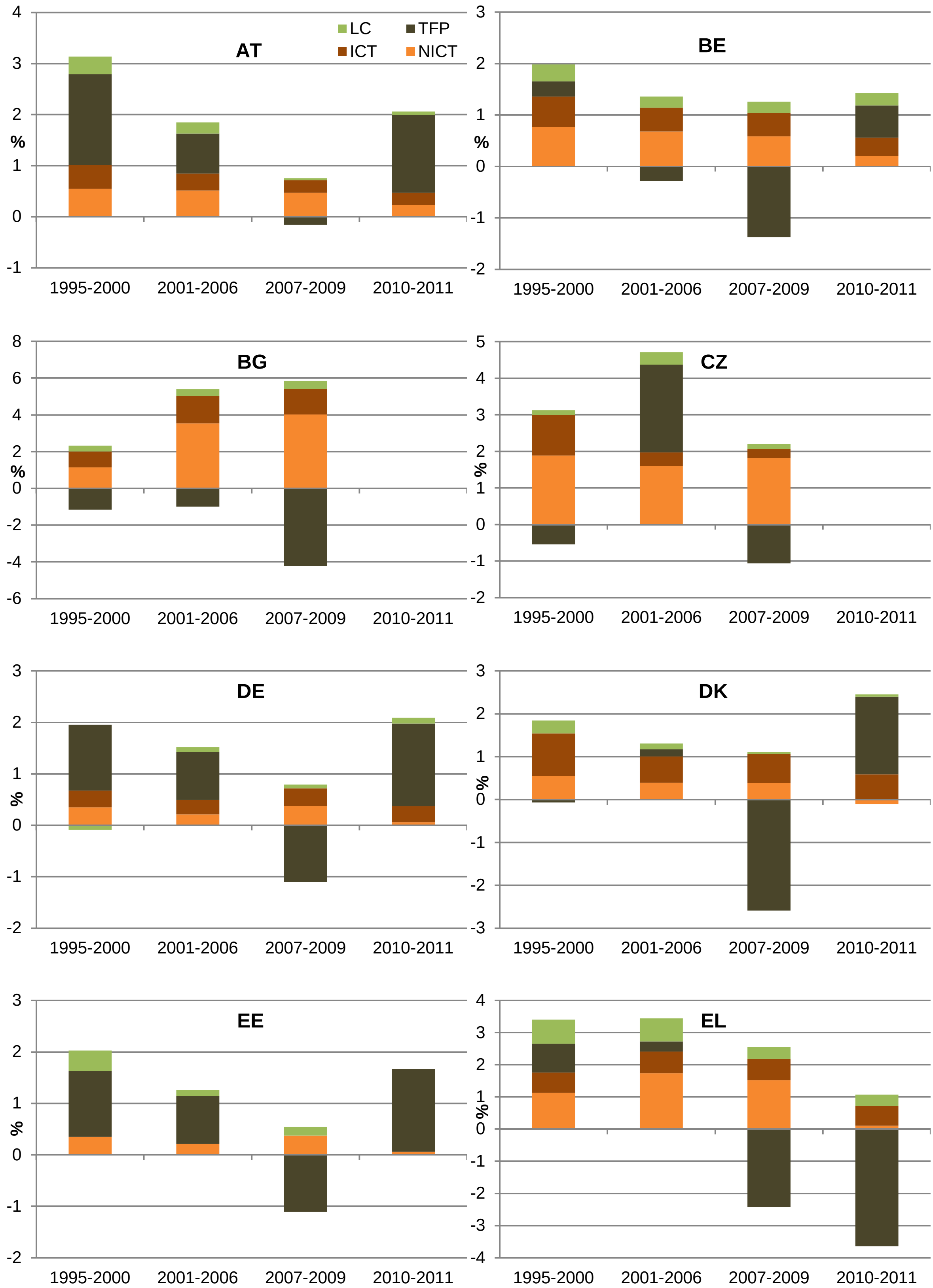
Source: Total Economy Database, The Conference Board, January 2013.

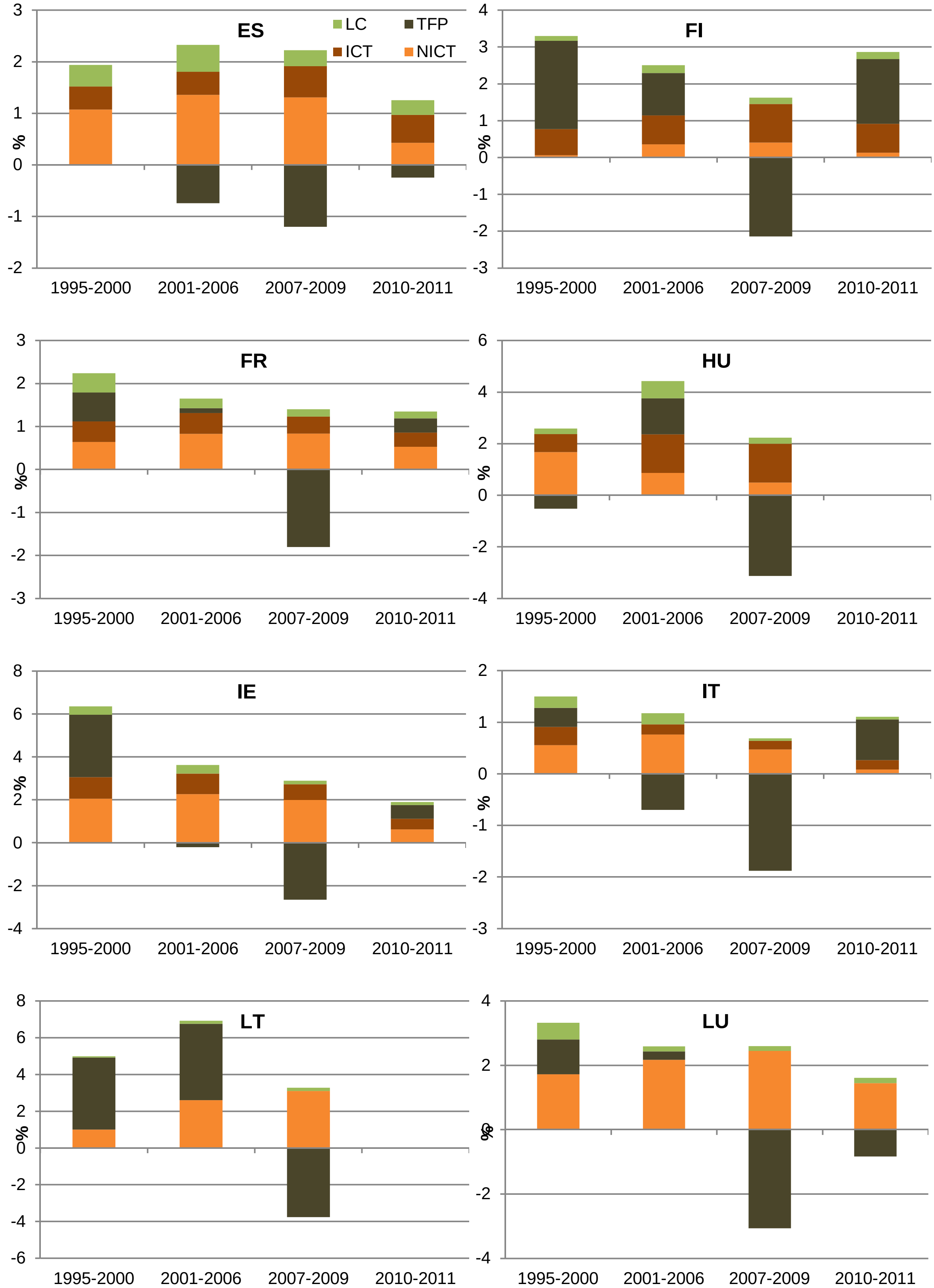
Table A.5 / Multifactor productivity growth rates (annual %), 1990-2011

	1990-1995	1995-2000	2000-2005	2005-2010	2011
AT	1.6	1.0	0.4	0.8	1.4
BE	0.3	0.6	-0.4	-0.6	0.5
BG	-0.9	-1.4	-0.8	-2.9	-
CY	-2.6	2.2	1.0	0.1	-0.5
CZ	-0.1	-1.0	1.9	0.3	-
DK	-2.2	-1.4	-0.1	-2.0	-
EE	0.7	6.9	3.3	-1.0	-
FI	1.2	2.4	1.0	-0.3	0.9
FR	0.1	0.6	-0.1	-0.7	-
DE	1.3	1.2	0.5	0.3	1.4
EL	-0.8	1.0	-0.2	-1.7	-3.1
HU	0.9	-0.8	1.5	-1.7	-
IE	2.5	2.6	-0.2	-1.6	0.6
IT	1.0	-	-0.8	-0.9	0.3
LV	-	2.7	3.0	-2.3	-
LT	-	4.7	4.3	-1.5	-
LU	0.3	1.6	0.2	-1.7	-1.7
MT	3.6	1.4	0.3	1.1	2.0
NL	0.6	0.8	0.2	0.1	1.2
PL	3.0	3.8	0.2	0.9	-
PT	-0.5	0.2	-1.7	-0.7	-2.3
RO	-	-0.9	6.6	1.7	-
ES	0.3	-0.4	-0.8	-0.8	-0.5
SK	2.7	2.2	2.9	1.7	-
SI	0.2	2.2	0.7	-0.9	-
SE	0.4	1.3	1.6	-0.6	1.6
UK	1.1	0.6	0.5	-0.5	-0.4
US	0.4	1.0	0.7	-	0.2
JP	-0.2	-0.2	0.7	0.4	-0.4

Source: Total Economy Database, The Conference Board, January 2013.

Figure A.3 / Growth accounting for EU-27 countries, 1995-2011

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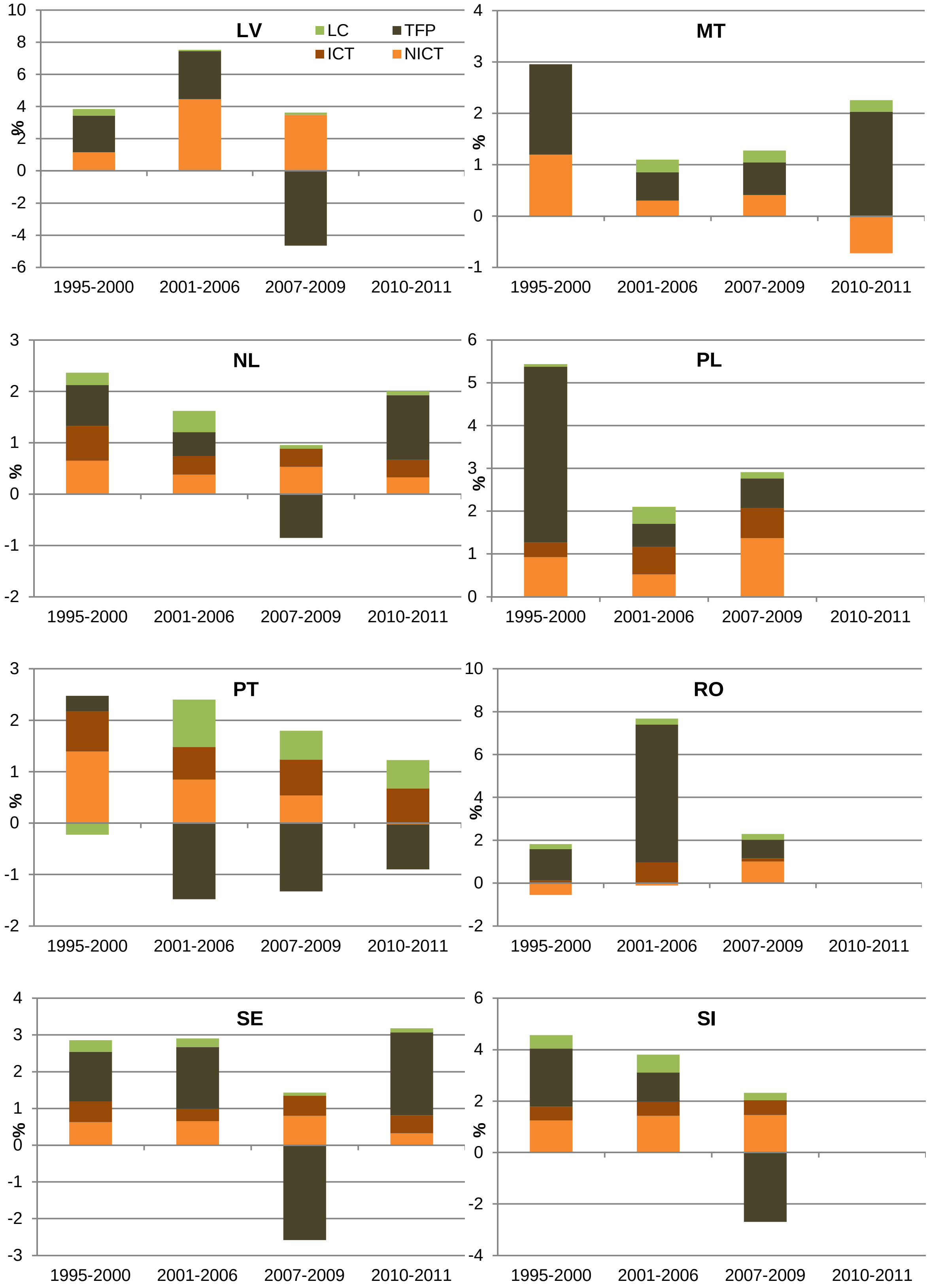
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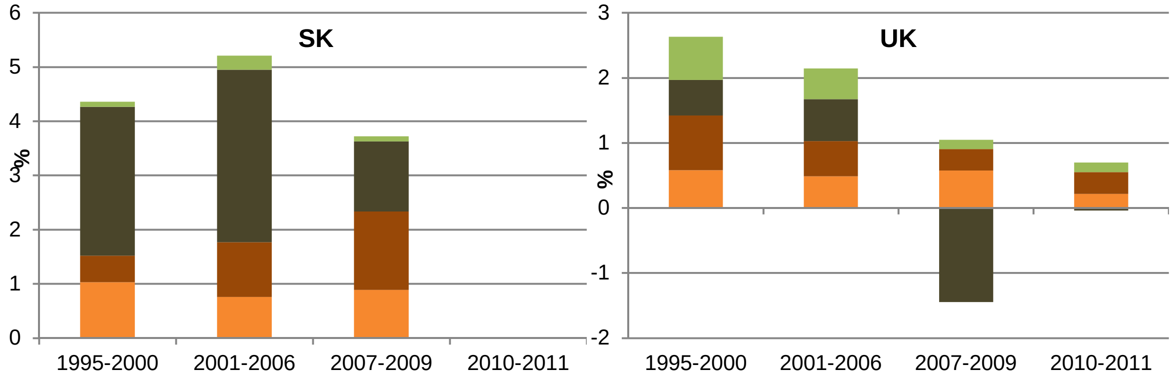
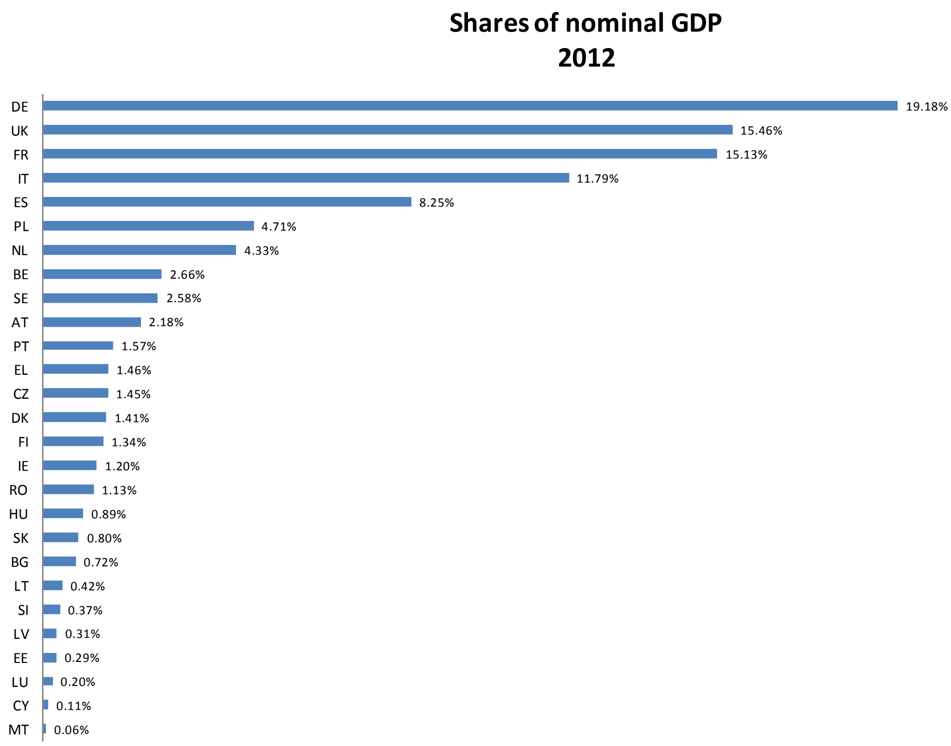


Figure A.4 / Shares of nominal GDP, EU-27 countries (US dollars, GK 1990 price levels)



Source: Total Economy Database, The Conference Board, January 2013.

Table A.6 / Labour productivity growth rates by sector and sub-period in the EU-8 and the US (%), 1995-2010

		US			EU-8		
NACE Rev. 2	**NACE Description**	**1995-2004**	**2004-2007**	**2007-2010**	**1995-2004**	**2004-2007**	**2007-2010**
TOT	TOTAL INDUSTRIES	2,32	0,98	1,72	1,68	2,72	0,59
A	AGRICULTURE, FORESTRY AND FISHING	6,39	0,07	6,47	3,05	4,68	-1,94
B	MINING AND QUARRYING	-1,92	-10,61	3,68	6,46	1,63	7,15
C	TOTAL MANUFACTURING	5,89	4,21	4,46	3,05	5,98	-1,28
10-12	Food products, beverages and tobacco	-1,19	5,76	-0,70	1,89	5,46	-4,88
13-15	Textiles, wearing apparel, leather and related prodcuts	5,92	-0,22	15,85	3,26	4,68	0,41
16-18	Wood and paper products; printing and reproduction of recorded media	2,10	2,37	1,86	1,85	4,29	0,67
19	Coke and refined petroleum products	14,94	-6,65	6,99	8,02	27,58	45,80
20-21	Chemicals and chemical products	3,86	5,42	-3,71	4,91	13,45	-4,11
22-23	Rubber and plastics products, and other non-metallic mineral products	3,31	-1,78	1,80	2,19	2,79	-5,47
24-25	Basic metals and fabricated metal products, except machinery and equipment	2,34	-3,10	1,22	1,58	3,54	-1,15
26-27	Electrical and optical equipment	20,82	16,43	16,78	4,37	4,08	0,18
28	Machinery and equipment n.e.c.	2,63	4,14	6,81	3,34	6,06	-4,97
29-30	Transport equipment	3,81	6,36	-9,65	2,58	9,02	-1,69
31-33	Other manufacturing; repair and installation of machinery and equipment	4,01	4,51	7,13	4,33	5,08	-0,29
D-E	ELECTRICITY, GAS AND WATER SUPPLY	2,32	-1,27	-1,00	5,85	-5,66	0,58
F	CONSTRUCTION	-1,12	-6,20	2,55	1,11	0,00	-3,45
G	WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES	4,84	1,35	1,27	1,47	3,01	0,92
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	-	-	-	-0,67	-0,71	-1,61
46	Wholesale trade, except of motor vehicles and motorcycles	5,84	1,04	-0,47	2,43	4,53	0,70
47	Retail trade, except of motor vehicles and motorcycles	2,33	1,49	2,94	1,27	1,97	2,02
H	TRANSPORTATION AND STORAGE	2,95	2,56	0,11	1,34	1,69	-0,31
49-52	Transport and storage	2,95	2,56	0,11	0,66	-0,09	-0,50
53	Postal and courier activities	-	-	-	5,65	14,21	0,98
I	ACCOMMODATION AND FOOD SERVICE ACTIVITIES	1,89	0,45	-0,19	0,06	0,96	0,74
J	INFORMATION AND COMMUNICATION	3,95	5,25	3,53	0,57	5,28	-1,89
58-60	Publishing, audiovisual and broadcasting activities	4,21	3,43	1,44	2,48	2,81	-3,64
61	Telecommunications	4,85	10,83	6,13	2,28	10,15	-0,09
62-63	IT and other information services	4,53	2,20	4,24	1,61	3,28	-0,72
K	FINANCIAL AND INSURANCE ACTIVITIES	3,63	1,53	4,89	6,18	4,94	6,29
L	REAL ESTATE ACTIVITIES	0,77	2,61	2,89	1,01	-2,83	0,99
M-N	PROFESSIONAL, SCIENTIFIC, TECHNICAL, ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES	1,31	0,28	1,39	-0,27	2,30	2,69
O-U	COMMUNITY SOCIAL AND PERSONAL SERVICES	-0,05	-0,14	0,39	-0,02	1,47	0,42
O	Public administration and defence; compulsory social security	0,24	-0,13	0,42	-0,32	1,36	1,72
P	Education	-0,57	-2,37	-1,14	-0,86	1,51	-1,08
Q	Health and social work	-0,33	-0,05	1,29	-0,21	0,86	0,32
R-S	ARTS, ENTERTAINMENT, RECREATION AND OTHER SERVICE ACTIVITIES	-0,17	0,45	-0,95	-1,05	1,34	1,53
R	Arts, entertainment and recreation	0,91	2,65	0,88	-0,36	2,09	0,29
S	Other service activities	-0,56	-0,41	-1,67	-0,14	2,25	-0,36
T	Activities of households as employers	-	-	-	-2,52	0,86	-0,67

Source: EUKLEMS dataset, own calculations.

Table A.7 / Sectoral value added shares in the EU-8 and the US, 1995-2010

NACE Rev. 2		US				EU-8			
		Total	1995-2004	2004-2007	2007-2010	Total	1995-2004	2004-2007	2007-2010
A	AGRICULTURE, FORESTRY AND FISHING	1.07	1.11	1.04	1.06	1.12	1.38	1.04	0.94
B	MINING AND QUARRYING	1.51	1.11	1.60	1.81	0.63	0.61	0.62	0.67
C	TOTAL MANUFACTURING	12.63	14.00	12.34	11.57	17.23	19.18	16.90	15.60
10-12	Food products, beverages and tobacco	1.45	1.62	1.35	1.39	2.49	2.76	2.42	2.30
13-15	Textiles, wearing apparel, leather and related prodcuts	0.35	0.52	0.30	0.23	0.48	0.63	0.44	0.38
16-18	Wood and paper products; printing and reproduction of recorded media	1.02	1.29	0.97	0.81	1.31	1.53	1.28	1.13
19	Coke and refined petroleum products	0.87	0.54	1.04	1.02	0.18	0.20	0.19	0.14
20-21	Chemicals and chemical products	1.58	1.63	1.54	1.56	2.68	2.89	2.62	2.54
22-23	Rubber and plastics products, and other non-metallic mineral products	0.88	1.06	0.85	0.73	3.75	4.35	3.69	3.23
24-25	Basic metals and fabricated metal products, except machinery and equipment	1.42	1.64	1.38	1.23	2.63	2.80	2.63	2.44
26-27	Electrical and optical equipment	1.86	1.93	1.75	1.88	1.25	1.44	1.21	1.10
28	Machinery and equipment n.e.c.	0.94	1.08	0.87	0.88	1.76	1.86	1.74	1.68
29-30	Transport equipment	1.44	1.80	1.46	1.06	1.10	1.22	1.09	0.99
31-33	Other manufacturing; repair and installation of machinery and equipment	0.83	0.88	0.82	0.78	1.59	1.75	1.54	1.48
D-E	ELECTRICITY, GAS AND WATER SUPPLY	2.08	2.14	2.01	2.10	1.62	1.61	1.58	1.67
F	CONSTRUCTION	4.44	4.45	4.76	4.09	6.28	5.73	6.51	6.61
G	WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES	12.39	13.10	12.33	11.74	12.73	12.98	12.70	12.51
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	0.00	0.00	0.00	0.00	1.67	1.72	1.78	1.52
46	Wholesale trade, except of motor vehicles and motorcycles	5.21	4.20	5.77	5.65	5.66	5.80	5.82	5.35
47	Retail trade, except of motor vehicles and motorcycles	5.83	4.83	6.55	6.09	4.98	5.46	5.09	4.38
H	TRANSPORTATION AND STORAGE	2.92	3.00	2.92	2.84	3.20	3.27	3.21	3.14
49-52	Transport and storage	2.92	3.00	2.92	2.84	2.73	2.86	2.84	2.50
53	Postal and courier activities	0.00	0.00	0.00	0.00	0.86	0.99	0.88	0.70
I	ACCOMMODATION AND FOOD SERVICE ACTIVITIES	2.85	2.79	2.90	2.85	1.95	1.88	1.96	2.00
J	INFORMATION AND COMMUNICATION	5.58	5.47	5.64	5.63	4.38	4.28	4.45	4.39
58-60	Publishing, audiovisual and broadcasting activities	1.51	1.52	1.57	1.45	1.16	1.21	1.14	1.14
61	Telecommunications	2.48	2.56	2.43	2.45	2.65	2.72	2.72	2.51
62-63	IT and other information services	1.59	1.39	1.65	1.74	1.60	1.41	1.65	1.75
K	FINANCIAL AND INSURANCE ACTIVITIES	7.75	7.46	7.92	7.85	7.13	6.67	7.14	7.58
L	REAL ESTATE ACTIVITIES	12.60	12.41	12.54	12.83	13.13	12.48	13.33	13.58
M-N	PROFESSIONAL, SCIENTIFIC, TECHNICAL, ADMINISTRATIVE AND SUPPORT SERVICES	10.19	9.51	10.34	10.73	7.28	6.95	7.39	7.50
O-U	COMMUNITY SOCIAL AND PERSONAL SERVICES	23.99	23.45	23.64	24.90	23.32	22.99	23.17	23.81
O	Public administration and defence; compulsory social security	12.84	12.73	12.57	13.21	7.07	7.13	6.97	7.12
P	Education	0.97	0.88	0.97	1.07	3.41	3.37	3.38	3.48
Q	Health and social work	6.71	6.27	6.65	7.23	7.41	6.90	7.45	7.87
R-S	ARTS, ENTERTAINMENT, RECREATION AND OTHER SERVICE ACTIVITIES	3.47	3.58	3.45	3.39	1.40	1.33	1.43	1.44
R	Arts, entertainment and recreation	0.94	0.92	0.96	0.95	3.21	3.21	3.21	3.22
S	Other service activities	2.53	2.66	2.49	2.44	1.45	1.51	1.43	1.42

Source: EUKLEMS dataset, own calculations.

Table A.8 / Sectoral contributions to labour productivity growth, EU-8, 1995-2010

NACE Rev. 2	NACE Description	EU-8 1995-2004	EU-8 2004-2007	EU-8 2007-2010
TOT	TOTAL	1,55	2,13	0,58
A	AGRICULTURE, FORESTRY AND FISHING	0,04	0,05	-0,02
B	MINING AND QUARRYING	0,04	0,01	0,05
C	TOTAL MANUFACTURING	0,59	1,01	-0,20
10-12	Food products, beverages and tobacco	0,05	0,13	-0,11
13-15	Textiles, wearing apparel, leather and related prodcuts	0,02	0,02	0,00
16-18	Wood and paper products; printing and reproduction of recorded media	0,03	0,05	0,01
19	Coke and refined petroleum products	0,01	0,05	0,07
20-21	Chemicals and chemical products	0,14	0,35	-0,11
22-23	Rubber and plastics products, and other non-metallic mineral products	0,10	0,10	-0,18
24-25	Basic metals and fabricated metal products, except machinery and equipment	0,05	0,09	-0,04
26-27	Electrical and optical equipment	0,06	0,05	0,00
28	Machinery and equipment n.e.c.	0,06	0,10	-0,08
29-30	Transport equipment	0,03	0,10	-0,01
31-33	Other manufacturing; repair and installation of machinery and equipment	0,08	0,08	0,00
D-E	ELECTRICITY, GAS AND WATER SUPPLY	0,09	-0,09	0,01
F	CONSTRUCTION	0,06	0,00	-0,23
G	WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES	0,19	0,38	0,11
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	-0,01	-0,01	-0,03
46	Wholesale trade, except of motor vehicles and motorcycles	0,14	0,26	0,03
47	Retail trade, except of motor vehicles and motorcycles	0,07	0,10	0,08
H	TRANSPORTATION AND STORAGE	0,04	0,05	-0,01
49-52	Transport and storage	0,02	0,00	-0,01
53	Postal and courier activities	0,06	0,13	0,01
I	ACCOMMODATION AND FOOD SERVICE ACTIVITIES	0,00	0,02	0,01
J	INFORMATION AND COMMUNICATION	0,03	0,24	-0,08
58-60	Publishing, audiovisual and broadcasting activities	0,03	0,03	-0,04
61	Telecommunications	0,07	0,28	0,00
62-63	IT and other information services	0,02	0,05	-0,01
K	FINANCIAL AND INSURANCE ACTIVITIES	0,41	0,35	0,49
L	REAL ESTATE ACTIVITIES	0,13	-0,37	0,13
M-N	PROFESSIONAL, SCIENTIFIC, TECHNICAL, ADMINISTRATIVE AND SUPPORT SERVICES	-0,02	0,17	0,20
O-U	COMMUNITY SOCIAL AND PERSONAL SERVICES	-0,07	0,32	0,10
O	Public administration and defence; compulsory social security	0,00	0,10	0,12
P	Education	-0,03	0,05	-0,04
Q	Health and social work	-0,01	0,06	0,02
R-S	ARTS, ENTERTAINMENT, RECREATION AND OTHER SERVICE ACTIVITIES	-0,01	0,02	0,02
R	Arts, entertainment and recreation	-0,01	0,07	0,01
S	Other service activities	0,00	0,03	0,00
T	Activities of households as employers	-0,02	0,01	-0,01
	Reallocation	0,13	0,59	0,01

Source: EUKLEMS dataset, own calculations.

Table A.9 / Sectoral contributions to labour productivity growth, US, 995-2010

		US		
NACE Rev. 2	**NACE Description**	**1995-2004**	**2004-2007**	**2007-2010**
TOT	TOTAL	2,34	1,04	2,08
A	AGRICULTURE, FORESTRY AND FISHING	0,07	0,00	0,07
B	MINING AND QUARRYING	-0,02	-0,16	0,07
C	TOTAL MANUFACTURING	0,81	0,52	0,50
10-12	Food products, beverages and tobacco	-0,02	0,08	0,00
13-15	Textiles, wearing apparel, leather and related prodcuts	0,03	0,00	0,03
16-18	Wood and paper products; printing and reproduction of recorded media	0,02	0,02	0,01
19	Coke and refined petroleum products	0,08	-0,07	0,07
20-21	Chemicals and chemical products	0,06	0,08	-0,06
22-23	Rubber and plastics products, and other non-metallic mineral products	0,03	-0,02	0,01
24-25	Basic metals and fabricated metal products, except machinery and equipment	0,03	-0,04	0,01
26-27	Electrical and optical equipment	0,40	0,29	0,32
28	Machinery and equipment n.e.c.	0,03	0,04	0,06
29-30	Transport equipment	0,07	0,09	-0,11
31-33	Other manufacturing; repair and installation of machinery and equipment	0,04	0,04	0,06
D-E	ELECTRICITY, GAS AND WATER SUPPLY	0,05	-0,03	-0,02
F	CONSTRUCTION	-0,05	-0,30	0,10
G	WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES	0,64	0,17	0,14
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	-	-	-
46	Wholesale trade, except of motor vehicles and motorcycles	0,23	0,06	-0,03
47	Retail trade, except of motor vehicles and motorcycles	0,11	0,10	0,18
H	TRANSPORTATION AND STORAGE	0,09	0,08	0,00
49-52	Transport and storage	0,09	0,08	0,00
53	Postal and courier activities	-	-	-
I	ACCOMMODATION AND FOOD SERVICE ACTIVITIES	0,05	0,01	-0,01
J	INFORMATION AND COMMUNICATION	0,22	0,30	0,20
58-60	Publishing, audiovisual and broadcasting activities	0,06	0,05	0,02
61	Telecommunications	0,12	0,26	0,15
62-63	IT and other information services	0,07	0,04	0,07
K	FINANCIAL AND INSURANCE ACTIVITIES	0,27	0,12	0,39
L	REAL ESTATE ACTIVITIES	0,09	0,33	0,38
M-N	PROFESSIONAL, SCIENTIFIC, TECHNICAL, ADMINISTRATIVE AND SUPPORT SERVICES	0,13	0,03	0,15
O-U	COMMUNITY SOCIAL AND PERSONAL SERVICES	-0,01	-0,03	0,10
O	Public administration and defence; compulsory social security	0,03	-0,02	0,06
P	Education	0,00	-0,02	-0,01
Q	Health and social work	-0,02	0,00	0,09
R-S	ARTS, ENTERTAINMENT, RECREATION AND OTHER SERVICE ACTIVITIES	-0,01	0,02	-0,03
R	Arts, entertainment and recreation	0,01	0,03	0,01
S	Other service activities	-0,01	-0,01	-0,04
T	Activities of households as employers	-	-	-
	Reallocation	-0,37	0,96	-0,36

Source: EUKLEMS dataset, own calculations.

Figure A.5.A / Factor contribution to value added growth in the EU-8, Agriculture, forestry and fishing, 1990-2009

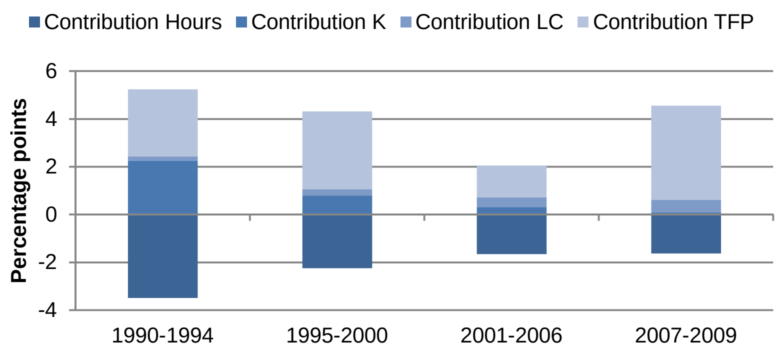


Figure A.5.B / Factor contribution to value added growth in the US, Agriculture, forestry and fishing, 1990-2009

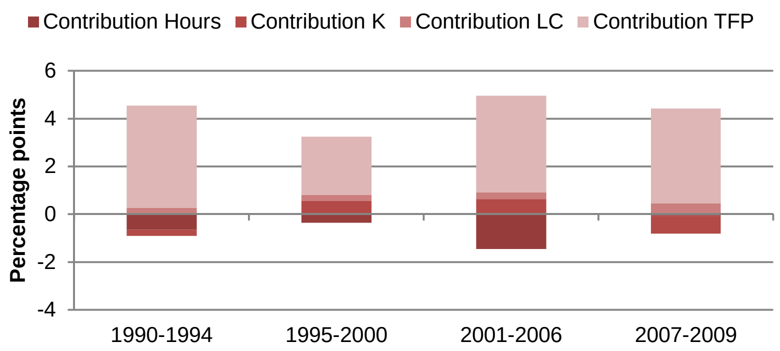


Figure A.5.C / Factor contribution to value added growth in the EU-8, Mining and quarrying (B), 1990-2009

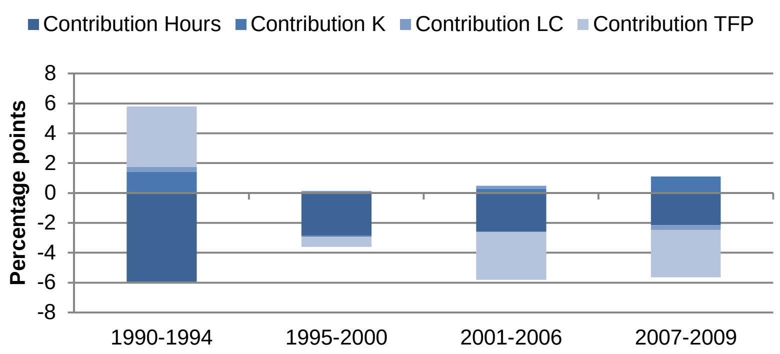


Figure A.5.D / Factor contribution to value added growth in the US, Mining and quarrying (B), 1990-2009

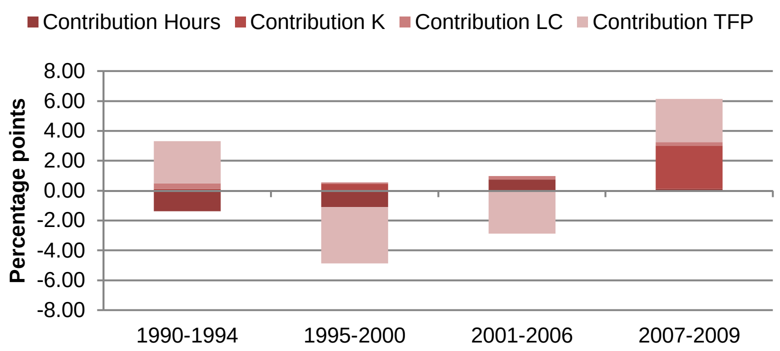


Figure A.5.E / Factor contribution to value added growth in the EU-8, Total Manufacturing (C), 1990-2009

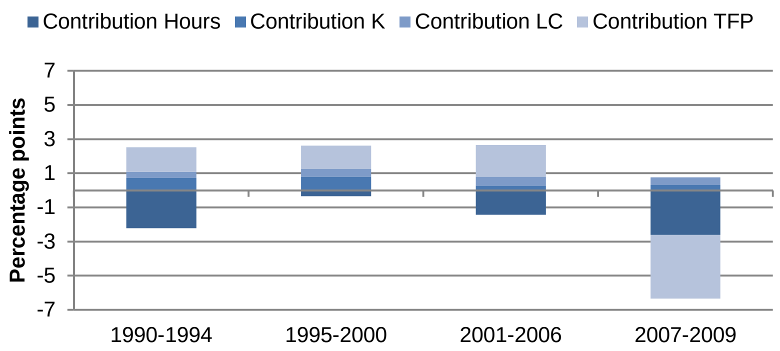


Figure A.5.F / Factor contribution to value added growth in the US, Total Manufacturing (C), 1990-2009

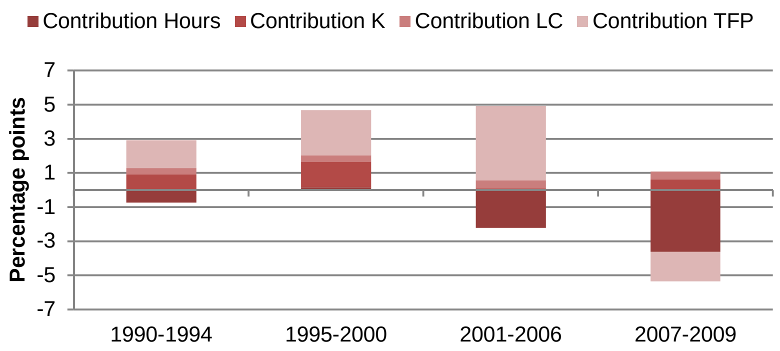


Figure A.5.G / Factor contribution to value added growth in the EU-8, Electricity, gas and water supply (D-E). 1990-2009

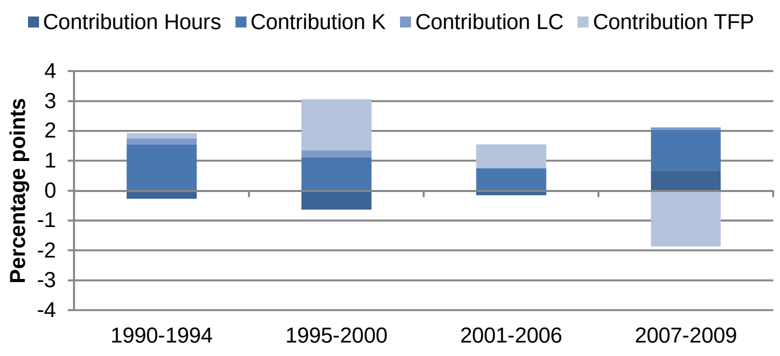


Figure A.5.H / Factor contribution to value added growth in the US, Electricity, gas and water supply (D-E). 1990-2009

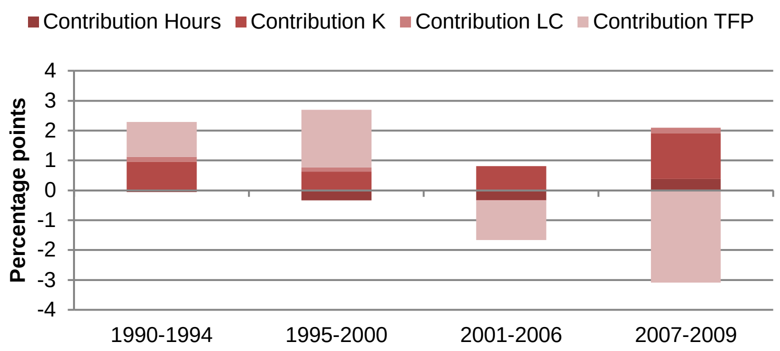


Figure A.5.I / Factor contribution to value added growth in the EU-8, Construction (F), 1990-2009

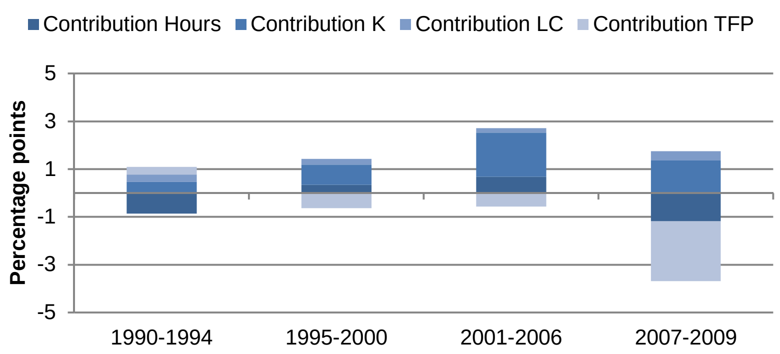


Figure A.5.J / Factor contribution to value added growth in the US, Construction (F), 1990-2009

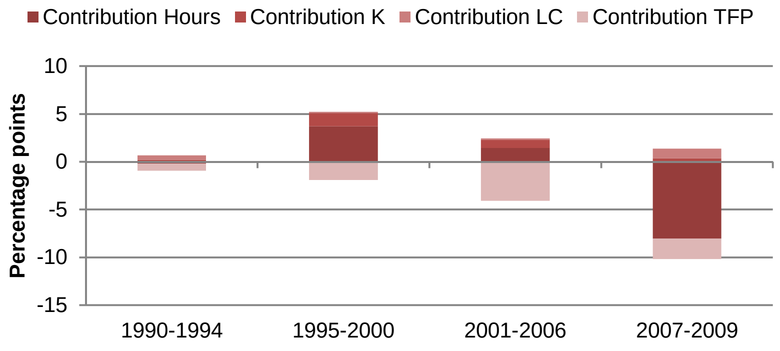


Figure A.5.K / Factor contribution to value added growth in the EU-8, Wholesale and retail, (G), 1990-2009

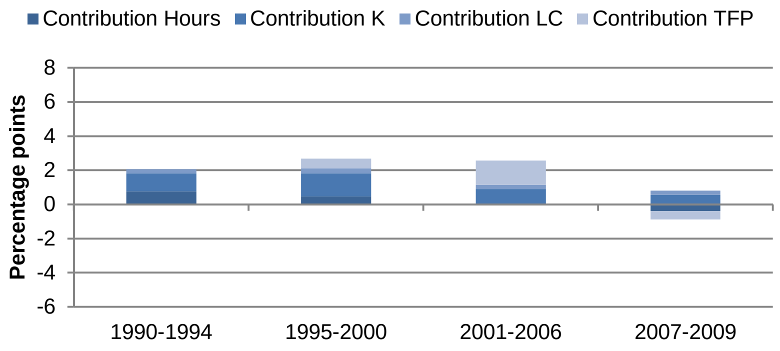


Figure A.5.L / Factor contribution to value added growth in the US, Wholesale and retail, (G), 1990-2009

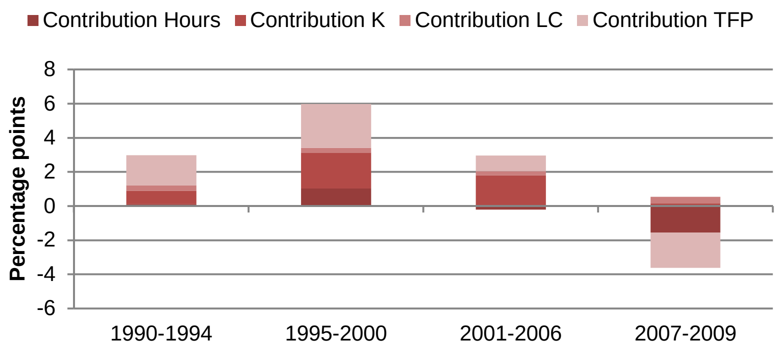


Figure A.5.M / Factor contribution to value added growth in the EU-8, Transport and storage (H), 1990-2009

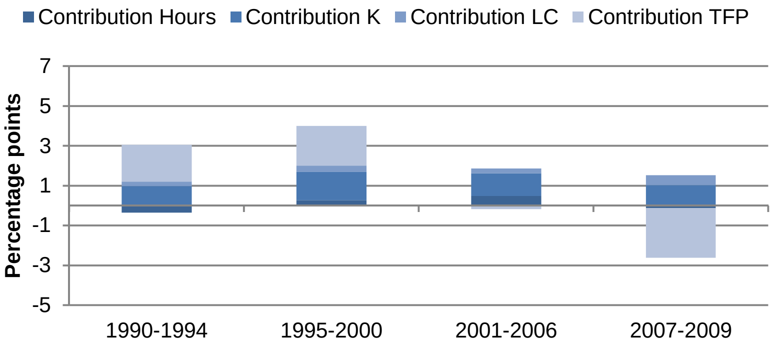


Figure A.5.N / Factor contribution to value added growth in the US, Transport and storage (H), 1990-2009

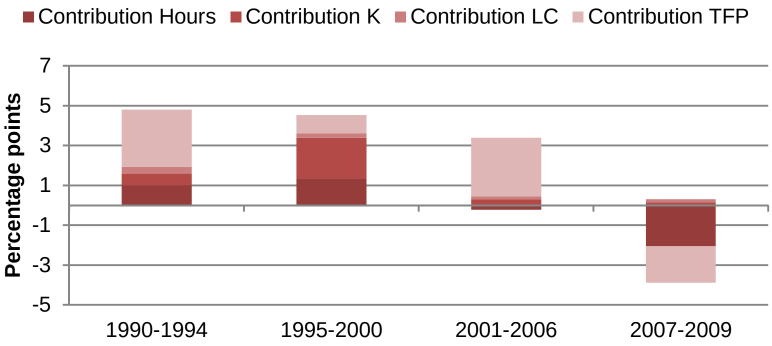


Figure A.5.O / Factor contribution to value added growth in the EU-8, Accommodation and food service activities (I), 1990-2009

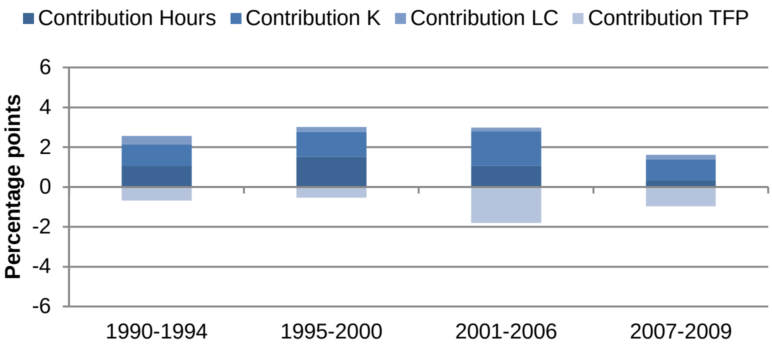


Figure A.5.P / Factor contribution to value added growth in the US, Accommodation and food service activities (I), 1990-2009

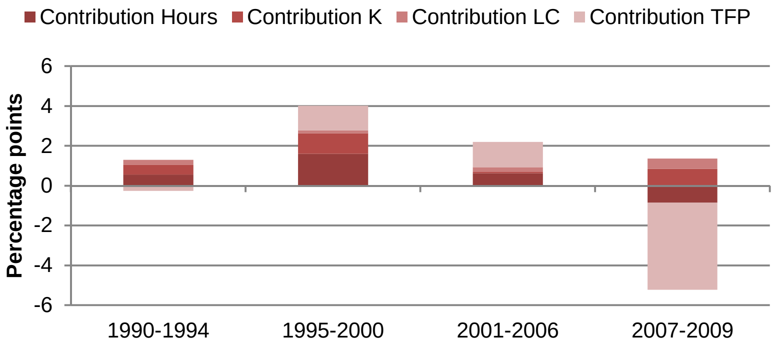


Figure A.5.Q / Factor contribution to value added growth in the EU-8, Information and communication (J), 1990-2009

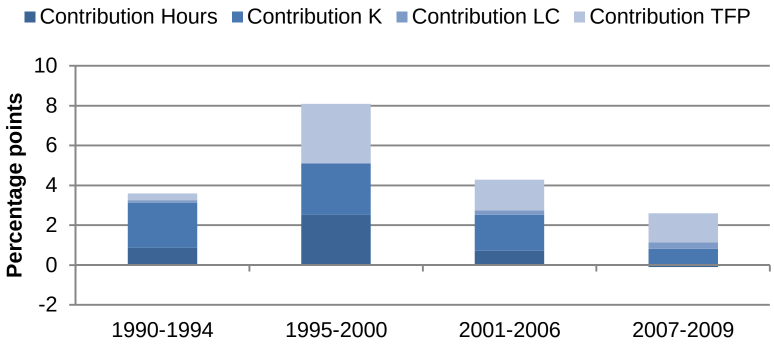


Figure A.5.R / Factor contribution to value added growth in the US, Information and communication (J), 1990-2009

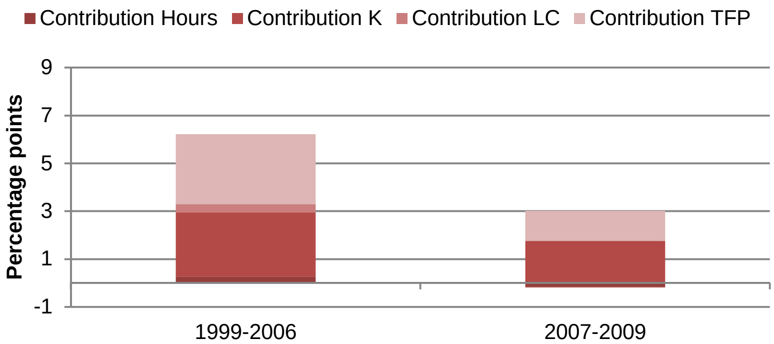


Figure A.5.S / Factor contribution to value added growth in the EU-8, Finance and insurance activities (K), 1990-2009

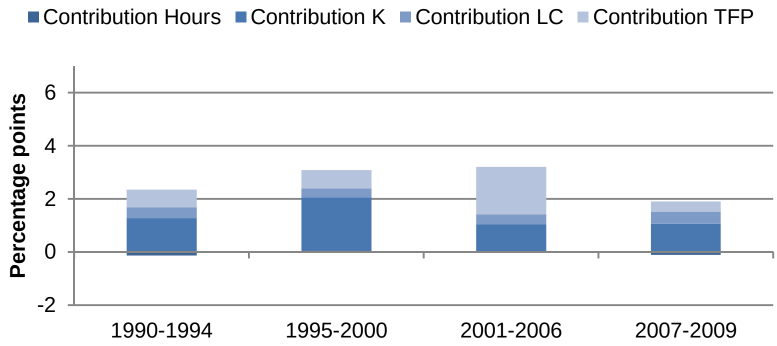


Figure A.5.T / Factor contribution to value added growth in the US, Finance and insurance activities (K), 1990-2009

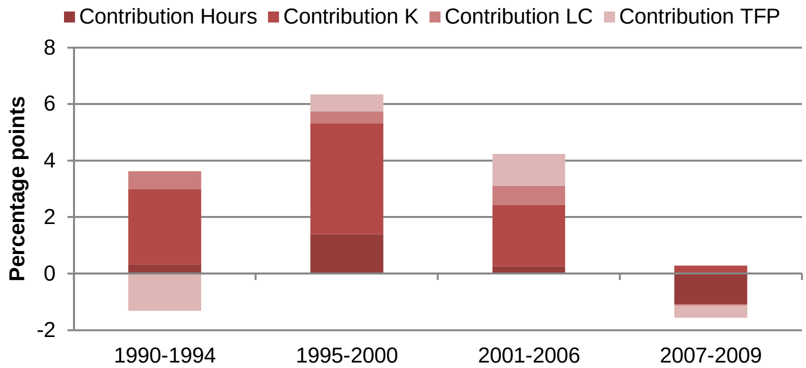


Figure A.5.U / Factor contribution to value added growth in the EU-8, Real Estate activities (K), 1990-2009

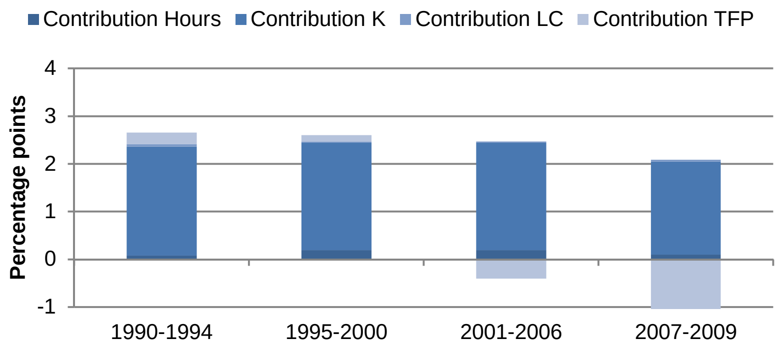


Figure A.5.V / Factor contribution to value added growth in the US, Real Estate activities (K), 1990-2009

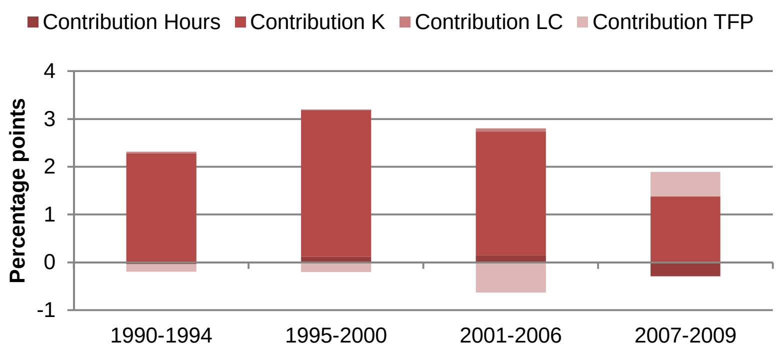


Figure A.5.W / Factor contribution to value added growth in the EU-8, Professional, Scientific, technical, administrative and support services (M-N), EU-8, 1990-2009

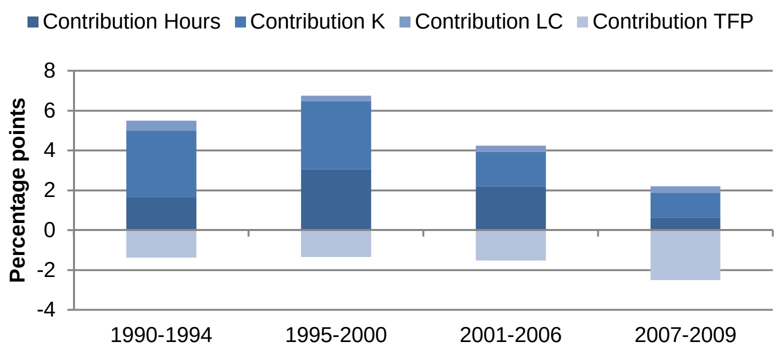


Figure A.5.X / Factor contribution to value added growth in the US, Professional, Scientific, technical, administrative and support services (M-N), US, 1990-2009

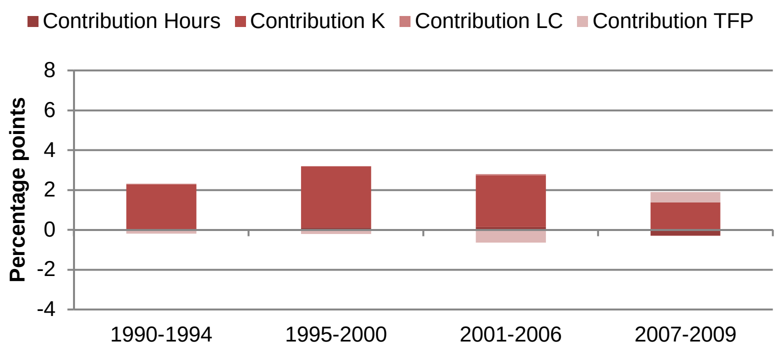


Figure A.5.Y / Factor contribution to value added growth in the EU-8, Community, social and personal services (O-U), 1990-2009

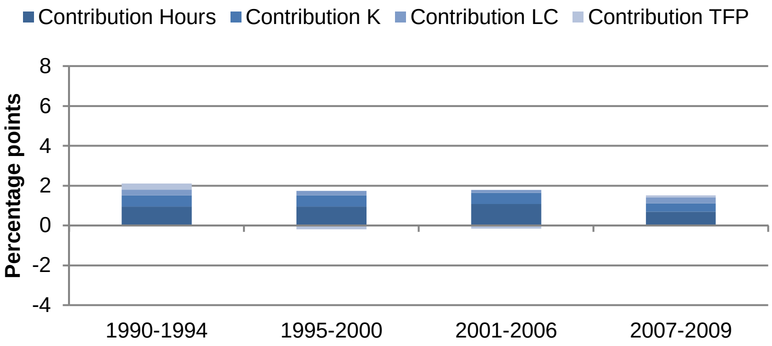


Figure A.5.Z / Factor contribution to value added growth in the US, Community, social and personal services (O-U), 1990-2009

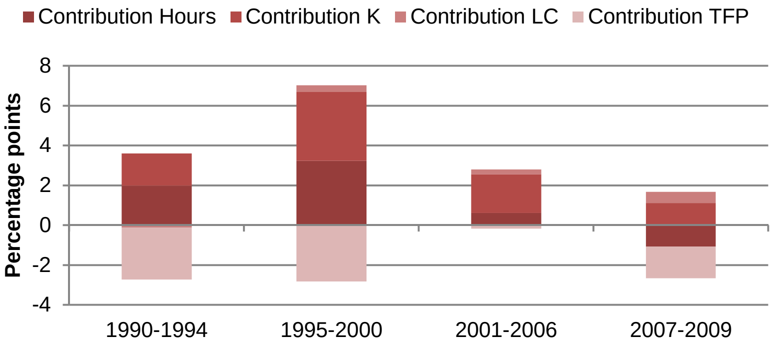
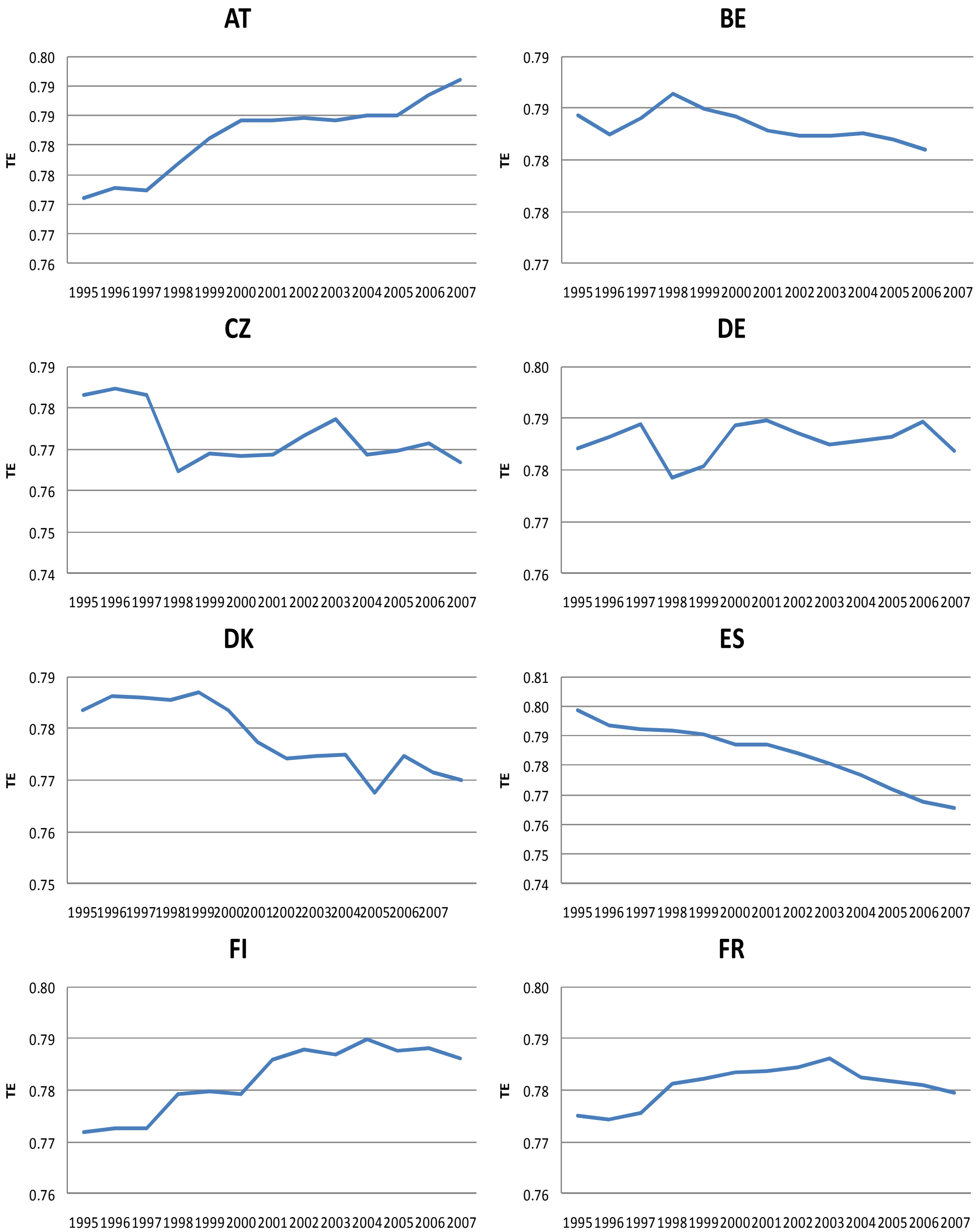


Figure A.6 / Technical efficiency trends: country average



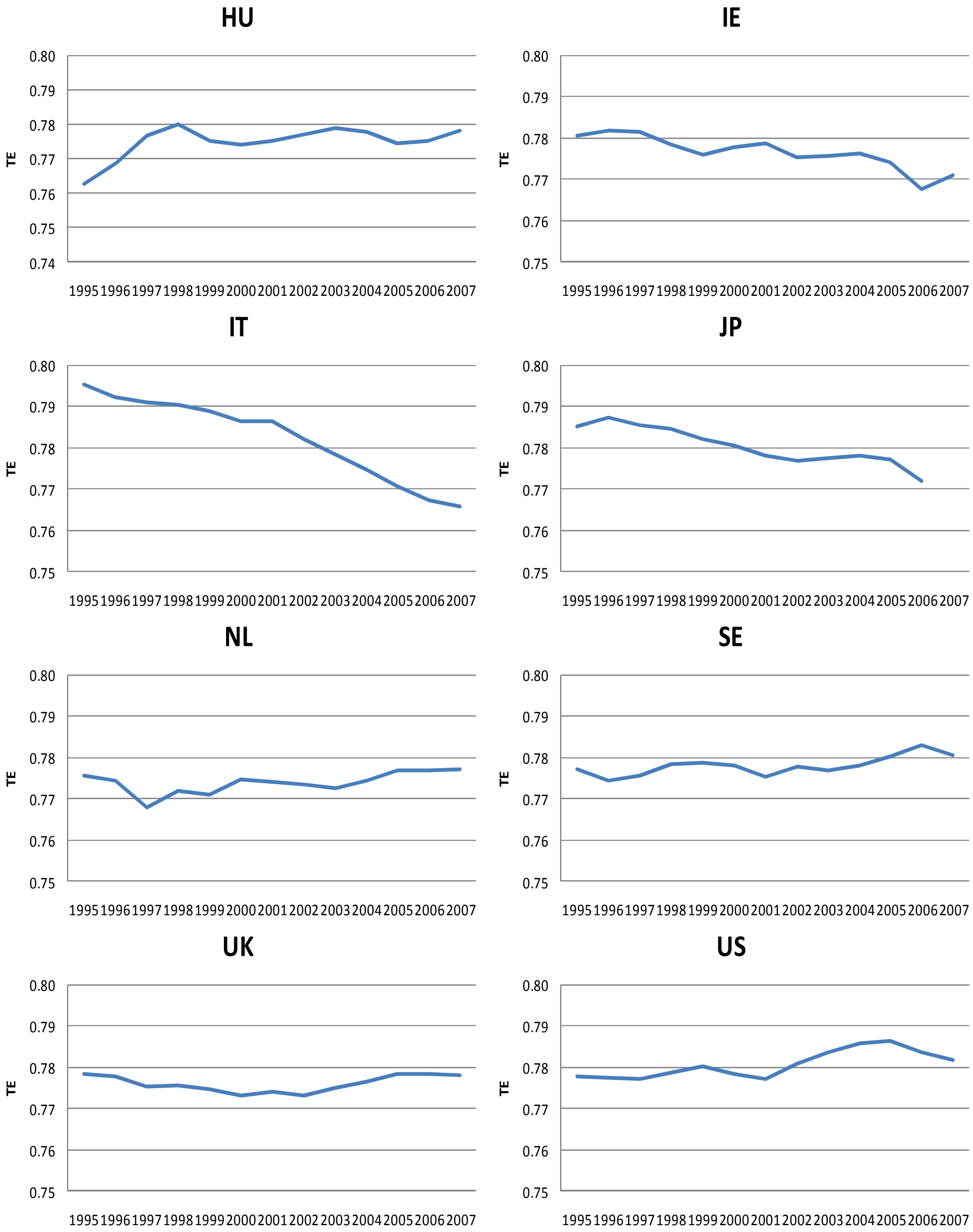

HU
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Table A.10 / Tests for stationarity

	Value added	Total hours	Total capital	Non-ICT capital	ICT capital	Labour quality	R&D capital
P	901.32	929.4951	1372.984	1225.531	1324.213	868.3818	169.525
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Z	0.878	-0.350	-1.664	0.235	-2.737	-0.124	-9.194
	(0.810)	(0.363)	(0.048)	(0.593)	(0.003)	(0.451)	(0.000)
L*	-0.229	-1.422	-5.771	-3.129	-6.925	-0.268	-19.526
	(0.409)	(0.078)	(0.000)	(0.001)	(0.000)	(0.395)	(0.000)
Pm	5.259	6.001	17.829	13.899	16.606	4.380	37.970
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: tests of the null hypothesis that all panels contain a unit root, following the 4 methods proposed by Choi (2001). Probability values in brackets. P = inverse chi-squared, Z= Inverse normal, L* = Inverse logit, Pm = Modified inverse chi - squared.

Table A.11 / Test for cointegration, based on models (5) - (8) of Table 6.1

	Model (1)	Model (2)	Model (3)	Model (4)
P	1039.227	1046.671	1168.807	1118.993
	(0.000)	(0.000)	(0.000)	(0.000)
Z	0.335	-0.385	-1.331	-1.6601
	(0.631)	(0.350)	(0.092)	(0.048)
L*	-1.6891	-2.367	-5.297	-5.152
	(0.046)	(0.009)	(0.000)	(0.000)
Pm	8.935	9.199	15.341	13.933
	(0.000)	(0.000)	(0.000)	(0.000)

Notes: tests of the null hypothesis that all panels contain a unit root, following the 4 methods proposed by Choi (2001). Probability values in brackets. P = inverse chi-squared, Z= Inverse normal, L* = Inverse logit, Pm = Modified inverse chi - squared.

Table A.12 / Estimation of production frontier and determinants of inefficiency: ICT and Product Market Competition

Production function	**(1)**	**(2)**	**(3)**	**(4)**
Total number of hours worked	0.562***	0.561***	0.644***	0.476***
	(0.036)	(0.036)	(0.047)	(0.047)
Total capital	0.418***	0.422***	0.308***	0.501***
	(0.027)	(0.027)	(0.037)	(0.039)
Labour quality	0.004**	0.004*	-0.003	-0.002
	(0.002)	(0.002)	(0.003)	(0.003)
R&D capital	0.061***	0.056***	0.155***	0.091***
	(0.007)	(0.008)	(0.011)	(0.012)
Determinants of inefficiency				
ICT capital	-0.623***	-0.636***	-0.693***	-0.004
	(0.043)	(0.044)	(0.075)	(0.055)
RI	3.081***	3.111***		
	(0.656)	(0.664)		
Enforcing contract time		0.639***		
		(0.174)		
Herfindal Index			0.747**	
			(0.369)	
Industry fragmentation				-1.097***
				(0.082)
year	0.115***	0.120***	0.103***	0.060***
	(0.019)	(0.019)	(0.025)	(0.019)
Observations				

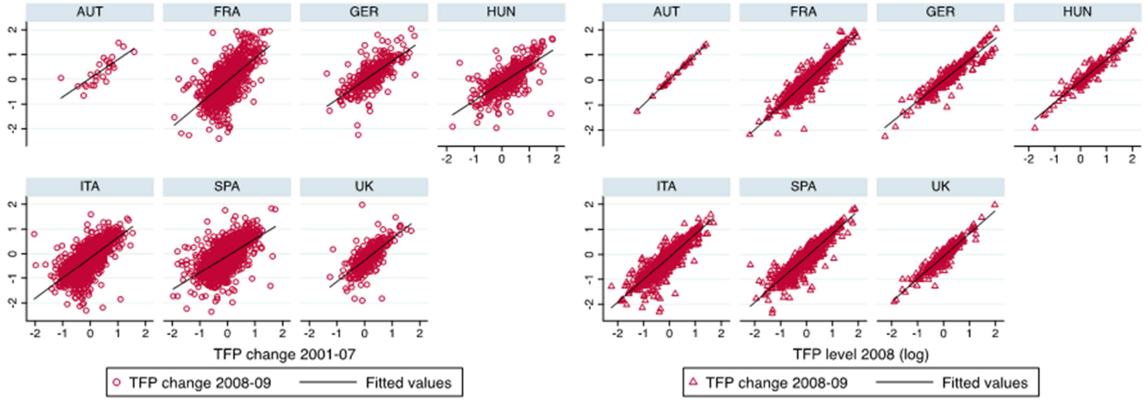
Table A.13 / Estimation of production frontier and determinants of inefficiency: ICT, Product market competition and employment protection legislation

Production function	**(1)**	**(2)**	**(3)**
Total number of hours worked	0.568***	0.567***	0.547***
	(0.04)	(0.036)	(0.04)
Total capital	0.500***	0.422***	0.446***
	(0.032)	(0.027)	(0.031)
Labour quality	-0.000	0.004**	0.004*
	(0.002)	(0.002)	(0.002)
R&D capital	0.021**	0.058***	0.061***
	(0.009)	(0.008)	(0.008)
Determinants of inefficiencies			
ICT capital	-0.574***	-0.559***	-0.557***
	(0.053)	(0.045)	(0.053)
RI	4.304***	2.926***	3.141***
	(0.9)	(0.642)	(0.751)
EPL burden indicator	0.142***		
	(0.018)		
EPL regular		4.351***	3.513***
		(0.673)	(0.781)
EPL temporary		-2.173***	-3.007***
		(0.465)	(0.536)
EPL collective dismissal			2.716**
			(01.089)
NMW			1.372***
			(0.208)
year	0.106***	0.093***	0.102***
	(0.022)	(0.019)	(0.024)
Observations	3146	3648	3021

Table A.14 / Estimation of production frontier and determinants of inefficiencies: financial market regulation, property rights protection and openness

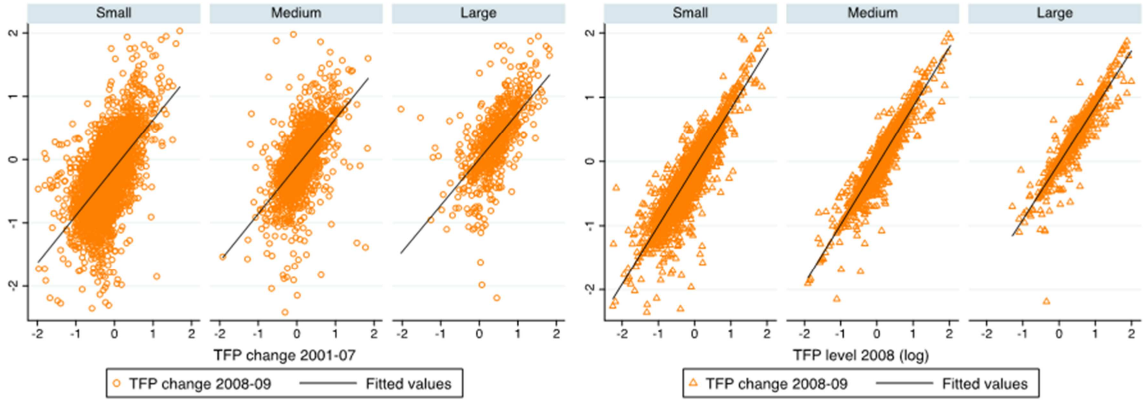
Production function	**(1)**	**(2)**	**(3)**	**(4)**
Total number of hours worked	0.557***	0.553***	0.553***	0.552***
	(0.036)	(0.036)	(0.035)	(0.037)
Total capital	0.420***	0.442***	0.449***	0.460***
	(0.027)	(0.027)	(0.027)	(0.03)
Labour quality	0.004**	0.003*	0.004*	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
R&D capital	0.062***	0.066***	0.060***	0.057***
	(0.007)	(0.007)	(0.008)	(0.009)
Determinants of inefficiencies				
ICT capital	-0.626***	-0.545***	-0.496***	-0.502***
	(0.043)	(0.043)	(0.042)	(0.045)
Upstream Regulation Index (RI)	3.057***	2.441***	2.204***	2.255***
	(0.652)	(0.65)	(0.615)	(0.658)
Financial Reform Index	(01.451)	-1.849**		
	(0.93)	(0.921)		
Private Bond Mkt Cap/GDP		-0.307***	-0.317***	-0.288***
		(0.057)	(0.058)	(0.069)
Financial Freedom			-2.650***	-2.776***
			(0.501)	(0.554)
IPR				-0.08
				(0.948)
Regulation of FDI				-1.303*
				(0.783)
Year	0.108***	0.112***	0.096***	0.091***
	(0.019)	(0.019)	(0.018)	(0.020)
Observations	3648	3648	3648	3648

Figure A.7 / TFP growth and levels (country)



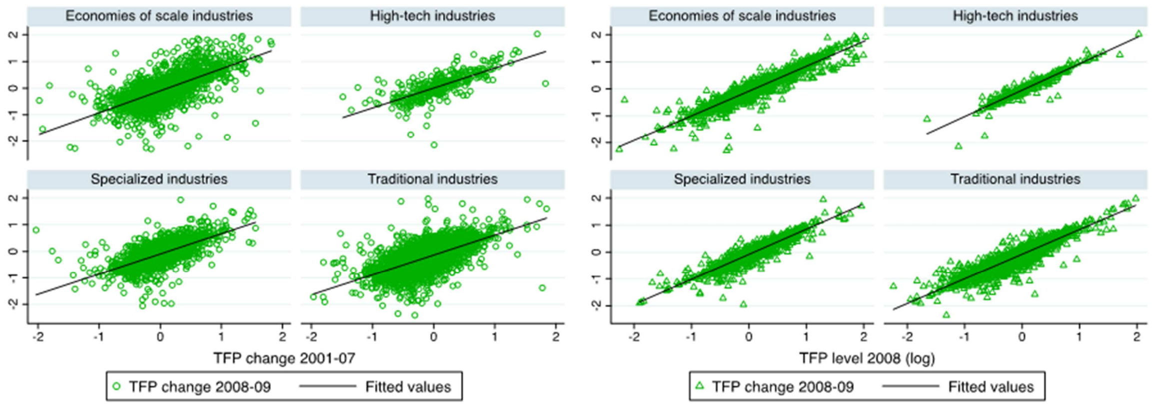
Source: EFIGE

Figure A.8 / TFP growth and levels (size groups)



Source: EFIGE

Figure A.9 / TFP growth and levels (Pavitt categories)



Source: EFIGE

BOX 1 / METHODOLOGY TO AGGREGATE COUNTRY INDUSTRY-LEVEL DATA

In obtaining productivity measures for the EU-8 group of countries and for industry aggregates, an aggregation scheme set out in Timmer et al. (2007) has been followed. Firstly, an aggregation has been performed over countries, and then, over industries. All aggregations of output and input volumes across industries in EUKLEMS use the Tornqvist quantity index.

First, to derive volume measures for country aggregates, a Tornqvist procedure is used. The shares of each country in EU nominal gross output are calculated using PPP converted values, which adjust for purchasing power parities prices differentials across countries (Inklaar and Timmer, 2008).

$$V_{c,j,t} = \frac{\left[\frac{PY_{c,j,t}}{PPP_{c,j,t}}\right]}{PY_{EU,j,t}}$$

Then two-year average shares are then calculated $\bar{V}_{c,j,t}$.

The growth rate of the EU aggregate is then calculated as a weighted average of country productivity growth rates. The weights are the shares of each country in total nominal output, as explained above.

$$\Delta lnY_{EU,j,t} = \sum_{c}^{n} \bar{V}_{c,j,t}\, \Delta LnY_{c,j,t}$$

To obtain industry aggregates, a similar procedure has been followed:

$$\Delta lnY_{EU,t} = \sum_{j}^{n} \bar{V}_{j,t}\, \Delta LnY_{j,t}$$

The Tornqvist quantity index is a discrete time approximation to a Divisia index. This aggregation approach uses annual moving weights based on averages of adjacent points in time. The advantages of the Tornqvist index are twofold. First, it belongs to the preferred class of superlative indices (Diewert, 1976). More precisely, it exactly replicates a translog model which is highly flexible, that is, a model where the aggregate is a linear and quadratic function of the components and time. This is in contrast to the chained Laspeyres index which is currently employed in many European National Accounts, which is prone to substitution bias. In practice, however, when applied as an annual chain, the Laspeyres index will not be far off the Tornqvist index as long as growth rates are modest. Secondly, the Tornqvist is relatively easy to implement.

BOX 2 / GROWTH ACCOUNTING: EXPLAINING THE SOURCES OF PRODUCTIVITY GROWTH

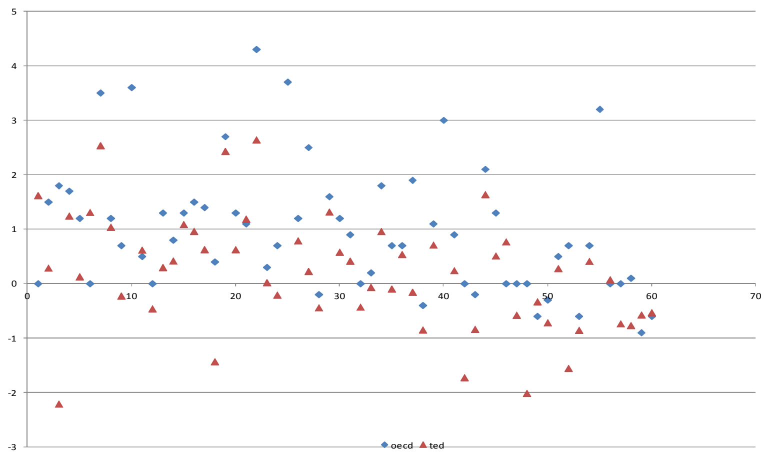
The TFP data used in this study are drawn from the EUKLEMS database and the Total Economy Database (The Conference Board). These measures of TFP are obtained using a growth accounting methodology that has been used widely to assess the structural drivers of productivity. It assumes that labour productivity can either be increased through more use of capital relative to labour (capital deepening) or through an increased efficiency in the use of inputs and increased technological changes (TFP growth).

$$\Delta\frac{y}{l}=\beta_{ict}\Delta\frac{ICTK}{l}+\gamma_{nict}\Delta\frac{NICTK}{l}+\alpha\Delta\frac{LC}{l}+MFP \quad \text{where} \quad \beta_{ict}+\beta_{nict}+\alpha=1$$

It is possible to identify and quantify the role of the following factors:

- The increase use of machinery in production processes or capital deepening (Capital deepening is defined as the ratio between capital services and total labour input, preferably hours worked).
- The different role of ICT capital deepening (computers, software and communications) and non-ICT capital deepening (machinery, transport equipment, residential buildings, infrastructure).
- The improvement in labour composition, which captures mix of skill levels according to educational attainment.

Taking into account the above factor inputs and weighting them by the share of each input in total compensation it is possible to identify the part of labour productivity growth that is due to accumulation of these inputs. The remaining part is attributed to growth in TFP. The standard assumptions of the growth accounting method are: constant returns to scale, competitive and factor markets. A limitation is related to the fact that these assumptions are unlikely to hold in reality.



The OECD produces alternative measures of total factor productivity (2012 Productivity Database). These measures allow for the existence of non-constant returns to scale and imperfect competition. In the OECD TFP data changes in workforce composition, however, are not explicitly accounted for, and therefore would be captured by the TFP term. See scatterplot below for a comparison of TFP rates from the two sources. These TFP measures correlate quite well (0.69) but OECD TFP growth rates tend to be larger.

BOX 3 / DATA SOURCES

OECD Employment Protection Indicators

Data on employment protection are from the OECD's Indicators on Employment Protection (1985-2008), which collects data at the country level. We use data on four variables:

EPR – an indicator for dismissal of employees on regular contracts - calculated as a weighted sum of the following indices: Notification procedures; Delay involved before notice can start; Length of notice period at 9 months of tenure; Length of notice period at 4 years of tenure; Length of notice period at 20 years of tenure; Severance pay at 9 months of tenure; Severance pay at 4 years of tenure; Severance pay at 20 years of tenure; Definition of justified or unfair dismissal; Length of trial period; Compensation following unfair dismissal; Possibility of reinstatement following unfair dismissal

EPT – an indicator of the strictness of regulation on temporary contracts - calculated as a weighted sum of the following indices: Valid cases for use of fixed-term contracts; Maximum number of successive fixed-term contracts; Maximum cumulated duration of successive fixed-term contracts; Types of work for which temporary work agency employment is legal; Restrictions on number of renewals of temporary work agency contracts; Maximum cumulated duration of successive temporary work agency contracts

EPC – an indicator for additional regulation of collective dismissal – calculated as the unweighted average of the following indices: Definition of collective dismissal; Additional notification requirements for collective dismissals; Additional delays involved before notice can start for collective dismissals; Other special costs to employers of collective dismissals

EP – an unweighted average of the indicators for regular contracts (EPR) and temporary contracts (EPT)

All of these variables take a value between zero and six, with six being the most restrictive.

OECD Product Market Regulations

Data on product market regulation are from the OECD's Indicators of Product Market Regulation. More details on the construction of this variable are available from Wölfl et al. (2009). The indices we use are based upon sub-indices capturing information on: State Control; Barriers to Entrepreneurship; and Barriers to Trade and Investment. The three indices are given a weight of one-third each when constructing the overall index. These sub-indices are themselves based upon further sub-indices.

The variable takes on a value between zero and six, with six being the most restrictive.

OECD Product Market Regulation database: Industry indicators

The 'knock-on' regulation indicators, OECD (Conway et al. 2006)

The effect of product market regulations that restrict competition in non-manufacturing sectors is by no means confined to these sectors. It will also have a less visible impact on the cost structures faced by firms that use the output of non-manufacturing sectors as intermediate inputs in the production process. For example, if product market regulation in the business services sector in a particular country is restrictive of competition then the prices charged by firms operating in this sector will tend to be higher and/or the quality of service lower than for firms operating in a competitive business services environment. In turn, this will affect the costs of entry for new firms that need to use these services, the extent to which existing firms outsource these services, the organisation of work within firms, the allocation of resources between firms and, ultimately, the scope for the associated productivity improvements.

These knock-on effects of non-manufacturing regulation are likely to have become particularly salient over recent years given the large and increasingly important role of the non-manufacturing sector as a supplier of intermediate inputs in OECD countries. For example, on average across countries for which(harmonised) input-output data exist, in the late 1990s almost 80 % of the output of the business services sector was used as an intermediate input in the production processes of other sectors in the economy. Similarly, between 50 and 70 % of the output of the finance, electricity, and post and telecoms sectors is destined to be used as intermediate inputs to the production process. In addition, the importance of non-manufacturing sectors as a source of intermediate inputs has been growing rapidly over recent decades, along with the rest of the services sector. For example, Kongsrud and Wanner (2005) report that the service sector now accounts for roughly 70% of all jobs and value-added in the OECD area, which is more than 5 percentage points higher than in 1990.

Indicators take value from 0 to 1. It is the result of the interaction of two variables: Indicators of product market regulation in non-manufacturing sectors (See below) and input-output shares. The indicator ranges from 0 to 1.

Index of product market regulation in the non manufacturing sectors of OECD (Conway and Nicoletti, 2006)

The indicator measures differences in the regulation of non-manufacturing sectors of OECD countries over the past three decades. The indicators focus on regulations that affect competitive pressures in areas where competition is economically viable and on the potential costs that these regulations entail for economic activities that use the output of regulated sectors as intermediate inputs in production. These indicators take value from 1 to 6.

Conway and Nicoletti (2006) construct three groups of indices of regulation in non-manufacturing industries:

1) the first group measures regulatory restrictions in energy, transport and communication;

2) the second group assess regulation in retail distribution and some business services;

3) the third group, called the regulatory impact (RI), which is derived from the first two groups plus an indicator of anti-competitive regulation in the finance sector (de Serres et al., 2006). The latter assesses the degree to which regulation encourages or inhibits competition in markets for banking services and financial instruments. One potential difficulty with measuring the impact of regulation on competition is accounting for the influence of enforcement. Stringent regulations may not bite on competition if not enforced, and even the most liberal regulatory settings may not promote

competition if not implemented correctly. Similarly, in some cases, regulations enacted at the national level may have little impact on markets if applied by local authorities or if local legislation is contradictory in spirit. To go some way towards overcoming this difficulty, data on actual market and industry structure (such as market shares or the degree of vertical integration) are incorporated into some of the sectoral indicators so as to proxy for the impact of policy enforcement. However, the indicator results may still incur some bias in countries with a federal structure, when regulatory policies are controlled by the sub-central levels of government. Moreover, as already mentioned, barriers to competition may not be fully captured by the indicators when they are mostly informal

OECD Trade Union Density

Data on trade union density are from the OECD's Database on Trade Unions. Trade union density corresponds to the ratio of wage and salary earners that are trade union members, divided by the total number of wage and salary earners (OECD Labour Force Statistics). Density is calculated using survey data, wherever possible, and administrative data adjusted for non-active and self-employed members otherwise. The data is available annually at the country level.

Heritage Foundation Economic Freedom Variables

The Heritage Foundation produces annually an index of economic freedom. We use information on some of the sub-indices for this variable in our analysis. Details on their construction are written below.

Financial Freedom Index – is a measure of banking efficiency as well as a measure of independence from government control and interference in the financial sector. State ownership of banks and other financial institutions such as insurers and capital markets reduces competition and generally lowers the level of available services.

In an ideal banking and financing environment where a minimum level of government interference exists, independent central bank supervision and regulation of financial institutions are limited to enforcing contractual obligations and preventing fraud. Credit is allocated on market terms, and the government does not own financial institutions. Financial institutions provide various types of financial services to individuals and companies. Banks are free to extend credit, accept deposits, and conduct operations in foreign currencies. Foreign financial institutions operate freely and are treated the same as domestic institutions.

The Financial Freedom Index scores an economy's financial freedom by looking into the following five broad areas:

› The extent of government regulation of financial services,

› The degree of state intervention in banks and other financial firms through direct and indirect ownership,

› The extent of financial and capital market development,

› Government influence on the allocation of credit, and

› Openness to foreign competition.

These five areas are considered to assess an economy's overall level of financial freedom that ensures easy and effective access to financing opportunities for people and businesses in the economy. An overall score on a scale of 0 to 100 is given to an economy's financial freedom through deductions from the ideal score of 100. A value of 100 indicates negligible government interference and zero repressive intervention. To be consistent with the other indicators we reverse this, such that higher numbers are associated with more regulation.

The Financial Freedom Index relies on the following sources for data on banking and finance, in order of priority: Economist Intelligence Unit, Country Commerce and Country Finance, 2009–2012; International Monetary Fund, Staff Country Report, 'Selected Issues,' and Staff Country Report, 'Article IV Consultation,' 2009–2012; Organisation for Economic Co-operation and Development, Economic Survey; official government publications of each country; U.S. Department of Commerce, Country Commercial Guide, 2009–2012; Office of the U.S. Trade Representative, 2011 National Trade Estimate Report on Foreign Trade Barriers; U.S. Department of State, Investment Climate Statements, 2009–2012; World Bank, World Development Indicators 2012; and various news and magazine articles on banking and finance.

Investment Freedom Index - in an economically free country, there would be no constraints on the flow of investment capital. Individuals and firms would be allowed to move their resources into and out of specific activities, both internally and across the country's borders, without restriction. Such an ideal country would receive a score of 100 on the investment freedom component of the Index of Economic Freedom. To be consistent with the other indicators we reverse this, such that higher numbers are associated with more regulation.

In practice, most countries have a variety of restrictions on investment. Some have different rules for foreign and domestic investment; some restrict access to foreign exchange; some impose restrictions on payments, transfers, and capital transactions; in some, certain industries are closed to foreign investment. Labour regulations, corruption, red tape, weak infrastructure, and political and security conditions can also affect the freedom that investors have in a market.

The Investment Freedom Index evaluates a variety of restrictions that are typically imposed on investment. Points are deducted from the ideal score of 100 for each of the restrictions found in a country's investment regime. These investment restrictions (and the extent of the restrictions) are: National treatment of foreign investment (no national treatment; some national treatment, some prescreening; some national treatment or prescreening); Foreign investment code (no transparency and burdensome bureaucracy; inefficient policy implementation and bureaucracy; some investment laws and practices non-transparent or inefficiently implemented); Restrictions on land ownership (all real estate purchases restricted; no foreign purchases of real estate; some restrictions on purchases of real estate); Sectoral investment restrictions (multiple sectors restricted; few sectors restricted; one or two sectors restricted); Expropriation of investments without fair compensation (common with no legal recourse; common with some legal recourse; uncommon but occurs); Foreign exchange controls: (no access by foreigners or residents; access available but heavily restricted; access available with few restrictions); and Capital controls (no repatriation of profits, all transactions require government approval; inward and outward capital movements require approval and face some restrictions; most transfers agreed with some restrictions). Additional points may be deducted for security problems, a lack of basic investment infrastructure, or other government policies that indirectly burden the investment process and limit investment freedom.

The Investment Freedom Index relies on the following sources for data on capital flows and foreign investment, in order of priority: official government publications of each country; Economist Intelligence Unit, Country Commerce, 2009–2012; Office of the U.S. Trade Representative, 2012 National Trade Estimate Report on Foreign Trade Barriers; and U.S. Department of Commerce, Country Commercial Guide, 2009–2012.

THE EUKLEMS DATABASE (2009 Release, and 2013 rolling updates) – see O'Mahony and Timmer, 2009. This database is publicly available at www.euklems.net. The EUKLEMS database is s cross-country harmonised database containing measures of outputs, inputs and productivity. It is available for period 1970-2010 on an industry and economy-level basis. The EUKLEMS database uses a harmonised methodology to measure capital input. Capital input is measured as capital services, which is a weighted growth of capital stocks of eight assets, comprising ICT and non-ICT assets. The weights are based on the rental prices of each asset which consists of a nominal rate of return, depreciation and capital gains.

On the labour input side, the EUKLEMS database provides information on both the number of persons engaged and the number of employees, on an annual basis from 1970 to 2007. Also, the EUKLEMS has total hours worked information by persons engaged and by employee. The number of hours worked is more relevant for productivity measurement than the number of people employed. In addition to the estimates of hours worked, the growth accounting section of EUKLEMS presents estimates of volume of labour input and labour services. The measure of labour input takes into account the changing composition of the labour force, rather than the number of hours worked. To calculate series on labour services input, data on hours worked and compensation by labour type are used in a Törnqvist quantity index of individual labour types. EU KLEMS publishes data on hours worked and wage shares by skill type; the estimates are based on the assumption that the remuneration of self-employed follows similar pattern than the employed.

THE CONFERENCE BOARD TOTAL ECONOMY DATABASE (January 2013). This database is downloadable free of charge from The Conference Board website, at www.conferenceboard.org/data/economydatabase. The Total Economy database covers up to 123 countries. The database provides first opportunity to analyse the impact of the 2008-2009 on productivity performance, providing data for up to 2012. Measurement of capital and labour and productivity follows the methodology of EUKLEMS.

The OECD Productivity Statistics Database. The OECD Productivity Database provides alternative calculations of productivity to those from the EUKLEMS and Conference Board database. OECD Productivity Database, December 2012. www.oecd.org/statistics/productivity

OECD Labour Market Statistics and EUROSTAT (labour market indicators).

BOX 4 / THRESHOLD REGRESSION

Threshold models have in recent times received a great deal of attention as a means of modelling parameter heterogeneity and non-linearities. In a series of papers Hansen (1996, 1999 and 2000) develops a technique that allows the sample data to jointly determine both the regression coefficients and the threshold value for OLS and (non-dynamic) fixed effects panel models. The threshold model for a single threshold can be written as:

$$y_i = \alpha_0 + \delta_1 x_i 1(q_i \leq \lambda_1) + \delta_2 x_i 1(q_i > \lambda_1) + \varepsilon_i$$

where 1 is the indicator function and q_i is the threshold variable. Here the observations are divided into two regimes depending on whether the threshold variable is smaller or larger than λ_1. The two regimes are distinguished by different regression slopes, δ_1 and δ_2. Chan (1993) and Hansen (1999) recommend estimation of λ_1 by least squares. This involves finding the value of λ_1 that minimises the concentrated sum of squared errors. In practice this involves searching over distinct values of q_i for the value of λ_1 at which the sum of squared errors is smallest, which is then our estimate of the threshold. Once we have an estimate for the threshold it is straightforward to estimate the model. Hansen (2000) extends this method to the case of non-dynamic fixed-effects panel models.

Having found a threshold it is important to determine whether it is statistically significant or not, that is, to test the null hypothesis; $H_0: \delta_1 = \delta_2$. Given that the threshold λ_1 is not identified under the null, this test has a non-standard distribution and critical values cannot be read off standard distribution tables. Hansen (1996) suggests bootstrapping to simulate the asymptotic distribution of the likelihood ratio test allowing one to obtain a p-value for this test. Firstly, one estimates the model under the null (i.e. linearity) and alternative (i.e. threshold occurring at λ_1). This allows one to construct the actual value of the likelihood ratio test (F_1):

$$F_1 = \frac{S_0 - S_1(\lambda_1)}{\sigma^2} \quad \text{where} \quad \sigma^2 = \frac{1}{n(t-1)} S_1(\lambda_1)$$

Here S_0 and S_1 are the residual sum of squares from the linear and threshold models respectively. Using a parametric bootstrap (see Cameron and Trivedi, 2005) the model is then estimated under the null and alternative and the likelihood ratio F_1 is calculated. This process is repeated a large number of times. The bootstrap estimate of the p-value for F_1 under the null is given by the percentage of draws for which the simulated statistic F_1 exceeds the actual one.

The approach is also easily extended to consider more than one threshold. While it is straightforward to search for multiple thresholds, it can be computationally time-consuming. Bai (1997) has shown, however, that sequential estimation is consistent, thus avoiding this computation problem. In the case of a two threshold model this involves fixing the first threshold and searching for a second threshold. The estimate of the second threshold is then asymptotically efficient, but not the first threshold because it was estimated from a sum of squared errors function that was contaminated by the presence of a neglected regime. Bai (1997) suggests estimating a refined estimator for the first threshold, which involved re-estimating the first threshold, assuming that the second threshold is fixed. The test of significance of the second threshold proceeds along the same lines as described above, with the null and alternative hypotheses being of a one and two threshold model respectively.

BOX 5 / SECTORAL CLASSIFICATION

WIOD Code	WIOD Sector Name
AtB	Agriculture, Hunting, Forestry and Fishing
C	Mining and Quarrying
15t16	Food, Beverages and Tobacco
17t19	Textiles and Textile Products and Leather, Leather and Footwear
20t22	Wood and Products of Wood and Cork and Pulp, Paper, Paper , Printing and Publishing
23t25	Coke, Refined Petroleum and Nuclear Fuel , Chemicals and Chemical Products and Rubber and Plastics
26	Other Non-Metallic Mineral
27t28	Basic Metals and Fabricated Metal
29	Machinery, Nec
30t33	Electrical and Optical Equipment
34t35	Transport Equipment
36t37	Manufacturing, Nec; Recycling
E	Electricity, Gas and Water Supply
F	Construction
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
H	Hotels and Restaurants
60	Inland Transport
61	Water Transport
62	Air Transport
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
64	Post and Telecommunications
J	Financial Intermediation
70	Real Estate Activities
71t74	Renting of Machinery and Equipment and Other Business Activities
L	Public Admin and Defence; Compulsory Social Security
M	Education
N	Health and Social Work
O	Other Community, Social and Personal Services
P	Private Households with Employed Persons

BOX 6 / STATIONARITY TESTS

Coe and Helpman (1995) in their study found that their data exhibited a clear trend, but that a cointegrating relationship existed between the variables, which allowed them to estimate their model in levels using OLS. They chose not to report t-statistics for their results, because at the time the asymptotic distribution of the t-statistic was unknown. As Kao et al. (2000) pointed out however, the OLS estimator is (super-) consistent even under panel cointegration, but has a second-order asymptotic bias that leads to invalid standard errors. Kao et al. (2000) recommend alternative estimation procedures, such as Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS), which are able to provide valid t-statistics in the presence of non-stationary data.

We use the Im-Pesaran-Shin test (IPS) (2003) to test whether our variables of interest are stationary or not. In contrast to the Levin-Lin-Chu (LLC) and the Harris-Tzavalis and Breitung tests, the IPS test relaxes the assumption of a common ρ for the whole panel. The method also allows for different serial correlation properties across cross-section units. The method involves averaging individual unit root tests based on the Augmented Dickey-Fuller (ADF) test. The null hypothesis is that each series in the panel contains a unit root ($\mathrm{H}_0\colon \rho_i = 0\ \forall i$), with the alternative being that at least one of the series is stationary.

The table below reports the results from the IPS test for the main variables of interest in both levels and first differences. The number of lags in the ADF test for each cross-section is determined by the Schwarz-Bayesian criteria where we impose a maximum number of four legs. In addition to the test statistic, the table also reports the average number of lags chosen by this criterion. The results in the top-half of the table are mixed. While we can reject the null hypothesis that all of the series contain a unit root in favour of the alternative that at least one does not at the 1% significance level for the main R&D variables, we can't reject the null hypothesis of a unit root for the measure of labour productivity and the capital-labour ratio. When considering the variables in first differences we find that we can reject the null hypothesis of a unit root for all variables. For this reason we estimate our model in first differences[59].

Im-Pesaran-Shin Unit Root Test Results

	Test Statistic	p-value	Average Number of Lags
Levels			
$\ln y$	11.82	1.0000	1.35
$\ln k$	3.88	0.9999	1.95
$\ln F$	-2.55	0.0054***	1.18
$\ln F_D$	-3.91	0.0000***	1.10
$\ln F^d$	-6.35	0.0000***	1.22
$\ln F_D^d$	-6.52	0.0000***	1.20
First Differences			
$\Delta\ln y$	-45.75	0.0000***	1.22
$\Delta\ln k$	-75.78	0.0000***	1.98
$\Delta\ln F$	-53.09	0.0000***	1.25
$\Delta\ln F_D$	-55.36	0.0000***	1.22
$\Delta\ln F^d$	-56.14***	0.0000***	1.25
$\Delta\ln F_D^d$	-57.01	0.0000***	1.22

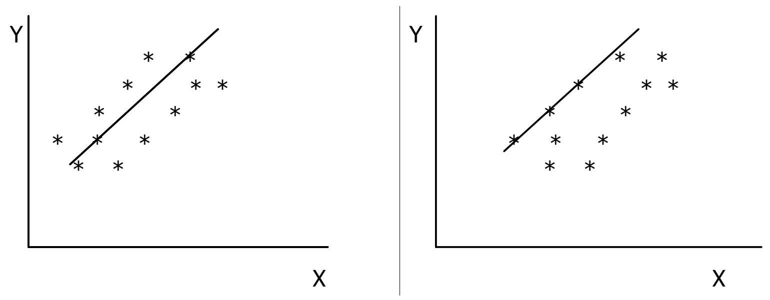
Notes: The number of lags is series specific and is based upon the Schwarz-Bayesian information criteria (maximum number of lags considered is four)

BOX 7 / STOCHASTIC FRONTIER ANALYSIS (SFA)

59 Results from the Westerlund cointegration test suggest a lack of cointegration in the levels regression, which thus supports the use of the first difference specification.

Frontier Analysis, initially developed in Farrell (1957) and successively extended by Aigner et al. (1977), Kumbhakar and Lovell (2000) and Greene (2005) among others, aims to identify the production frontier, i.e. the maximum level of output that can be achieved by using the available inputs. Compared to regression analysis, the estimation of the frontier production function implies fitting a regression line over the units (industries in our case) that produce the most output. The difference between the two techniques can be easily seen in the following figure, where Y indicates output and X denotes a generic input:

A: Regression analysis   B: Frontier analysis



Countries/industries at the frontier are those that are making the most efficient use of their resources. Those below the frontier have some level of inefficiency, which can be directly estimated by the distance between each industry and the frontier industry.

It is possible to distinguish between two frontier methods, Deterministic Frontier (DEA) and Stocastic Frontier (SFA). DEA (Farrel, 1957; Charnes, Cooper and Rhodes, 1978) provides a nonparametric approach for estimating production technologies and measuring inefficiencies in production and it relies on the assumption that all deviations from the frontier are caused by technical inefficiency, without making allowanced for measurement errors and/or random components. This implies that not only the method is very sensitive to the presence of outliers, but also lacks the necessary diagnostic to help the user determine whether or not the chosen model is appropriate, which variables are significant and which are not. These shortcomings are overcome by the use of SFA. Here the identification of the frontier technology is based on the econometric estimation of a production function, usually a Cobb-Douglas or a semi-translog function. Differently from standard regression analysis, frontier analysis allows for the presence of a composite error term, which includes a random component and an inefficiency term. The random components allows for the presence of measurement errors and other effects not captured by the model. The inefficiency term measures technical inefficiencies, i.e. the distance of each country/industry from the frontier. This ranges between 0 and 1, with higher values identifying more efficient units. Technical efficiency scores derived for each unit/industry can then be analysed across different dimensions to pinpoint areas characterised by low/high inefficiencies.

The performance of an industry depends not only on the inputs used in the production process but also on other external or environmental factors that can affect the efficient use of resources. These are usually factors that are outside the control of an industry, even though it is possible that some factors play a dual role, i.e. they affect both frontier output and inefficiency (Kneller and Stevens 2006). The SFA framework can easily account for this by modelling the mean level of the inefficiency term as a function of these additional factors. Production frontier and determinants of inefficiency are estimated simultaneously by maximum likelihood (ML) (Battese and Coelli, 1995).

BOX 8 / PAVITT TAXONOMY (1984)

Using industry-specific characteristics of UK innovative firms between 1945 and 1979. Pavitt (1984) identifies some major technological trajectories in the manufacturing, on the basis of which it is possible to identify some specific patterns of sectoral innovation.

The Pavitt (1984) taxonomy maps industries according to the source of innovation activities made by the firms (internal vs external), the nature of innovation (informal vs formal, or learning vs R&D), firm size (small, medium, or large), appropriability of innovation (low vs high returns to innovation), method of protection (secrecy vs patents) etc. According to such criteria, industries or firms can be grouped into the following categories:

1) Scale intensive: They are large firms exploiting increasing returns to scale and learning-by-doing associated with the size of the reference market, or of their own plant. The source of innovation may be both external and internal. In the former case, these firms acquire production technologies by the specialised suppliers. In latter case, in-house R&D activities are performed to develop new types of products; in this case, patenting is effective to protect innovation. The main economic activities of such firms are basic metals or the production of durable goods.

2) Science based: They are mainly large firms using internal sources of knowledge to produce innovations (R&D). Their knowledge base is complex and relies upon scientific advances. Sometimes, innovations are developed between private firms and Universities and other research institutes. Patents are the major, but not exclusive, tools to protect innovations. Small firms may be very competitive in certain technologically advanced niches. The main economic activities of such firms are pharmaceuticals, electronics, etc.

3) Specialised suppliers: They are small- and medium-sized firms manufacturing sophisticated equipment and/or precision machinery. They strongly rely upon internal sources of innovation (engineering and design capabilities are pivotal), developing new products by continuously interacting with their customers, i.e. downstream firms using in their production the equipment developed by this category. The nature of innovation of this type of firms is therefore informal and based on learning.

4) Supplied dominated: They are traditional firms, representing the least technologically advanced branch of the manufacturing sector. Their main source of innovation is external and consists in introducing cost-saving process innovations, or implementing advanced technologies, equipment and materials, developed in other sectors. The only internal source of innovation is the learning associated with the usage of acquired inputs. Given the low level of appropriability of internal innovation, patenting is not very developed. The main economic activities of such firms are food, textile, footwear, etc.

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Herausgeber, Verleger, Eigentümer und Hersteller:
Verein „Wiener Institut für Internationale Wirtschaftsvergleiche“ (wiiw),
Wien 6, Rahlgasse 3

ZVR-Zahl: 329995655

Postanschrift:: A 1060 Wien, Rahlgasse 3, Tel: [+431] 533 66 10, Telefax: [+431] 533 66 10 50
Internet Homepage: www.wiiw.ac.at

P.b.b. Verlagspostamt 1060 Wien

Offenlegung nach § 25 Mediengesetz: Medieninhaber (Verleger): Verein "Wiener Institut für Internationale Wirtschaftsvergleiche", A 1060 Wien, Rahlgasse 3. Vereinszweck: Analyse der wirtschaftlichen Entwicklung der zentral- und osteuropäischen Länder sowie anderer Transformationswirtschaften sowohl mittels empirischer als auch theoretischer Studien und ihre Veröffentlichung; Erbringung von Beratungsleistungen für Regierungs- und Verwaltungsstellen, Firmen und Institutionen.

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