TFP growth: Drivers, Components and Frontier Firms

Final Report

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1. Introduction and Research Questions

Productivity is widely recognized as a key mechanism for increasing living standards and forms a policy priority in the EU2020 agenda. In the post-crisis years productivity differences amongst economies of otherwise similar levels of economic development have amplified, and there is a renewed interest in understanding why some nations are more able than others to lead the productivity race. A few recent papers shed light on how cross-country differences in economic outcomes relate to differences in the within-industry productivity dispersion across firms (Bartlesman *et al.,* 2013, Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009). A recurrent theme in this literature is that heterogeneity in firm-level productivity performance may indicate misallocation of resources across firms with detrimental effects at the aggregate level. The development of firm-level databases allows us to improve our understanding of what lies behind the aggregate outcomes. For instance, it enables us to shed some light on the mechanisms and attributes that allow some firms to become the `best-performers', while others experience a process of convergence to best practice. It also allows us to provide a quantitative estimate of the extent to which economies are becoming more or less efficient, as the use of firm-level data enables us to explore the misallocation hypothesis directly.

The main objective of this research is to deepen our understanding of the forces driving total factor productivity growth in Europe and explain differences in the level of efficiency and competency across firms. It is crucial to understand what makes some businesses perform better than others and how government policies can further stimulate the growth process, particularly for firms clearly behind the frontier of knowledge. An increase in productivity dispersion has been observed in recent years and the economic crisis saw a halt in the catching-up process that many countries were experiencing in the years before the financial crisis. The analysis of different firm-level data sources, each with their own advantages and limitations, is an important contribution of this study, and aims to provide a comprehensive assessment of productivity performance in EU countries. While some of the data sources offer a richer array of indicators of firms' performance, others are more appropriate for illustrating aggregate productivity developments, or provide an indication of business perceptions and responses to policy.

The resilience to the crisis and the ability to recover inherently depends on companies' attitudes towards change and, more generally, on firm idiosyncratic characteristics. From this perspective, frontier firms perform better as, by their very nature, they seek new ways of production, new products/services, new markets to serve, and adopt more efficient business practices. After the financial crisis of 2007-08, the European firms achieving better productivity performance were those engaging in innovative practices, exploiting routine management practices and active in international markets (Foster *et al*., 2013). It is possible that firms at the frontier have continued to see significant productivity gains but that others have stagnated.

FDI and the import of services were associated with the largest TFP premia, followed by outsourcing, import and export strategies (Altomonte and Ottaviano, 2011).

One strand of literature stresses that certain companies, generally those that are more open to technology transfers and diffusion, have a greater ability to pull up the productivity performance of laggard firms (Andrews *et al*., 2015). Using firm-level data it is also possible to more credibly identify the effects of certain policies than when using only country or industry-level data. Recent OECD research has utilized harmonized cross-country firm-level data to explore the contribution of public policies to cross-country differences in productivity, innovation and resource allocation (see Andrews and Cingano, 2012; Andrews and Criscuolo, 2013). At the national level, public policies such as reforming of the product and factor markets can speed up convergence to the productivity frontier and the impact of these measures is much stronger the closer the firm is to the frontier (Arnold *et al*., 2011). Other cross-country studies using firm-level data are focused on how the characteristics of the institutional setting in which firms operate influences their size and growth (Bravo-Biosca et al., 2013). They find that increased financial development, greater competition in the banking sector and better contract enforcement are associated with a more dynamic growth distribution. Conversely, stringent employment protection legislation and generous R&D fiscal incentives are associated with more stable firms and fewer growing and shrinking firms.

In this introductory section we briefly review the contents of each of the remaining sections of the report. Section 2 commences with a detailed description of the data work undertaken. We first describe in detail the construction of our main firm-level database, based on Amadeus, and characterise our main analysis samples. We also describe the EFIGE database, which provides us with an alternative view of firms' performance for a sample of European countries in the aftermath of the recession. An advantage of using this data source is that it allows us to assess firms' behaviour in the manufacturing sector, strongly hit by the recession. We also describe in detail the UK's Annual Respondents Database, a nationally representative database of the population of UK firms, which allows us to explore the underpinnings of the UK's so-called productivity puzzle phenomenon.

In section 3 we present new estimates of allocative efficiency (in terms of TFP) for EU countries for a number of years pre- and post- recession. The degree to which barriers to reallocation prevent the flow of resources to the most productive uses is a mechanism put forward in the literature to explain variation in levels of productivity across different economies. In section 4 we adopt an alternative approach to investigate the sources of differences in the levels of TFP across countries, by looking at the issue of TFP inequality. We present an analysis based on the Theil index, which enables us to explore whether the overall evolution of TFP differences is more likely to be driven by differences across groups (e.g. industries or countries) or instead by differences within more homogeneously-defined groups.

In section 5 we provide a careful characterisation of the best performing or frontier firms (in terms of productivity) versus non-frontier firms and we also consider what determines the TFP gap between these firms. In section 6 we provide an exhaustive econometric analysis of the determinants of TFP growth in a more general framework, looking at firm-specific factors as well as other influences such as technological distance and environmental and policy factors. We also analyse the patterns of (sigma and beta) TFP convergence among European Union countries at the country level. Section 7 provides a comprehensive review of the literature on the impact of public policies on productivity performance, and more specifically on the role of misallocation, including useful real life examples of productivity-enhancing policies. Section 8 provides state-of-the art evidence on the role misallocation may have played in the recent UK productivity slowdown, and are able to draw conclusions in relation to entry and exit. Finally, section 9 concludes and summarises the main results of the research.

2. Data description

2.1 Data sources

We make use of a number of firm-level data sources. Firstly, we use the **Amadeus database,** which draws together balance sheet data from all EU countries, and it is used to estimate TFP measures at firm level in a cross-country setting. The Amadeus contains essential data for a range of variables, such as turnover, assets, age, number of employees, exporting and FDI activity, and a wide range of firm characteristics and financial variables. The Amadeus database does not provide uniform coverage across firms, and the coverage of some variables that are essential in the calculation of the TFP measures (for example, value added and intermediate inputs), is limited in some countries. In section 2,2 below we outline in detail the construction of the TFP indicators at firm level using this data source, and we provide more detailed information in the Appendix.

Secondly, we use the results contained in the **CompNet** database (ECB, 2014, ECB, 2016). We were granted access to the indicators constructed by the consortium at both country and sector level[1], and we able to compare the main findings with those emerging from the Amadeus database analysis. The CompNet database draws from firm-level balance sheets in a number of European countries, and contains a number of competitiveness-related variables. One of the indicators produced by CompNet consortium is the Olley and Pakes allocative efficiency indicator, both in its labour productivity and total factor productivity versions. The main feature of this database is that it should improve some of the issues that are important when using Amadeus, such as the lack of representativeness in terms of size and sector distribution of some country samples and the fact that many firms do not report on variables essential for the construction of productivity indicators.

[1] [1] We are grateful to the European Central Bank for granting us access to this dataset.

A drawback is that in CompNet there is no information on the age of firms and therefore it is not possible to distinguish between incumbent and new firms (In Amadeus the age can be derived using information on the year of incorporation).

The underlying sources of the national firm-level data varies by country, although in most countries the information comes from business registries and/or balance sheets offices of the Central Banks or finance ministries. For France, Belgium (for small firms) and Hungary fiscal sources are used, and in the case of Czech Republic, Poland and Slovakia the National Statistical Offices are the main source. With respect to size thresholds, Poland and Slovakia have samples restricted to firms with more than 20 employees or more than 5 million euros of turnover (in the case of Slovakia). For the rest of countries firms of all sizes are covered although the coverage of the smallest size class is very different across countries.

We then use the EFIGE (**"European Firms in a Global Economy") survey dataset**[2] in the regression analysis part. This dataset covers the manufacturing sector only, in the aftermath of the 2007-2008 crisis. The survey includes representative samples on manufacturing firms from seven EU countries: Austria, France, Germany, Hungary, Italy, Spain and the United Kingdom. This data source includes harmonised information on several firm dimensions during the period 2007 to 2009, covering a number of categories: structural characteristics (age, size, sector, country, etc.), R&D and innovation activities, ownership structure, management practices, workforce characteristics, international operations, financial conditions, market competition and pricing behaviour. The main limitation of the EFIGE lies in the cross-sectional nature of the data, and the over-representation of larger firms (a characteristic of databases containing company accounts information). However, in estimation, weights reflecting the incidence of each firm category over the national population are applied to ensure the generalisability of regression results.

The EFIGE dataset has several valuable features. A significant advantage is that it provides rich, cross-country information on company performance around the time of the financial crisis. In particular, EFIGE enables us to assess whether public measures aimed at raising firm competitiveness were effective in improving productivity performance over this period. Governments, either at country or regional levels, have various policy instruments at hand to influence firm activity. Earlier studies were able to account for only a subset of these instruments (see OECD 2015). However, despite a relatively short time span, EFIGE allows assessment of the productivity impact of several policy measures, namely public support for investment, public support for exporting activities, public support for R&D, technological collaborations with universities and public research centres and, finally, public ownership of company shares. All these variables are defined as binary indicators (dummy variables) indicating whether or not the firm exploited the public support in question. Public support for investment, export and R&D include either

[2] We are grateful to Bruegel for facilitating access to the data.

public funding (direct grant) or fiscal incentives (tax credit or discounts). More details can be found in the Appendix.

Finally, we use the UK's **Annual Respondents Database (ARD),** which allows us to undertake the decomposition of productivity analysis using a nationally-representative database for the UK. The ARD pulls together information from the Inter-Departmental Business Register (IDBR), Annual Business Inquiry, Annual Business Survey and the Business Register Employment Survey (BRES). The ARD holds information on the nature of production in British establishments and is essentially a census of larger establishments and a stratified random sample of establishments with less than 250 employees. Details of the ARD data can be found in Bovill (2012), and additional discussion is available in Riley and Rosazza-Bondibene (2016).

The sampling frame for the ARD is the IDBR, a list of all incorporated businesses and other businesses registered for tax purposes. The ARD includes basic information (e.g. industry, ownership structure, and indicative employment) for all establishments in the sampling frame. These population data allow us to determine entry and exit, which cannot be calculated from the surveyed sample alone (Disney *et al.*, 2003), and allow us to calculate grossing weights.

Further details on these data sources and a full description of data construction issues can be found in the Appendix.

2.2 Total Factor Productivity Measures

We describe here the construction of the firm-level TFP measures using the information contained in the Amadeus database.

In constructing our main indicator we follow the Solow index number approach. According to this approach, TFP for a firm *i* in a sector *k*, year *t* and country *c* can be defined as:

$$TFP_{iktc}^{Solow} = \frac{VA_{iktc}}{L_{iktc}^{s^L} K_{iktc}^{1-s^L}} \tag{2.1}$$

where *VA* is value added of the firm, *L* is labour input, *K* is capital and s^L is the share of value added that accrues to labour.

We use two main versions of the Solow TFP measure, depending on the method used for the calculation of the factor shares (Gal, 2013). The first approach uses country-specific and industry-specific shares, drawing on industry information contained in the Eurostat National Accounts (A64). In the second approach, industry-specific labour shares, that are common across all countries, are assumed. The latter type of indicator is likely to improve the international comparability of the resulting productivity levels, which is crucial when assessing the positions of firms in relation to the global TFP frontier of the European Union countries.

If we take logarithms of expression (2.1), the Solow TFP measure can be written as:

$$\ln TFP_{iktc}^{Solow} = \ln VA_{iktc} - s^{L} \ln L_{iktc} - \left(1 - s^{L}\right) \ln K_{iktc} \qquad (2.2)$$

Although the Solow approach is computationally simple, and less likely to suffer from measurement error, it also presents some disadvantages; for example the need to assume a functional form for the technology (Cobb-Douglas with constant returns to scale), and the fact that the residuals obtained from an expression such as (2.2) will not be scale invariant.

We also compute a superlative TFP index[3], which is based on the comparison of a firm's productivity in relation to a benchmark e.g. another firm or aggregate. Input shares are based on firms' observed expenditure and revenue information and, compared to the Solow's methodology, this approach reduces the need for cross-section/time-series comparisons of productivity measures across units (Good, Nadiri and Sickles, 1996).

Caves, Christensen and Diewert (1982) and Hulten and Schwab (1993) define a superlative TFP index as follows:

$$\ln TFP_{iktc}^{superlative} = \left(\ln VA_{iktc} - \ln VA_{0}\right) - \frac{1}{2}\left(s_{iktc}^{L} + s_{0}^{L}\right)\left(\ln L_{iktc} - \ln L_{0}\right) - \frac{1}{2}\left(\left(1 - s_{iktc}^{L}\right) + \left(1 - s_{0}^{L}\right)\right)\left(\ln K_{iktc} - \ln K_{0}\right) \qquad (2.3)$$

where subscript *0* indicates a reference firm or an aggregate chosen as a benchmark (industry, country, etc.) in a base year. In our case, the chosen reference will be the mean (or the median) of all European Union firms in the initial year.

The TFP for the reference unit takes the value of 1 (100 if expressed in percentages) in the base year. The TFP of the rest of the firms in the sample takes values with reference to this value. That is, a value of 120 means that the firm is 20% more productive than the reference unit in the base year.

There are other types of TFP indicators that we do not explore in this study. An additional family of TFP indicators is that based on econometric techniques (Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Wooldridge, 2009; or Ackerberg, Caves and Frazer, 2015; among others). These methods propose the use of the demand for investment as a proxy for "unobserved" productivity and solve the problem of endogeneity associated with traditional measures of TFP. A problem with

[3] Diewert (1976) defines as *superlative* an index that it is: 1) *exact*, i.e. it can be derived from an underlying production function; and 2) *flexible* in the sense that it can provide a second order approximation to an arbitrarily twice differentiable and linearly homogeneous production function.

this approach is that a substantial number of firms declare zero investment in some periods which precludes its use in estimation. The EFIGE database contains firm-level measures of TFP, calculated according to the methodology of Levinsohn and Petrin (2003). As a result, the initial set-up and preparatory work was more straightforward in the case of the EFIGE dataset, than in the case of the Amadeus database, as the TFP measures were already computed by the Bruegel consortium.

Table 2.1 provides a detailed account of the sample of firms for which we were able to obtain measures of TFP in Amadeus. We can see that the number of firms for which we were able to derive TFP measures is rather small in some countries. This is the case for Austria, Luxembourg, Malta and Latvia (all under 1,000 observations per annum). There are also two countries, Cyprus and Lithuania, for which we do not have any information in the sample. A handful of other countries show a significantly lower number of observations in the earlier years of the period; for example Portugal (before 2006), Slovenia (before 2010), Slovakia (before 2005), Hungary (before 2007, Germany (before 2006), and Denmark (no information prior to 2008). In several cases (e.g. United Kingdom) we have a disproportionately lower number of observations in the last year of our sample. More details on the calculation of the TFP measures and the characteristics of the database underlying these are provided in the data and methodology section.

Table 2.1. Number of firms by country and year in the sample used for TFP measurement. Amadeus database, 2003-2014.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Austria	19	213	68	144	116	341	845	822	880	885	913	343
Belgium	73.749	70.457	62.086	67.840	67.457	67.184	66.450	66.556	66.830	66.849	66.170	55.469
Bulgaria	7.663	7.611	10.051	11.129	13.252	9.819	9.321	9.283	13.857	18.730	19.043	21.931
Croatia	29.230	24.701	20.130	20.090	19.336	18.756	20.118	19.053	18.291	18.853	18.300	15.936
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	17.185	22.640	25.768	27.935	31.163	26.233	34.710	34.605	34.548	32.113	28.456	12.077
Denmark	0	0	0	0	0	0	3.253	18.746	13.686	9.727	8.664	6.576
Estonia	12.125	12.388	11.290	11.744	12.443	12.822	11.014	13.104	13.766	14.036	14.007	13.040
Finland	33.583	34.058	26.216	28.584	26.219	19.803	21.290	20.522	24.997	25.062	24.890	24.175
France	179.609	226.958	196.045	171.107	172.614	163.959	179.343	187.850	168.546	140.027	137.892	79.673
Germany	3.792	5.044	9.382	19.321	20.868	20.006	19.363	18.840	18.675	18.343	17.271	2.124
Greece	10.730	10.577	8.255	8.177	8.107	8.217	9.141	9.537	9.778	9.767	8.885	6.382
Hungary	236	898	1.889	3.666	45.458	10.015	79.193	51.897	51.642	84.200	72.710	69.205
Ireland	0	9	75	292	498	609	658	704	703	727	689	287
Italy	114.050	60.406	53.478	107.276	122.853	174.289	143.490	112.899	232.881	242.382	239.774	186.201
Latvia	81	102	68	64	63	41	33	180	296	388	442	449
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0
Luxembourg	7	5	2	12	98	190	251	301	304	275	238	114
Malta	0	1	4	5	11	18	23	18	21	14	7	0
Netherlands	3.518	3.487	2.403	2.173	2.114	1.811	1.853	1.670	1.773	1.715	1.479	756
Poland	10.415	10.215	10.514	17.078	17.330	20.123	33.952	12.589	9.732	10.779	7.286	409
Portugal	1.288	1.387	2	125.099	123.309	119.284	115.334	110.409	105.678	98.854	94.977	88.715
Romania	88.446	97.961	92.231	77.356	92.667	91.382	83.571	80.820	79.518	77.536	74.796	74.494
Slovakia	1.946	2.440	10.171	14.363	14.158	14.037	28.313	26.561	24.255	21.625	22.045	23.706
Slovenia	5.517	6.248	5.847	6.572	6.440	6.198	7.087	27.290	25.941	23.747	23.012	14.397
Spain	255.389	251.167	223.937	232.959	218.686	243.725	249.231	248.467	250.484	238.844	214.808	115.650
Sweden	98.694	96.174	83.423	83.459	83.171	84.693	84.048	82.581	81.103	78.934	77.522	60.015
United Kingdom	35.476	31.246	24.747	23.819	23.255	22.171	22.128	21.699	20.560	19.592	18.492	9.399
European Union-28	**982.748**	**976.393**	**878.082**	**1.060.264**	**1.121.686**	**1.135.726**	**1.224.013**	**1.177.003**	**1.268.745**	**1.254.004**	**1.192.768**	**881.523**

[1] The sample includes only firms with data of VA (availabe or that can be imputed), data on fixed assets, depreciation, and employment.

3. Allocative Efficiency and TFP across EU Countries.

In this research we undertake an analysis of the extent to which EU economies may differ in their ability to reallocate resources towards the most productive units. This is captured by the concept of *allocative efficiency*. We present estimates of allocative efficiency for a number of sub-periods and aim to draw conclusions as to how these may have evolved over time. This is of high policy relevance as there is a renewed interest in understanding the reasons for the increasingly diverging productivity performance of EU economies, and their different abilities to adjust in the light of a major global negative shock.

We implement a simple decomposition methodology, first proposed by Olley and Pakes (Olley and Pakes, 1996), but which has since been widely used in the academic literature. We also review here other examples found in the literature that use alternative decomposition methods to quantify the role played by resource reallocation on aggregate productivity outcomes. Ahn (2001) reviews a number of the early decomposition studies. Mason *et al.* (2014) provides a more recent detailed review of the most common decomposition approaches in their pre-crisis study of the sources of the UK's labour productivity growth.

In their influential paper, Olley and Pakes (1996) studied the level of efficiency in the allocation of resources in the US telecommunications industry, during a time when intense de-regulation led to a more competitive industry structure, using cross-sectional data. A key limitation of the Olley and Pakes (OP) method, as well as of other similar static decomposition approaches, is that it does not allow us to disentangle the productivity contribution of the dynamic process of entry and exit of firms, from the changes to the market shares of incumbent firms. The influence of the Schumpeterian creative destruction process in driving aggregate productivity has gained broad empirical support over the last few decades. Business churn is considered as one of the major mechanisms of resource allocation across business units, and can explain a significant part of productivity gains in modern economies (see for example Disney *et al.,* 2003, for the UK). Despite this important drawback, the use of an OP decomposition approach is a useful tool to illustrate differences in the efficiency of the allocation of output across country and/or industries, and it is considered a robust indicator of the impact of distortions to reallocation of resources on aggregate productivity levels (Bartelsman, Haltiwanger and Scarpetta, 2013).

The main data limitations, preventing us from reliably capturing the entry and exit of firms into a market, are related to the characteristics of Amadeus. As we describe in further detail in the data sources section, in Amadeus the reporting of key data items is selective, rather than the result of sampling. Therefore, it is difficult to estimate the

separate contributions to productivity growth of resource reallocation from continuing firms and *via* the entry and exit of firms. This is not least because data items for entering firms are particularly under-reported.

Other more sophisticated methods are available to study the dynamic contribution of entry and exit to productivity growth, but their use always depends on the availability of data. Baily *et al.* (1992) develop a methodology that distinguished a `within' effect (growth within surviving businesses) from a `between' effect (changes of market shares of survivors), as well as of entry and exit of firms. An assumption of the Baily *et al.* methodology is that the contribution of new entrants is always positive regardless of the productivity level of entrants, while the contribution of exit is always negative, regardless of the productivity level of the exiting firms. Acknowledging this limitation, Foster, Haltiwanger and Krizan (2001) explicitly consider an average reference productivity level against which the productivity level of both entrants and exiting firms can be benchmarked. They decompose productivity using plant-level data in 23 industries in the US over the period 1977 to 1992, and conclude that reallocation played a significant role for productivity growth in US industries, in particular with regards to entry and exit effects. This approach has subsequently been adopted in a number of empirical studies.

More recently Melitz and Polanec (2012) propose a dynamic version of the Olley and Pakes approach, allowing for the separate identification of the contributions from entering and exiting firms to aggregate productivity changes. This method identifies the contribution of continuing firms as having two separate components; a component capturing changes in the firm-level distribution of productivity, and a component capturing reallocation of market shares among those firms. Their study, applied to Slovenian manufacturing data for the period 1995-2000, looks at both labour productivity and TFP outcomes, and found a much more important role for market share reallocations among surviving firms in driving aggregate productivity changes, compared to other prior studies.

In general the literature has shown considerable heterogeneity in findings, which may arise for a number of reasons; for example, because of methodological differences (in data sampling, type of business units, productivity measures, and indicators of market shares considered) as well as differences in coverage (regarding sector, time periods etc).

3.1 Aggregate productivity developments – findings from the Amadeus database

Figure 3.1.1 shows the average level of TFP on a country-by-country basis in the year 2005 – prior to the financial crisis. This measure of TFP is computed by applying the Solow methodology to our sample of Amadeus firms, as in expression 2.2. We choose as our baseline TFP indicator the one that assumes industry-specific common-across-

countries labour shares[4]. In this analysis we consider the market sector only, and exclude the agricultural, mining, financial and real estate sectors, which are more prone to issues in accurately measuring output.

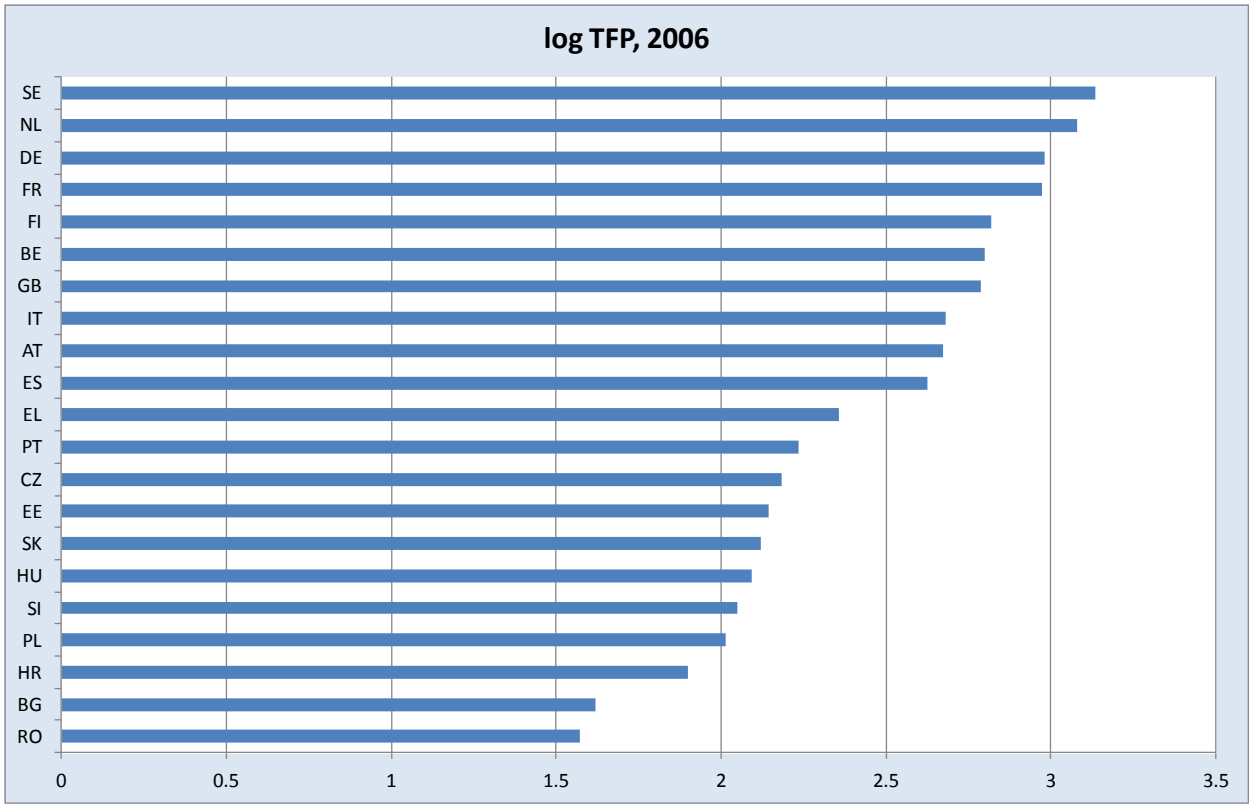
Our results, aggregated up from firm-level data, suggest that in 2005, on average, Netherlands was the EU country with the highest level of TFP followed by Sweden, France, Germany, Finland and Belgium. Out of the countries we can include in the analysis, those countries presenting the lowest level of TFP are Romania, Bulgaria, Poland. It is not feasible to include all of the EU-28 countries in this analysis due to the reduced sample sizes or missing information for some countries. Countries excluded from this graph, due to the reduced number of observations available, include Malta, Luxembourg, Austria, Ireland and Denmark (data only available after 2008).

Figure 3.1.2 presents TFP estimates for 2013 and shows a similar ranking to that observed in Figure 3.1.1. We now include Denmark for whom we did not have data in the earlier period. Sweden is now the country with the highest mean level of TFP, but followed very closely by the Netherlands. France, Denmark, Germany and UK display higher levels of TFP. The list of countries with the lowest level of TFP has not changed greatly, and the two economies with the lowest level of TFP continue to be Bulgaria and Romania.

This type of cross-country comparison of productivity levels, however, has to be interpreted with caution, as the results are based on company accounts information, and are therefore not to be taken as being fully representative of each country's population of firms.[5] Reassuringly, previous research has also ranked Netherlands as the EU country with the highest level of multifactor productivity (see Groningen Growth and Development Growth Levels Database, Inklaar (2008)). There is however more variation in the ranking of the other countries. The 2005 rankings presented in Inklaar (2008) are based on a 1997 benchmark exercise extrapolated to the year 2005, built upon national accounts data.

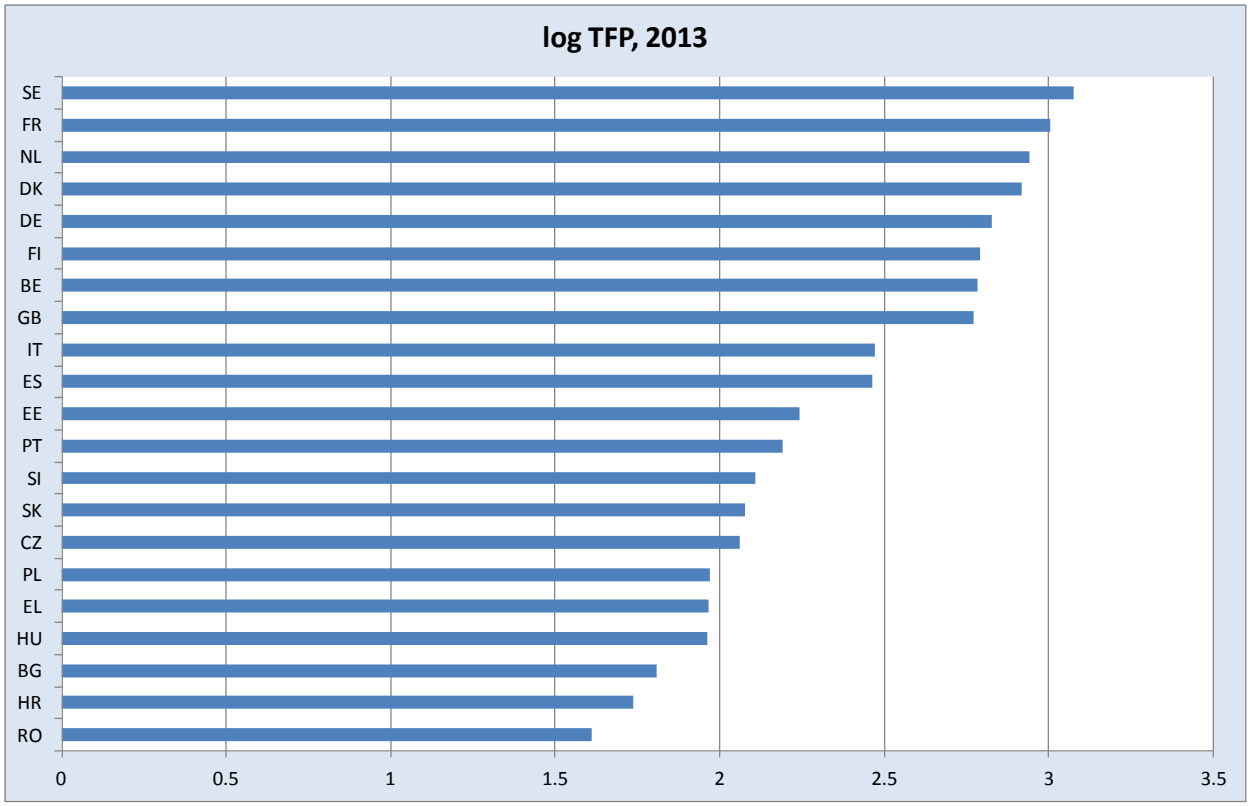
[4] We account for outliers, defined as firms at both ends of the TFP distribution both in growth and levels terms. We also exclude firms with extreme weighting, and companies with less than 12 months accounts.
[5] In order to improve representativeness along the sectoral and size dimensions, especially of small firms, we apply re-sampling weights.

Figure 3.1.1. Levels of TFP in 2006, Market sector.



Source: Authors' calculations based on Amadeus data base. Excludes financial, real estate sector, agriculture, fishing and mining sector'; based on firms with over 20 employees.

Figure 3.1.2. Levels of TFP in 2013, Market sector.



Source: Authors' calculations based on Amadeus data base. Excludes financial, real estate sector, agriculture, fishing and mining sector; based on firms with over 20 employees.

Based on the aggregation of these firm-level data, Figure 3.1.3 shows the recent TFP growth performance in the six largest EU economies, that is, Germany, UK, France, Italy, Spain and Netherlands. The three different sub-periods, 2003-2007, 2008-2010 and 2011-2014 are distinguished to illustrate the overall productivity behaviour not only before the crisis, but also in the aftermath of the crisis and during the recovery years. While it is useful to illustrate these trends, we need to be careful in drawing conclusions that apply to the overall economy; these data are not fully representative of the business populations and therefore we should not expect them to provide an exact match to the actual aggregate developments. Moreover, we do not provide a comprehensive coverage of all sectors in the economy; the agriculture and mining sectors are not covered by Amadeus and we exclude businesses in real estate and the financial sectors.

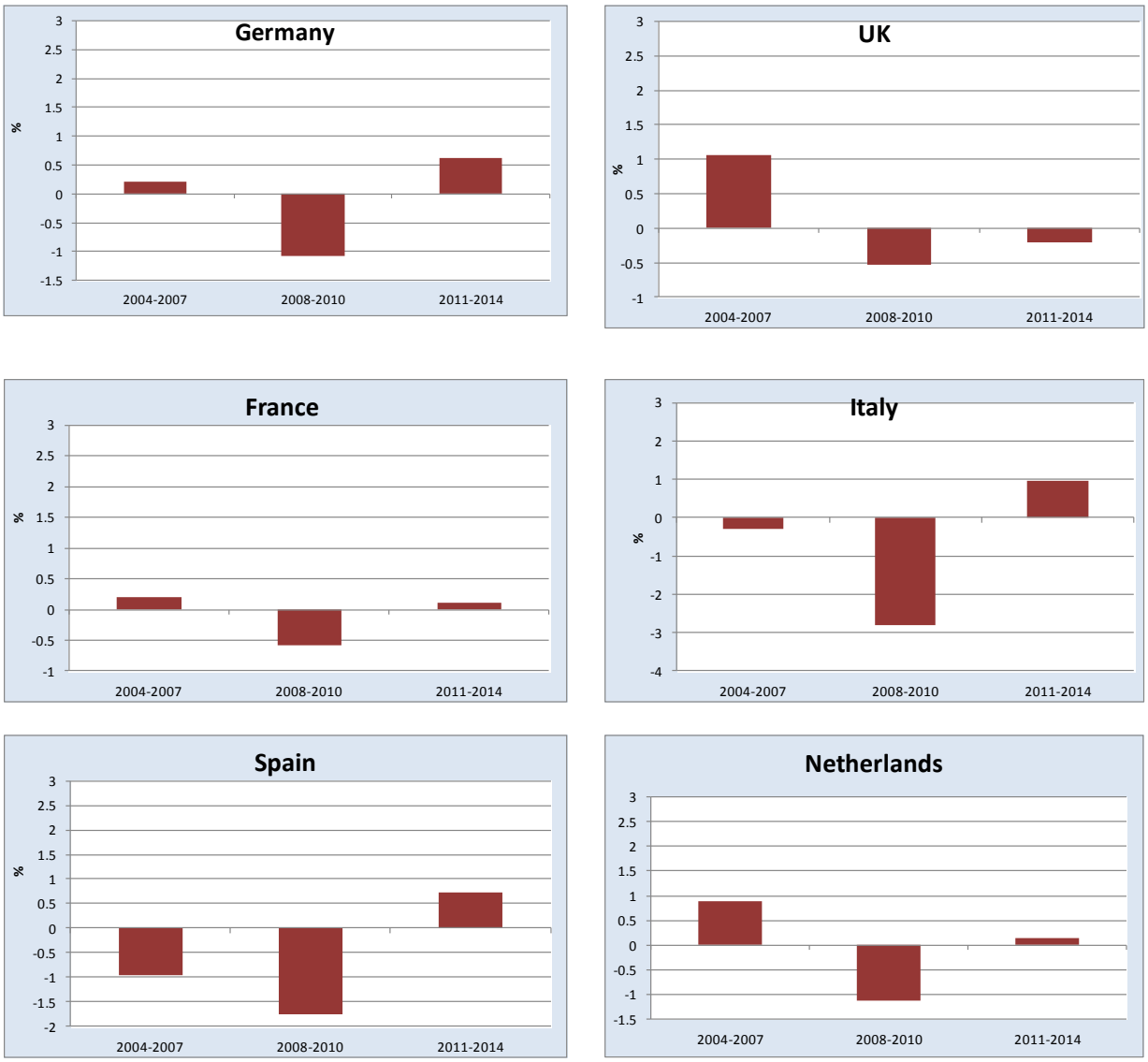
What emerges from the analysis of these data is that prior to the crisis, TFP firm growth was positive on average in Germany, UK, France and Netherlands. The highest average growth rate in TFP was achieved in the UK (just above 1% per annum). This figure is relatively close to National Accounts-consistent EUKLEMS statistics for the overall market economy during the period 2004-2007 (which is just under 1 per cent, see EUKLEMS database 2012 release).

The average growth rates for Germany and France reported here for the years prior to the financial crisis are however lower than those in the published statistics. In the case

of Germany this finding may be affected by the small number of firms present in Amadeus prior to 2006. TFP also deteriorated significantly in Germany and to a lesser extent in France. During the height of the crisis, TFP deteriorated significantly and turned negative in these countries. Here we report the average growth rates for the period 2008-2010. The UK experienced an average negative growth rate of just under 1% (during the period 2008-2009 this was around -2.3%, which is just slightly below the figure emerging from the EUKLEMS statistics). The case of Italy and Spain is a little different as TFP firm growth was on average already negative before the onset of the crisis, and deteriorated even further during the crisis. In the last sub-period considered, 2011-2014, TFP growth has recovered in the majority of countries but remains weak. The UK is the country with the worst recent productivity performance as growth remains close to zero. Despite the limitations, the country-broad patterns that emerge from the analysis of the Amadeus firm-level data appear broadly consistent with those emerging from the analysis of National Accounts-consistent data (see also the country-by-country sources of growth analysis described in Foster *et al.,* 2013, based on EUKLEMS database).

Figures 3.1.4 and 3.1.5 illustrate TFP growth trends for the manufacturing and market services sectors. Several years after the financial crisis TFP continues to be deteriorating in the UK – in this figure, however TFP growth for the period 2011-2014 is below the figure provided by the ONS in its experimental MFP statistics (around -0.7 %). In the rest of the countries TFP decreased sharply in the aftermath of the crisis, but recovered afterwards in the majority of these economies. In the case of services, the recovery of TFP after the crisis appears stronger, especially in the case of UK, Germany and Netherlands. In the case of the UK, again the average growth for the period 2011-2014 aggregate from firm-level data is slightly below the figure reported by ONS (not part of the 'official' statistics, but included in the experimental statistics, see ONS (2014)). For a similar set of services sectors to the ones considered here (that is, excluding non-tradable sectors, finance and real estate), TFP growth is also reported to be positive, but lower in magnitude than our estimate.

Figure 3.1.3. TFP growth rates by sub-period- Six largest EU economies, market sector.



Source: Authors' calculations based on Amadeus data base. Excludes financial and real estate sector, agriculture, fishing and mining sector; based on firms with over 20 employees. Germany's figure includes data from 2006 only.

Figure 3.1.4. TFP growth rates by sub-period- Six largest EU economies, Manufacturing sector.

Source: Authors' calculations based on Amadeus data base. Excludes financial and real estate sector, agriculture, fishing and mining sector; based on firms with over 20 employees.

Figure 3.1.5. TFP growth rates by sub-period- Six largest EU economies, Services sector.

Source: Authors' calculations based on Amadeus data base. Excludes financial and real estate sector, agriculture, fishing and mining sector; based on firms with over 20 employees.

3.2. The Olley-Pakes static decomposition of productivity – findings from the Amadeus Database

In this section we present estimated indicators of efficiency in the allocation of resources for a large number of EU countries over time. We use the OP methodology to obtain measures of allocative efficiency, a measure of the relationship between market shares and productivity. Using a cross section of firms covering a number of countries and sectors, the Olley and Pakes method, in essence, measures the gains or losses in aggregate productivity relative to a situation where market shares are distributed randomly across firms within industries/countries. A positive OP measure suggests that the resources are being allocated efficiency, as firms with relatively high productivity levels have higher market shares. With this methodology, however, we are not able to assess the importance of dynamic processes. For instance, we cannot ascertain whether an increase in allocative efficiency from one period to another is the result of high productivity firms gaining market shares, the result of entry of more productive units to the market and/or exit or contraction of firms at the bottom of the productivity distribution.

A simple decomposition of *multifactor productivity levels*, as proposed by Olley and Pakes, is given by the following expression:

$$TFP_{ct} = (1/N_{ct}) \sum_i TFP_{ict} + \sum_i (\theta_{ict} - \bar{\theta}_{ct}) * (TFP_{ict} - \overline{TFP}_{ct}) \quad (3.1)$$

where: TFP_{ct} is a measure of total factor productivity for country c in time period *t;* TFP_{ict} *is* the individual firm-level productivity, θ_{ict} *is* the market share of a firm i (e.g. in terms of output[6]). Note that as we are decomposing the level of multifactor productivity we use value added shares (in real terms) as the relevant measures of market shares. Note that the bars over the variables in (3.1) indicate the un-weighted industry average of the firm-level measure (either the average output share or TFP measure).

As we explain in more detail in the data section, we follow the standard approach of estimating for each firm a production function in logarithmic form and take the residual as our measure of TFP, *i.e.* the part of output that is not explained by the accumulation of factor inputs. Our baseline measure of TFP is one that uses industry specific shares that are common across countries, but we also test the robustness of the results to the use of other alternative measures.

The expression in (3.1) allows us to decompose aggregate total factor productivity into two distinct terms: the first one is an un-weighted average of firm-level productivity in a

[6] Value added in constant terms (and PPP adjusted).

particular sector (or country); the second is a cross-term (covariance term) that captures the cross-sectional efficiency of the allocation of activity. This term (allocative efficiency) is indicative of the importance of market distortions or misallocation as it shows the extent to which the most efficient firms have a greater market share. The allocative efficiency can also be derived as the difference between the un-weighted average productivity *and* the weighted average productivity, in percentage terms.

We carry out static decomposition of TFP levels on a year-by-year basis, from 2003 to 2014. We then estimate the extent to which resources become more efficiently allocated over time using this approach by comparing findings over three sub-periods throughout the full period of 2003-2014. We also analyse the importance of resource allocation and reallocation for sectoral total factor productivity levels and growth for the same time period. We calculate the Olley-Pakes measure of allocative efficiency for different sectors and time periods, illustrating how this measure of allocative efficiency changed since the 2007-2008 financial crisis.

Figure 3.2.1 and Table 3.1 present detailed estimates of average allocative efficiency for three different sub-periods on a country-by-country basis. These estimates provide us with snapshots of allocative efficiency in different time periods that can give us some indication of changes over time. We focus on the sample that includes firms with at least 20 employees, thus ensuring alsoh comparability with the results of the CompNet database.

As a result of the financial crisis, allocative efficiency showed some changes, although the extent of this change varied by country. For example, it can be seen from the Figure that allocative efficiency decreased in some countries just after the recession, for example in, Bulgaria, Croatia and Hungary. These countries had experienced high levels of allocative efficiency in the years leading up to the recession. Hungary experienced a larger reduction in allocative efficiency immediately after the crisis, but then showed stability in the subsequent years. In other countries, these reductions have been small in magnitude, with the allocative efficiency component appearing largely stable over this period; this is the case for economies such as Finland, Estonia, France and Spain.

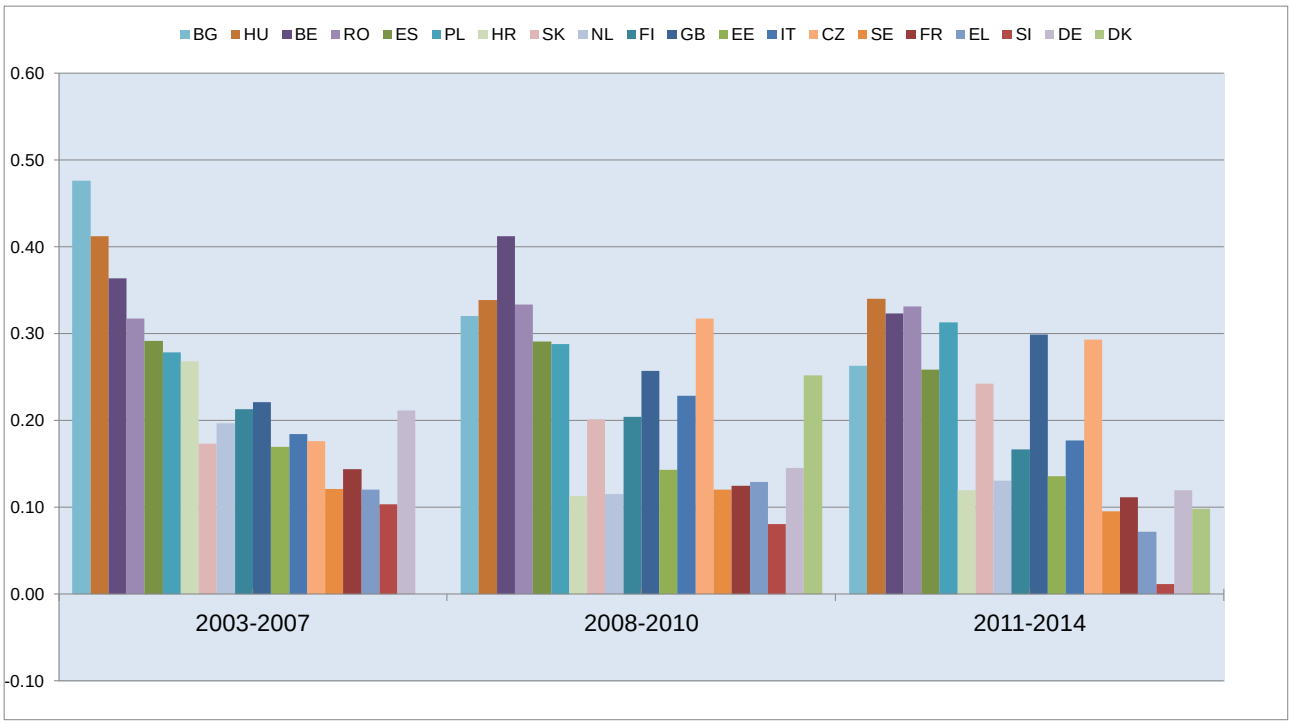
In other countries, the level of allocative efficiency increased in the aftermath of the financial crisis; this can be seen mainly in the case of the UK, which experienced an increase in the period 2008-2010, and remained stable afterwards. Italy and Belgium also saw an increase in the level of allocative efficiency during the period 2008-2010 but this had decreased again by 2011-2014.

Lope-Garcia *et al*. (2014) show the results of a similar decomposition for the period leading up to the financial crisis, that is, 2003-2007. They use the CompNet database, which is a new cross-country firm-level database covering a large number of EU countries. The CompNet data should provide better firm coverage and in particular an

improved representativeness for smaller firms, compared with the Amadeus database[7]. They focus also on the market sector but consider only firms with more than 20 employees, as well as focusing on labour productivity decomposition. Their results, while not fully comparable, share some similar traits. Their findings show that EU countries exhibit differences in their allocative efficiency. They show that countries displaying a high level of allocative efficiency during the period 2003-2007 include Hungary, Poland, Belgium and Spain, and countries with a lower level of allocative efficiency include Slovenia and Estonia. Bartelsman *et al*. (2009) provide an earlier account of the importance of allocative efficiency for the overall productivity performance of a number of countries. They also find that allocative efficiency is positive in all the countries (EU and non-EU) investigated suggesting that resources are allocated to more productive businesses. For many countries, the allocative efficiency term is not only positive but large. They conclude that the allocative efficiency term accounts for about 50 percent or more of labour productivity. In the EU, the productivity boost is smaller than in the US, ranging from 15 to 38 percent. Varying time spans are covered depending on the country from about the mid 1980s to early 2000s. Bartelsman *et al*. find that the degree of allocative efficiency in the United Kingdom is fairly low, although these data refer mainly to the manufacturing sector during the 1990s. The latter finding is in contrast with the higher levels of allocative efficiency reported in Arnold *et al.* (2008) for the UK during the early 2000s. The two sets of findings are not fully comparable however as the results reported in Arnold *et al*. (2008) also cover the business service sector.

[7] The CompNet framework covers 11 countries in the EU, which account for about two-thirds of the total European Union's GDP; these are Belgium, Czech Republic, Germany, Estonia, France, Hungary, Italy, Poland, Spain, Slovakia and Slovenia. The underlying sources of the national firm-level data differ by country, although in the majority of countries this information comes from business registries and/or balance sheets offices of the Central Banks or finance ministries. Fiscal sources are used by France, Belgium (for small firms) and Hungary, and the National Statistical Offices are the main source in the case of Czech Republic, Poland and Slovakia.

Figure 3.2.1. Allocative efficiency by country and sub-period; 2003-2014.



Source: Authors' calculations based on Amadeus data base, Eurostat- Firms with more than 0 employees only. Countries with no observations: CY and LT. Countries with reduced samples (with less than 1000 observations pear year) are LU, LV, MT, IE, AT.

We next compute measures of allocative efficiency for the whole of the EU (using appropriate country weights). See Figure 3.2.2 and Table 3.2.2. The EU grouping excludes those countries with insufficient observations. It thus includes the following countries: Belgium, Bulgaria, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, United Kingdom, Croatia, Hungary, Italy, Netherlands, Portugal, Poland, Portugal, Romania, Sweden, Slovenia, Slovakia.

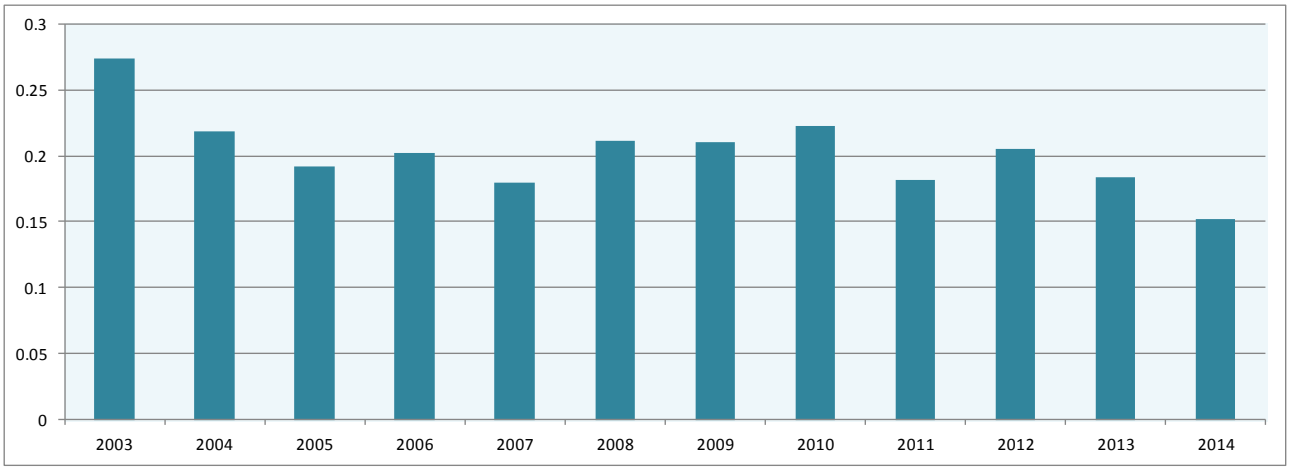
Our results suggest that overall allocative efficiency was at its highest levels during the early part of the 2000s and decreased in the years prior to the recession. In the wake of the financial crisis, allocative efficiency increased slightly. Since then, despite experiencing some fluctuations, it has remained relatively stable. These aggregate results, however, mask a considerably degree of heterogeneity across countries.

Table 3.2.1. Static Olley and Pakes decomposition of total factor productivity using gross value added shares as weights (2003-2014), firms with 20 or more employees.

	Aggregate productivity (un-weighted)			Aggregate productivity (weighted)			Allocative efficiency			Number of observations		
country	**2003-2007**	**2008-2010**	**2011-2014**	**2003-2007**	**2008-2010**	**2011-2014**	**2003-2007**	**2008-2010**	**2011-2014**	**2003-2007**	**2008-2010**	**2011-2014**
AT	2.89	2.70	2.77	3.01	2.91	2.93	0.12	0.16	0.17	214	979	3,330
BE	2.791	2.745	2.765	3.155	3.131	3.090	0.363	0.412	0.323	73,450	29,438	71,645
BG	1.640	1.692	1.784	2.117	2.027	2.045	0.476	0.320	0.263	19,252	10,298	26,521
CZ	2.131	2.096	2.077	2.308	2.398	2.371	0.176	0.317	0.293	62,822	27,835	63,077
DE	2.901	2.838	2.839	3.113	2.975	2.958	0.211	0.145	0.120	48,602	34,210	66,157
DK	0.000	2.970	2.907	0.000	3.145	2.989	0.000	0.252	0.098	.	829	23,215
EE	2.089	2.003	2.148	2.258	2.167	2.302	0.169	0.143	0.136	13,658	4,813	11,593
ES	2.576	2.405	2.434	2.867	2.692	2.694	0.291	0.291	0.258	332,285	123,479	238,946
FI	2.782	2.706	2.740	2.994	2.928	2.891	0.213	0.204	0.166	26,539	8,614	23,827
FR	2.958	2.912	2.934	3.101	3.044	3.042	0.144	0.125	0.111	253,376	76,699	165,111
GB	2.771	2.747	2.777	2.993	3.061	3.043	0.221	0.257	0.299	92,136	31,732	59,522
GR	2.373	2.178	2.000	2.493	2.262	2.047	0.120	0.129	0.072	26,332	9,972	22,768
HR	1.898	1.837	1.744	2.166	1.921	1.863	0.268	0.113	0.119	24,936	9,886	21,472
HU	2.047	2.000	1.943	2.459	2.319	2.283	0.412	0.338	0.340	14,615	18,883	67,236
IT	2.645	2.413	2.475	2.829	2.655	2.644	0.184	0.228	0.177	201,096	96,533	306,952
NL	3.067	2.978	3.072	3.264	3.111	3.221	0.197	0.115	0.130	9,720	2,833	3,852
PL	2.020	2.022	1.951	2.299	2.316	2.242	0.279	0.288	0.313	46,485	35,418	25,493
PT	2.252	2.195	2.184	2.583	2.485	2.499	0.331	0.295	0.310	48,034	48,091	102,079
RO	1.559	1.495	1.575	1.876	1.850	1.910	0.317	0.334	0.331	82,640	38,920	94,421
SE	2.980	3.016	3.041	3.101	3.152	3.124	0.121	0.120	0.095	63,373	27,199	67,067
SI	2.076	2.012	2.129	2.179	2.109	2.140	0.103	0.081	0.011	11,256	5,322	17,112
SK	2.051	2.063	2.080	2.224	2.294	2.314	0.173	0.201	0.242	17,469	13,455	31,083

The average level of allocative efficiency ranges between 0.22-0.24 for the overall period analysed. The allocative efficiency can be interpreted, in percentage terms, as the difference between the weighted and unweighted level of productivity in a sector or an economy. Our results indicate that allocative efficiency for firms with over 10 employees in the market sector during the period 2011-2014 is equal to 0.20. This means that allocative efficiency is 20% higher than it would have been if all firms had an equal share.

Figure 3.2.2. Allocative efficiency for the EU as a whole 2003-2014.



Source: Authors' calculations based on Amadeus data base, Eurostat- Firms with more than 20 employees only. Countries with no observations: CY and LT. Countries with reduced samples (with less than 1000 observations pear year) are LU, LV, MT and IE

The OP decomposition suggests that in all countries allocative efficiency accounts for a sizable fraction of the overall observed MFP levels, but that this varies by country.

Table 3.2.2. Allocative efficiency for the EU as a whole, by sub-period.

	Allocative efficiency	Average TFP (un-weighted)	Average TFP (weighted)	Total number observations
2003-2007	0.21	2.973	2.760	893,494
2008-2010	0.21	2.892	2.677	570,836
2011-2014	0.18	2.868	2.687	684,851

Source: Authors' calculations based on Amadeus data base, Eurostat- Firms with more than 10 employees only. Countries with no observations: CY and LT. Countries with reduced samples (with less than 1000 observations pear year) are LU, LV, MT, IE and AT.

3.3 The Olley-Pakes static decomposition of productivity by industry.

In this section we present an analysis of allocative efficiency on a country-by-country basis for three different sectors of economic activity. We derive measures of allocative efficiency for each of the following sectors: Manufacturing, other production (construction and utilities) and services. We then modify the equation to add a subscript j that denotes industry (j=3 as we have three broad industry groupings).

$$TFP_{cjt} = \left(1/N_{cjt}\right)\sum_i TFP_{icjt} + \sum_i\left(\theta_{icjt} - \bar{\theta}_{cjt}\right) * \left(TFP_{icjt} - \overline{TFP}_{cjt}\right) \quad (3.2)$$

In order to derive measures of allocative efficiency for each of these three broad sectors a weighted average of 2-digit industry level OP cross terms is used (see table A.2 for a list of the 26 industries for which we computed the OP covariance term). In Table 3.3.2 we present OP allocative efficiency estimates by broad industry grouping for the EU countries, distinguishing before and after the recession. In general we observe that the overall levels of allocative efficiency are positive. This is the case for all manufacturing and services sectors considered here. We only derive some negative estimates of allocative efficiency in other production sectors, which include utilities (electricity, gas and water) and construction activities. We can see that there is significant variation in the sector measures of OP allocative efficiency across industries.

We can see from Table 3.3.1 that the manufacturing sector experiences a higher level of allocative efficiency on average for the EU. This increased just after the recession, but has fallen again in the last few years. The levels of allocative efficiency in the services sector, which are higher than in the manufacturing sector, also rose after 2007 and fell by a smaller proportion afterwards.

Table. 3.3.1. Allocative efficiency in the EU, by broad sector, 2003-2014.

	Manufacturing	Other production	Services
2003-2007	0.188	0.175	0.322
2008-2010	0.250	0.164	0.390
2011-2014	0.177	0.073	0.211

Source: Authors' calculations based on Amadeus data base, Eurostat- Firms with more than 10 employees only. Countries with no observations: CY and LT. Countries with reduced samples (with less than 1000 observations pear year) are LU, LV, MT and IE

Table 3.3.2. Static Olley and Pakes decomposition of total factor productivity using gross value added shares as weights (2003-2014), firms with 20 or more employees.

country	sector	Allocative efficiency		Average productivity (weighted)		Average productivity (weighted)		Number of observations	
		2003-2007	2008-2014	2003-2007	2008-2014	2003-2007	2008-2014	2003-2007	2008-2014
BE	Manufacturing	0.490	0.463	2.652	2.723	3.142	3.186	18585	23866
BE	Other production	0.203	0.099	2.325	2.319	2.528	2.418	13404	18526
BE	Services	0.566	0.590	2.791	2.727	3.357	3.318	41461	58691
BG	Manufacturing	0.351	0.258	1.645	1.733	1.996	1.991	5377	10359
BG	Other production	0.019	0.069	1.405	1.701	1.423	1.770	2799	5661
BG	Services	0.535	0.283	1.567	1.728	2.102	2.011	11076	20799
CZ	Manufacturing	0.150	0.270	2.041	2.091	2.191	2.361	24692	37142
CZ	Other production	0.007	0.280	1.765	1.552	1.773	1.832	11240	15884
CZ	Services	0.062	0.321	2.255	2.152	2.317	2.473	26890	37886
DE	Manufacturing	0.045	0.057	3.084	3.008	3.128	3.065	13468	41230
DE	Other production	0.301	0.221	2.100	2.117	2.400	2.338	4183	12500
DE	Services	0.539	0.335	3.131	3.029	3.671	3.364	16189	46637
DK	Manufacturing	.	0.141	.	2.642	.	2.782	.	6163
DK	Other production	.	0.126	.	2.665	.	2.791	.	3762
DK	Services	.	0.073	.	2.963	.	3.035	.	14119
EE	Manufacturing	0.205	0.185	1.992	2.043	2.197	2.228	3853	5290
EE	Other production	-0.092	-0.015	1.507	1.467	1.415	1.452	2379	2587
EE	Services	0.218	0.152	2.209	2.250	2.428	2.402	7426	8529
ES	Manufacturing	0.280	0.261	2.519	2.394	2.799	2.656	98855	105865
ES	Other production	0.321	0.166	2.504	2.127	2.825	2.294	65160	50466
ES	Services	0.287	0.226	2.471	2.338	2.758	2.563	168270	206094
FI	Manufacturing	0.209	0.259	2.567	2.600	2.776	2.859	7740	9487
FI	Other production	0.223	0.155	1.976	1.960	2.199	2.115	4764	6638
FI	Services	0.249	0.157	2.803	2.788	3.052	2.945	14035	16316

FR	Manufacturing	0.068	0.041	2.787	2.842	2.854	2.883	66280	60240
FR	Other production	0.040	0.117	2.843	2.759	2.883	2.876	47768	46728
FR	Services	0.166	0.050	3.070	3.026	3.235	3.076	139328	134842
GB	Manufacturing	0.122	0.387	2.760	2.833	2.882	3.220	29314	29643
GB	Other production	0.469	0.124	2.772	2.581	3.241	2.705	10307	9060
GB	Services	0.157	0.276	2.972	2.961	3.129	3.237	52515	52551
GR	Manufacturing	0.108	0.083	2.495	2.060	2.604	2.143	9694	11116
GR	Other production	0.063	0.057	1.892	1.298	1.955	1.355	1290	1974
GR	Services	0.044	0.037	2.505	2.235	2.549	2.272	15348	19650
HR	Manufacturing	0.230	0.272	1.847	1.755	2.078	2.026	7104	9812
HR	Other production	0.017	-0.084	1.818	1.548	1.835	1.464	4377	5348
HR	Services	0.422	0.055	1.958	1.787	2.380	1.842	13455	16198
HU	Manufacturing	0.429	0.371	2.059	1.967	2.488	2.338	5347	29163
HU	Other production	0.209	0.138	1.495	1.410	1.703	1.548	2152	12516
HU	Services	0.558	0.453	2.040	2.020	2.598	2.473	7116	44440
IE	Manufacturing	0.001	0.177	3.206	2.755	3.207	2.931	67	271
IE	Other production	0.121	-0.008	2.973	2.830	3.094	2.822	22	96
IE	Services	0.261	0.654	2.188	2.750	2.450	3.404	257	1226
IT	Manufacturing	0.167	0.219	2.639	2.517	2.807	2.736	104019	188971
IT	Other production	-0.040	-0.009	2.170	1.893	2.130	1.884	25586	57879
IT	Services	0.199	0.111	2.528	2.340	2.726	2.451	71491	156635
NL	Manufacturing	0.133	0.058	3.093	3.173	3.226	3.231	2604	1731
NL	Other production	-0.114	-0.112	2.806	2.804	2.692	2.692	1249	725
NL	Services	0.479	0.424	3.096	3.045	3.575	3.469	5867	4229
PL	Manufacturing	0.246	0.259	1.979	2.008	2.225	2.267	15135	19964
PL	Other production	0.191	0.494	1.807	1.773	1.998	2.267	7329	9115
PL	Services	0.214	0.244	2.302	2.114	2.516	2.358	24021	31832
PT	Manufacturing	0.390	0.362	2.141	2.141	2.531	2.502	16908	54966
PT	Other production	0.658	0.439	1.830	1.955	2.488	2.394	8245	21120

PT	Services	0.353	0.331	2.243	2.183	2.596	2.514	22881	74084
RO	Manufacturing	0.378	0.402	1.743	1.704	2.121	2.106	31796	45370
RO	Other production	-0.048	-0.041	1.544	1.304	1.495	1.263	13030	20834
RO	Services	0.292	0.297	1.544	1.662	1.836	1.959	37814	67137
SE	Manufacturing	0.102	0.130	2.689	2.742	2.791	2.872	17767	24526
SE	Other production	0.194	0.147	2.101	2.041	2.295	2.188	10980	18469
SE	Services	0.202	0.201	3.057	3.107	3.259	3.309	34626	51271
SI	Manufacturing	0.079	0.061	2.000	2.021	2.079	2.082	5163	8260
SI	Other production	0.021	0.081	1.738	1.713	1.759	1.794	1258	3461
SI	Services	0.071	-0.021	2.055	2.019	2.126	1.998	4835	10713
SK	Manufacturing	0.213	0.212	2.043	2.069	2.257	2.281	6275	15648
SK	Other production	-0.044	-0.136	1.372	1.324	1.328	1.188	2916	6453
SK	Services	0.198	0.425	2.351	2.197	2.549	2.623	8278	22437

Source: Authors' calculations based on Amadeus data base, Eurostat- Firms with more than 20 employees only. Countries with no observations: CY and LT. Countries with reduced samples (with less than 1000 observations pear year) are LU, LV, MT and LU, IE, AT.

Table 3.3.3. Static Olley and Pakes decomposition of total factor productivity using gross value added shares as weights (2003-2014), firms with 20 or more employees, total EU, by broad sector.

Year	Broad indutry	Average productivity (un-weighted)	Average productivity (weighted)	Allocative efficiency	Number of observations
2003	Manufacturing	2.79	3.07	0.28	68,063
2004	Manufacturing	2.67	2.85	0.18	63,894
2005	Manufacturing	2.67	2.82	0.15	59,068
2006	Manufacturing	2.69	2.85	0.17	69,798
2007	Manufacturing	2.72	2.88	0.16	74,402
2008	Manufacturing	2.66	2.87	0.21	70,827
2009	Manufacturing	2.53	2.73	0.20	72,192
2010	Manufacturing	2.62	2.96	0.34	70,534
2011	Manufacturing	2.66	2.86	0.19	74,378
2012	Manufacturing	2.62	2.84	0.22	71,811
2013	Manufacturing	2.66	2.83	0.17	70,006
2014	Manufacturing	2.82	2.93	0.12	47,820
2003	Other production	2.35	2.79	0.44	26,743
2004	Other production	2.22	2.29	0.07	26,183
2005	Other production	2.24	2.33	0.10	23,519
2006	Other production	2.23	2.37	0.14	27,471
2007	Other production	2.18	2.31	0.13	29,165
2008	Other production	2.05	2.21	0.15	27,731
2009	Other production	2.05	2.27	0.22	28,084
2010	Other production	2.04	2.16	0.12	26,573
2011	Other production	2.00	2.08	0.08	26,546
2012	Other production	1.95	2.02	0.06	24,443
2013	Other production	2.08	2.15	0.07	23,043
2014	Other production	1.89	1.97	0.08	15,837

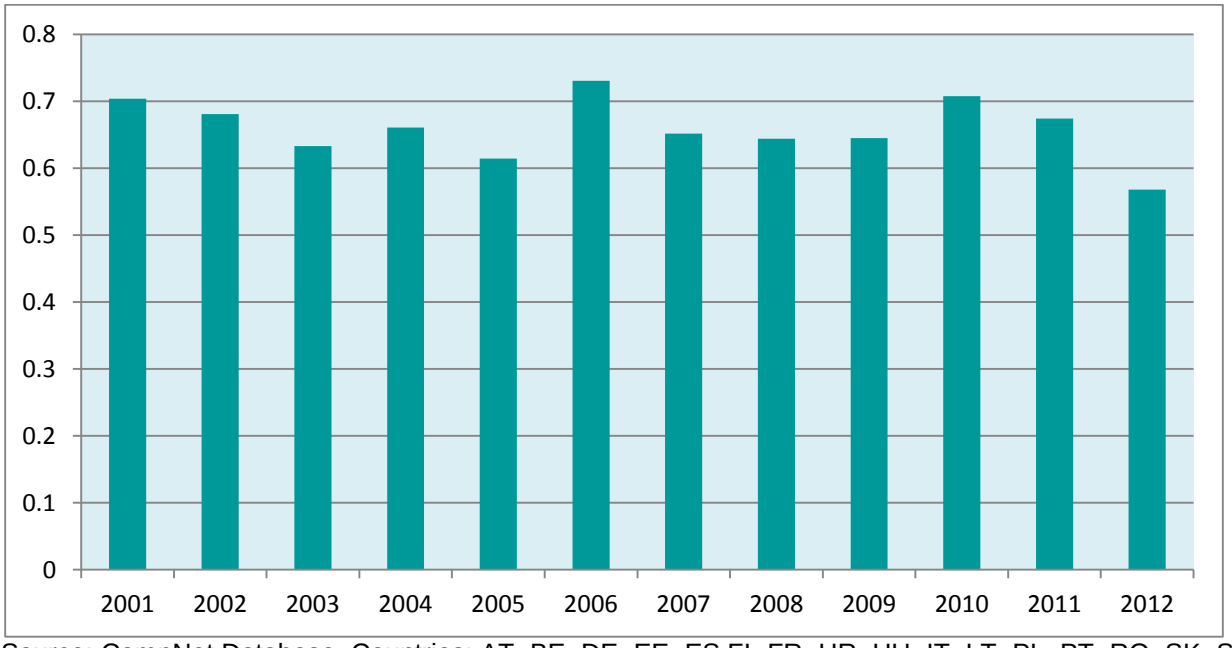
2003	Market services	3.09	3.75	0.67	86,843
2004	Market services	2.87	3.15	0.28	83,346
2005	Market services	2.84	3.07	0.22	75,409
2006	Market services	2.83	3.09	0.25	88,005
2007	Market services	2.86	3.04	0.18	92,356
2008	Market services	2.80	2.99	0.18	89,900
2009	Market services	2.80	3.35	0.55	94,210
2010	Market services	2.81	3.24	0.44	93,595
2011	Market services	2.82	3.04	0.22	95,980
2012	Market services	2.84	3.10	0.26	92,032
2013	Market services	2.83	3.03	0.20	89,648
2014	Market services	2.95	3.12	0.17	57,278

3.4 Analysis of allocative efficiency using CompNet database

In this section we show the results of the TFP-based allocative efficiency measures (Olley and Pakes, 1996). The CompNet database also includes labour-productivity indicators of allocative efficiency indicators, also widely used in the literature. The countries currently included in the CompNet dataset are: Austria, Belgium, Croatia, Estonia, Finland France, Germany, Hungary, Italy, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain. Originally the CompNet dataset included 11 economies.

In figure 3.4.1 we illustrate an average measure of O-P allocative efficiency for the EU countries included in the sample. Note that this is a simple EU average, not weighted for the size of each country, and it is intended to illustrate the recent developments of this measure of efficiency in the EU. This is based on firms with at least 20 employees, as this ensure better comparability across countries. The figure shows that the level of allocative efficiency was at higher levels in the early 2000s, although experienced another surge in the year leading up to the 2007-2008 financial crisis. In the aftermath of the crisis the level of allocative efficiency remained largely stable and increased again by 2010. In the last few years, it appears to have deteriorated again. These trends are largely consistent with those Amadeus-based illustrated in Figure 3.2. The most important finding is that we do not observe large fluctuations, overall, in allocative efficiency, similarly to what we found in our main Amadeus analysis. The magnitude of the allocative efficiency emerging from the CompNet analysis appears larger, and this may be due to a series of methodological choices (level of sectoral analysis) and data issues. However the trends over time are largely consistent and lead to similar conclusions.

Figure 3.4.1. Average allocative efficiency in the EU using the Compnet database.

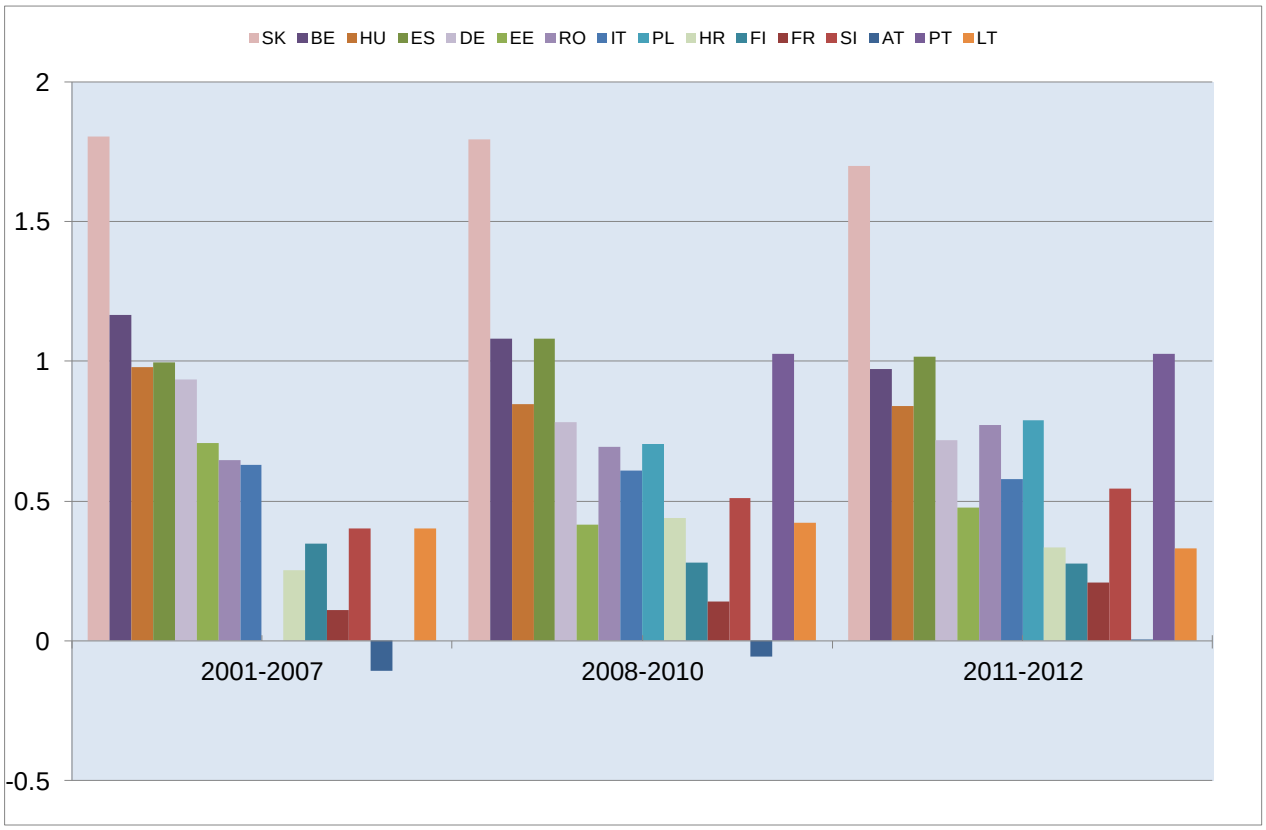


Source: CompNet Database. Countries: AT, BE, DE, EE, ES,FI, FR, HR, HU, IT, LT, PL, PT, RO, SK, SI; for firms with at least 20 employees.

Note: Data for early years (2001 and 2002) includes only few countries: BE,EE,FI,FR,DE,SI,ES. Two countries were added in later year, PL in 2008 and PT in 2009.

On a country-by-country basis we also observe important differences in allocative efficiency. We illustrate the trends in AE for three different sub-periods, 2001-2007, 2008-2010 and 2011-2012. The periods are very similar to those considered in the Amadeus analysis, although the CompNet coverage is a little less recent (up to 2012) but covers the period since 2001. According to CompNet data, those countries that present higher levels of allocative efficiency include: Slovakia, Belgium, Hungary and Spain. Countries with lower levels of allocative efficiency include Austria (mostly negative), France, Finland, and Slovenia. These are similar results to what we find in Amadeus, although the list of countries for which the analysis is feasible does not fully overlap. The results are slightly different for Slovakia, as according to CompNet has the highest score in AE in the sample, while according to our analysis in Amadeus, would rank medium to medium-high in a AE scale. The level of AE in Germany also appears higher according to the CompNet analysis.

Figure 3.4.2. Allocative efficiency by EU country, CompNet database, 2001-2012.



Source: CompNet Database.
Notes: Portugal, and Poland are only available from 2008 (PL) and 2009 (PT).

Table 3.4.1 provides summary measures of allocative efficiency for our sample of EU countries (again these averages are not weighted by size of the country). Overall we see that the level of allocative efficiency is higher in services, but the differences are small. This is in contrast to our analysis reported in the Amadeus section, where we also see that allocative efficiency tends to be higher in services, but the differences seem larger with the rest of sectors.

Table 3.4.1. Average allocative efficiency in the EU by sector, 2001-2014.

Period	Sector	Allocative efficiency	Number of observations
2001-2007	Manufacturing	0.43	371,566
2008-2010	Manufacturing	0.44	229,023
2011-2014	Manufacturing	0.44	142,348
2001-2007	Other production	0.43	375,381
2008-2010	Other production	0.46	243,664
2011-2014	Other production	0.45	151,700
2001-2007	Market services	0.44	153,561
2008-2010	Market services	0.46	106,602
2011-2014	Market services	0.46	73,462

Source: CompNet data, own calculations.

3.5 Policy conclusions

Cross-country differences in allocative efficiency can be substantial, and this suggests that some nations are more successful than others at reallocating resources to their most productive uses. What lessons can we learn from this analysis, and how can this inform policy? In section 7 we outline in detail the main strands of evidence on the role of public policy in fostering productivity growth through its effect on the efficiency of resource allocation. The main focus of the review is to document the extent to which the regulation or de-regulation of markets (for products, labour services, financial services and so on) influences allocative efficiency within a given economy.

Andrews and Cingano (2014) argue that differences in the efficiency of resource allocation across countries are closely related to regulations affecting product, labour and credit markets. With regards to labour markets, higher levels of efficiency are associated with lower dismissal costs. Restrictive dismissal laws can raise the costs of adjusting the workforce, thus deterring firms from hiring even when the marginal product of workers exceeds their market wage, and firms may retain workers even when their wage is higher than their productivity, with detrimental effects for overall productivity. In terms of product markets, regulations can limit the extent of competition in a market and therefore incumbents may have less incentive to allocate resources efficiently. Product and labour market regulations are more likely to have a negative influence on allocative efficiency in more innovative sectors, which are likely to be subject to greater technological change and rely on a more flexible resource allocation. Olley and Pakes (1996) showed that the deregulation of US telecommunication raised allocative efficiency in that industry.

In general, however, there is little evidence that productivity gains associated with reform initiatives are channelled through a more efficient resource allocation. Since the crisis, the level of allocative efficiency has increased in some countries but decreased in others. Overall allocative efficiency appears to have slightly increased immediately after the crisis, but has decreased again in more recent years. Overall the changes are not large and cannot be closely linked to weak aggregate productivity performance in the EU in recent years.

The findings from an allocative efficiency analysis alone do not lead to straightforward policy recommendations. A static analysis of allocative efficiency poses key limitations too, as it does not reveal much about the source of gains in efficiency. For instance, it may not be apparent whether an economy is becoming more efficient because more productive firms are capturing a larger share of the market, and/or alternatively because new and more productive firms enter the market thus replacing older and less productive firms. However, a number of relevant policy factors aimed at improving allocative efficiency would include: less strict entry regulation and lower administrative requirements for start-ups, and a bankruptcy legislation that punishes failure less severely (lower costs of closing down a business). Lower barriers to growth would also

be conducive to increased allocative efficiency. In contrast, policies that help businesses that have lost their productivity advantage and thus can maintain their market shares can be detrimental for allocative efficiency.

Allocative efficiency has traditionally been higher in countries such as the US and some northern European countries (Arnold et al, 2008), while it has been lower in southern European countries. However, transition countries that have liberalised markets and privatised state owned-enterprises are also likely to experience temporary surges in allocative efficiency. During the period 2003-2007 countries with higher allocative efficiency include certain Central and Eastern European countries (as well as others such as Belgium and Spain). In the case of the Central and Eastern European countries the high covariance found between size and productivity could be reflecting a duality between the very large and productive foreign-owned firms, and the small and less productive local firms. In general while high covariance suggests that the most efficient firms in a country may be the largest, the scope for productivity gains in these countries may be sizeable, especially as the productivity gains from an improved resource allocation increases with the distance to the productivity frontier (Lopez-Garcia et al, 2014). This finding suggests that there may be further scope to raise productivity by firms catching up to the global frontier.

In this analysis we do not observe that levels of allocative efficiency in the services sectors are lower than in manufacturing, which suggests some evidence of moving towards more business-friendly environment in services too, but again differences across countries are likely to be substantial.

4. Analysis of dispersion in TFP levels

Evidence suggests that dispersion of productivity levels is likely to have increased since the financial crisis both within countries and across countries. Given this widespread firm heterogeneity the assessment of aggregate productivity requires consideration of the distributional characteristics of TFP. In this section we provide a characterization of the firm-level TFP distribution in EU member states as well as in the EU as a whole, and for selected countries and sectors.

The literature shows[8] that there are substantial and persistent differences in productivity levels across firms. We propose here to look at the sources of TFP inequalities in Europe, from an aggregate perspective. We look at differences in dispersion levels between industries and within industries in the European Union. We compute a Theil inequality index, and distinguish industries, countries and size classes as sources of inequality.

The other main contribution of the Theil index stems from its property of being decomposable into two additive components: a between component (differences in TFP across groups of firms – countries, industries or size classes) and a within component (differences in firm's TFP within a particular group). This type of decomposition allows us to assess whether the overall evolution of the differences in TFP are driven by the between component, i.e. the convergence or divergence in the average levels across industries (countries or size classes); or alternatively, by a reduction of the differences within firms belonging to the same sector (country or size classes).

More formally, the Theil index[9] is defined by:

$$T(b) = \frac{1}{b(b-1)} \sum_i p_i \left[\left(\frac{x_i}{m} \right)^b - 1 \right] \qquad (4.1)$$

where x_i is the variable of interest, TFP, μ the weighted average of x_i, p_i the weight of each firm i in the total sample, and β a factor measuring the sensitivity of the index to factor reallocation between firms with high levels of x_i to firms with low levels. We need to assume $\beta=0$ in order to obtain the decomposition of the Theil index into the two – between and within – additive components. Additionally, when $\beta=0$, each group is weighted by its own weight in the total number of firms, thus favouring the inequality of those groups which represent a greater percentage of the total sample.

With this assumption equation (4.1) becomes:

$$T(0) = -\sum_i p_i \log\left(\frac{x_i}{m} \right) \qquad (4.2)$$

[8] See for example the surveys Bartelsman and Doms (2000) or Syverson (2011).

[9] More details on different inequality measures and their properties can be found in Shorrocks (1980 and 1984).

We assume that the total sample may be separated into *G* groups (countries, industries or size classes), that each group represents a percentage p_g of the total sample and that the weighted average of variable x_i of each grouping is μ_i. Then, the decomposition property of the family of Theil indexes allows us to express the previous equation in the following manner:

$$T(0) = \sum_{g=1}^{G} p_g T_g(0) + T_0(0) \qquad (4.3)$$

where

$$T_g(0) = -\sum_{i \in n_g} \left(\frac{p_i}{p_g} \right) \log \left(\frac{x_i}{\mu_g} \right) \qquad (4.4)$$

is the internal inequality (within groups) index of each grouping and

$$T_0(0) = -\sum_{g} p_g \log \left(\frac{\mu_g}{\mu} \right) \qquad (4.5)$$

is the external inequality (between groups) index between groupings.

Thus, we compute the decomposition of the Theil index as per the above equations for the TFP indicators. The analysis is carried out by defining groups by countries, by industries and by size classes[10].

Table 4.1 and Figure 4.1 show the Theil index calculated for our baseline TFP indicator[11] considering all firms in the European Union sample[12]. The overall evolution of the Theil index shows that inequalities in the TFP of European Union firms have steadily increased, reaching a value in 2014 which was 49% higher than in 2003. Since the beginning of the crisis, 2007, the increase in inequality has been 20%. Hence, there is evidence of an increase in inequalities of productivity in European firms during this period.

[10] Four size classes are defined: 1) microenterprises: an enterprise which employs fewer than 10 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 2 million; 2) small enterprises: defined as an enterprise which employs fewer than 50 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 10 million. 3) medium-sized enterprises: enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million; 4) Large firms: those that do not fulfill the criteria for the other groups.

[11] To guarantee that the decomposition of the Theil index is exact, the weights used are built on the geometric aggregation of labour and capital of each firm using as the aggregation factors the factor shares used in the construction of the TFP indicator. Additionally, the resampling weights are also considered.

[12] The Theil index is sensitive to the presence of outliers. Hence, in addition to the filtering of outliers based on the yearly growth rate of the TFP indicator previously described, a new filter has been added to the TFP levels. More precisely, the top 0.25% and bottom 0.25% of the observations have been discarded. Additionally, as previously mentioned, countries/years with less than 1000 observations have been removed from the sample. Real estate industry has also been removed from the sample.

The decomposition in the between and within component of the Theil index sheds some light on the sources of inequality. The last three columns of Table 4.1 and Figure 4.2 show the percentage that the within groups component represents over total inequality. The decomposition has been calculated defining groups by countries, by industries or, alternatively by size classes. The idea is to test whether the firms' TFP differences across countries, industries or size-classes are larger than that observed within each group. Results show that when TFP inequality is broken down by country, industry or size class the major source of the difference is the within component, which explains more than 90% of the total inequality when the index is broken down by size classes, more than 84% by countries and more than 70% when the decomposition is carried out by industries. This means that, despite the existing differences in TFP across countries or by size classes, these are lower than the inequality existing within the country, industries or size-classes. Therefore, the dynamics of productivity within a given country, industry or in the firms of similar size class, is relevant to explaining the differences in productivity. The evolution of the share of the within component is persistent throughout the period.

We can test whether these results are robust to the specification of the groups in terms of countries and sectors. Table 4.2 shows the Theil index calculated for each country, and Figure 4.3 shows the same information but only for the years 2006, 2013 and 2014. Although 2014 is the last year available, results are ordered by 2013 due to the fact that in 2014 the sample size reduces. There are large differences in the TFP inequalities across countries. For example, the inequality indexes are 2.5 and 2.1 times larger in the United Kingdom and in the Netherlands respectively, the two countries with the highest scores, than in Italy, the country with the lowest value. The more homogeneous countries in terms of TFP are Italy, France, Spain and Hungary, with Theil indexes below 0.4. In contrast, the highest TFP inequalities are observed in the United Kingdom, Netherlands, Poland, Germany and Sweden. Inequality decreased between 2006 and 2013 in Bulgaria, France, Czech Republic, Finland and Italy, but particularly in Slovakia, Germany and Romania, with a reduction of more than 20%. In the remaining 12 countries the differences in productivity widened between these two years. The highest increases were in Croatia, United Kingdom, Portugal, Poland and Estonia, all above 15%.

Are firms' TFP inequalities in EU countries driven by the industry differences in TFP or, alternatively, are they driven by the productivity differentials within industries? Table 4.3 and Figure 4.4a show the percentage of the Theil index explained by the within component when the index is broken down according to industry groups. In general, inequality within industries is higher than the differences that arise across industries. In fact, in only 6 EU Member States (Slovenia, Finland, Estonia, Greece, Sweden) the within component of the Theil index accounted for less than 50% of total inequality in 2013. In the remaining 14 EU Member States, the differences within industries are the main component of inequality. This share was particular high, above 70%, in Hungary, Italy, United Kingdom, Poland, Portugal, Spain and in Germany. Therefore, differences within industries (the within component) account for a large proportion of the inequality of TFP in European countries.

Table 4.4 and Figure 4.4b show the proportion of the firms' TFP inequality in each country that is explained by the differences within firm size class. In all countries except for Greece, Slovenia, Estonia and Croatia, the within component accounts for more than 90% of the differences in productivity. This means that the dispersion of productivity within each size class in the EU countries is more relevant than the differences that exist between size classes.

The analysis of TFP inequality has shown that, the inequality within industries is sizeable. To complement the analysis, Table 4.5 shows the Theil index calculated for each industry considered. Figure 4.5 shows the same information but only for 2006, 2013 and 2014. As previously shown, the TFP inequalities are lower when all industries are pooled together than when they are considered separately. In general, all industries share a relatively similar value of the Theil index in 2013. Sixteen industries showed an index below 0.4; six industries between 0.4 and 0.6; and only in four industries (Coke and refined petroleum products, Construction, Professional, scientific and support service activities and Publishing, audiovisual and broadcasting activities) is the Theil index above 0.6. In general, manufacturing industries are more homogenous in terms of productivity than services, which show higher inequality levels across firms. In eleven industries inequality decreased from 2006 to 2013 (all from manufacturing except for Retail trade, except of motor vehicles and motorcycles; Professional, scientific and support service activities; Wholesale trade, except motor vehicles; and Telecommunications). In the remaining fifteen industries the Theil index increased, particularly in Postal and courier activities.

Table 4.6 shows the proportion of the Theil index that is explained by the differences in TFP within countries for each industry. Figure 4.6a plots the same information for the years 2006, 2013 and 2014. In all industries, except for three (Postal and courier activities; Coke and refined petroleum products; and Manufacture of basic pharmaceutical products), it is the differences within countries, rather than between them, which explain the TFP inequalities, with a share above 60% in 2013. In 12 industries the share reaches 80% in 2013, and in four industries it is almost 90% or higher (IT and other information services; Publishing, audiovisual and broadcasting activities; Accommodation and food service activities; Professional, scientific and support service activities).

Tables 4.7 and Figure 4.6b show the contribution of the within component to the Theil index when the groups are defined according to firm size class. This shows quite clearly that the inequalities in TFP productivity across firms in European industries depend more on the differences within the size classes rather than on the differences between the size categories, as the differences within size classes are the main source of TFP inequality in every industry.

Summary and policy implications

Overall the analysis indicates that TFP inequalities across EU firms remained fairly stable up to the beginning of the crisis in 2008 and have been growing since. A remarkable increase (49%) was observed over the period from 2003 to 2014. The analysis indicates that differences within countries, industries or size classes are the main sources of TFP inequalities across firms. That is, the disparities of productivity in each country, industry or in each size class exceed the differences observed between countries or size classes. Therefore, cross-cutting policy measures addressed to all countries and industries will be necessary.

However, the inequality in productivity across EU firms does seem to have an industry specific component. Generally, the dispersion of productivity is higher in services than in manufacturing. Therefore, policy measures will be needed to improve the efficiency of the laggard industries, particularly in the services sector. Given that the differences in productivity are largely driven by the dynamics inside specific sectors, policies aimed at the reduction of barriers and frictions to factor mobility or to the functioning of the markets, and also on easing the exit of the less productive firms in the sectors, may be of benefit. Results show that there is scope for the improvement of aggregate productivity if the laggard firms converge to the industry's frontier firms, or, alternatively, if the leader increases their market share.

Figure 4.1. Theil index of the TFP for the EU over time, 2003-3014.

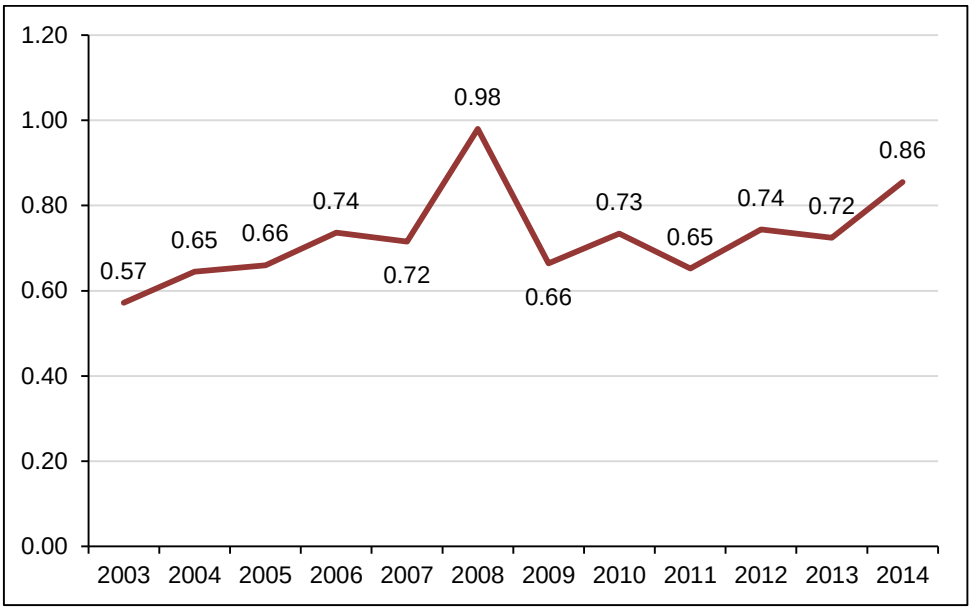


Table 4.1. Theil index for the EU over time, 2003-2014; total index and percentage of the within component

	Theil index	% of the within component of Theil index		
		By country	By industry	By size
2003	0.572	90.035	67.483	94.930
2004	0.645	87.287	71.628	94.419
2005	0.660	84.091	70.758	94.697
2006	0.736	89.130	73.098	97.283
2007	0.715	87.692	73.287	96.783
2008	0.980	88.163	76.633	99.184
2009	0.664	87.500	75.151	98.042
2010	0.734	85.559	75.068	99.046
2011	0.652	84.356	73.773	97.699
2012	0.744	87.231	73.790	98.522
2013	0.724	87.293	73.895	98.757
2014	0.855	82.105	69.357	92.047

Figure 4.2. Share of the within component of the Theil index. % of the within component over total Theil index

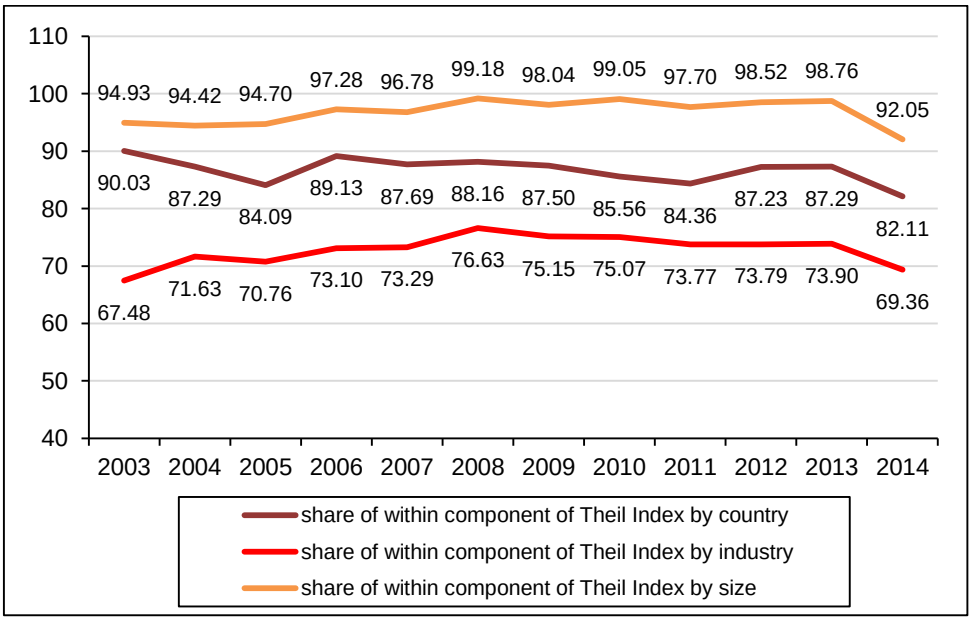


Figure 4.3. Theil index by EU Member State

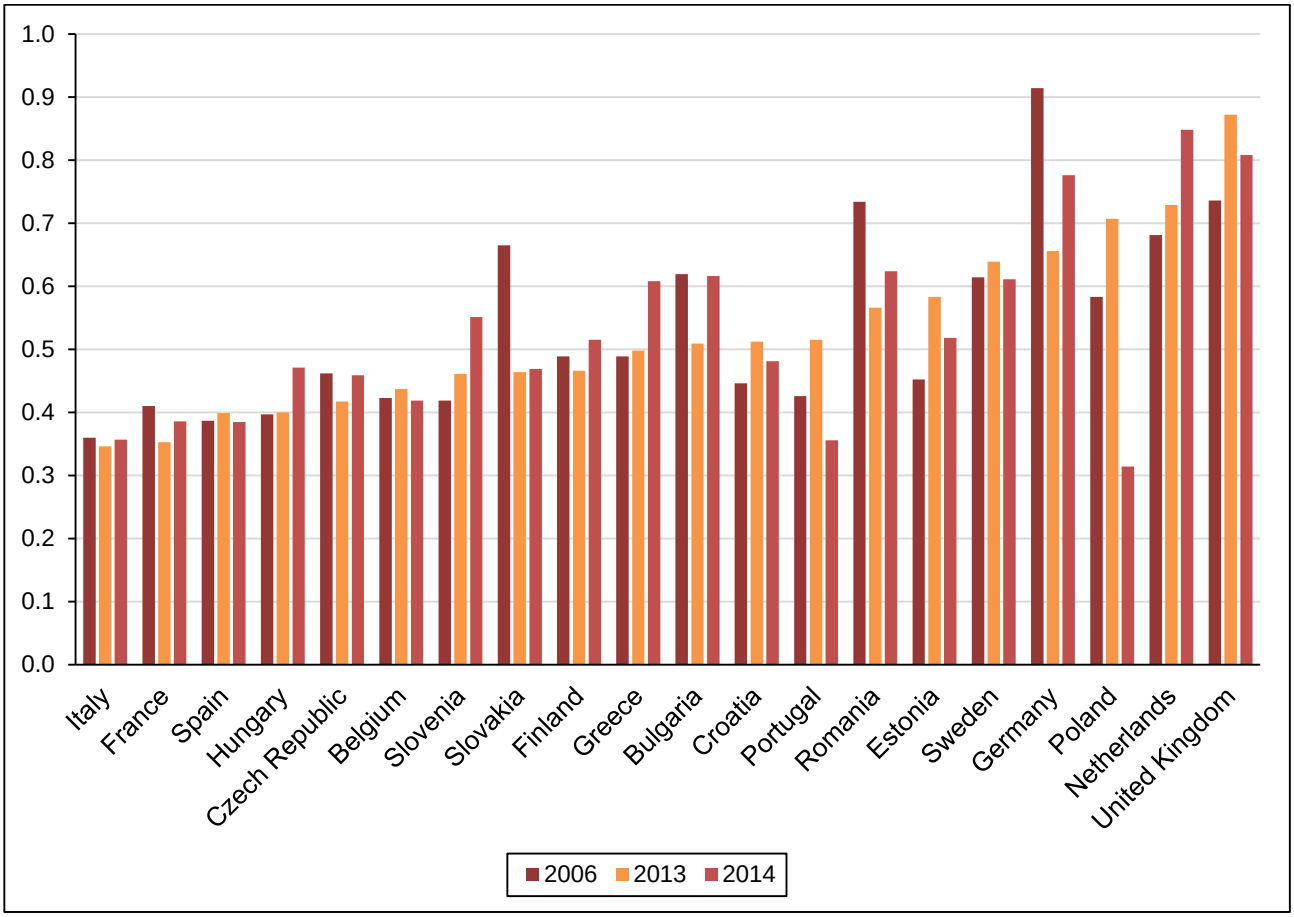
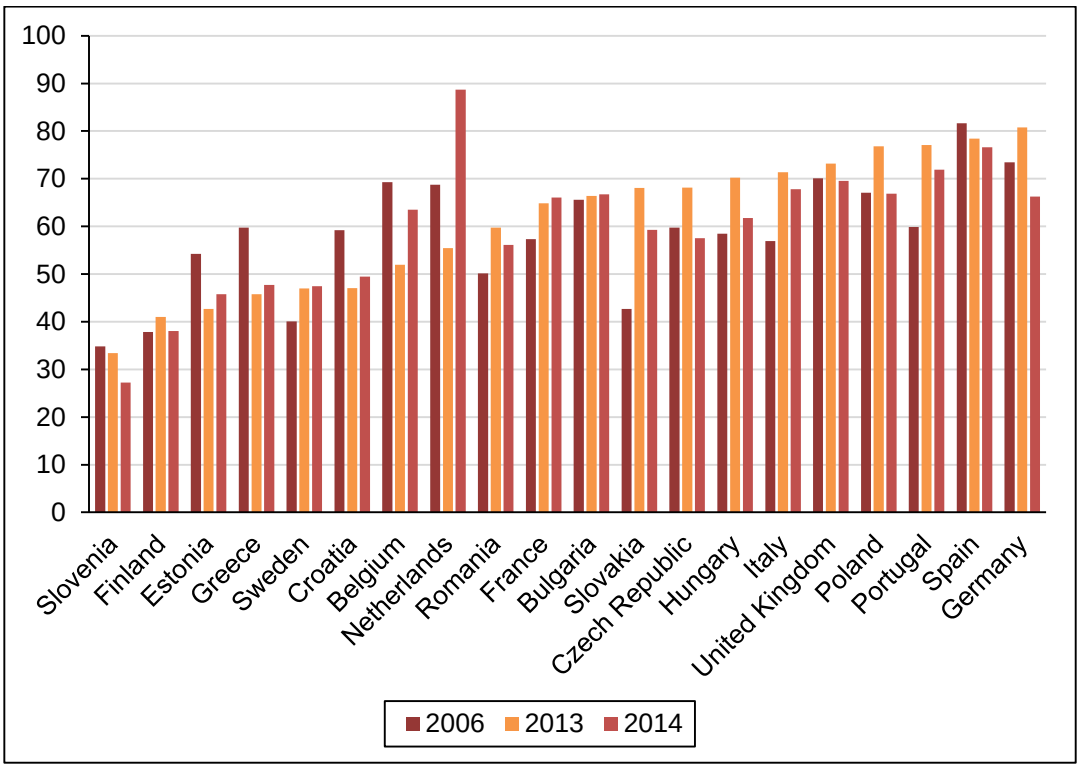


Table 4.2. Theil index by EU Member State and year.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Belgium	0.393	0.464	0.395	0.423	0.419	0.376	0.325	0.358	0.330	0.375	0.437	0.419
Bulgaria	0.557	0.590	0.591	0.619	0.659	0.732	0.673	0.802	0.672	0.745	0.509	0.616
Croatia	0.488	0.445	0.462	0.446	0.477	0.472	0.487	0.495	0.550	0.547	0.512	0.481
Czech Republic	0.528	0.454	0.419	0.462	0.454	0.425	0.533	0.410	0.427	0.480	0.417	0.459
Estonia	0.458	0.446	0.466	0.452	0.507	0.493	0.516	0.573	0.594	0.561	0.583	0.518
Finland	0.441	0.491	0.475	0.489	0.471	0.513	0.468	0.531	0.505	0.500	0.466	0.515
France	0.481	0.436	0.381	0.410	0.373	0.363	0.394	0.399	0.388	0.366	0.353	0.386
Germany	-	-	-	0.914	0.706	1.309	0.630	0.771	0.521	0.749	0.656	0.776
Greece	0.505	0.499	0.534	0.489	0.457	0.341	0.376	0.425	0.491	0.479	0.498	0.608
Hungary	-	-	0.370	0.397	0.404	0.495	0.435	0.403	0.451	0.454	0.400	0.471
Italy	0.383	0.406	0.357	0.360	0.370	0.391	0.392	0.354	0.333	0.346	0.346	0.357
Netherlands	0.633	0.813	0.766	0.681	0.926	1.068	0.701	0.831	0.638	0.689	0.729	0.848
Poland	0.718	0.703	0.632	0.583	0.699	0.577	0.589	0.595	0.595	0.813	0.707	0.314
Portugal	-	-	-	0.426	0.450	0.485	0.486	0.367	0.400	0.477	0.515	0.356
Romania	0.547	0.845	0.799	0.734	0.513	0.530	0.462	0.641	0.698	0.601	0.566	0.624
Slovakia	0.911	0.892	0.705	0.665	0.583	0.649	0.553	0.608	0.528	0.572	0.464	0.469
Slovenia	0.364	0.401	0.373	0.419	0.379	0.308	0.356	0.417	0.460	0.467	0.461	0.551
Spain	0.470	0.412	0.424	0.387	0.389	0.345	0.381	0.343	0.373	0.379	0.399	0.385
Sweden	0.410	0.507	0.590	0.614	0.570	0.672	0.575	0.606	0.609	0.620	0.639	0.611
United Kingdom	0.596	0.668	0.725	0.736	0.772	0.792	0.773	0.686	0.784	0.786	0.872	0.808

Figure 4.4. Within component of the Theil index in each EU Member State (% of total Theil index)

a) Decomposition by industry



b) Decomposition by size classes

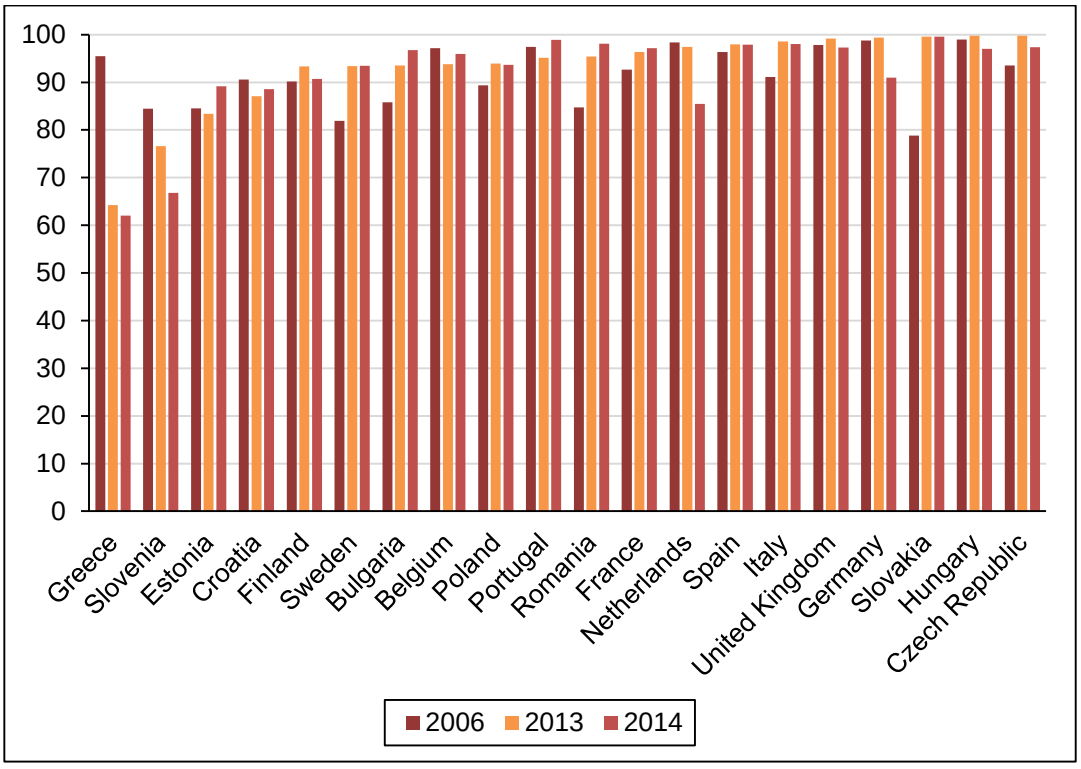


Table 4.3. Share of the within component of the Theil index in the decomposition by industry. % of the within component over total Theil index in each country

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Belgium	79.389	76.293	65.316	69.267	68.019	64.362	63.077	62.849	70.303	65.867	51.945	63.484
Bulgaria	62.118	62.203	57.699	65.590	65.706	63.251	69.391	67.706	65.327	61.879	66.405	66.721
Croatia	55.943	54.157	52.165	59.193	59.748	45.339	48.049	54.747	50.545	46.069	47.070	49.480
Czech Republic	65.341	71.366	71.122	59.740	65.198	77.647	75.235	66.829	62.998	59.583	68.106	57.516
Estonia	43.450	49.776	59.013	54.204	49.112	50.304	51.550	61.431	46.465	47.594	42.710	45.753
Finland	45.578	38.493	32.000	37.832	39.490	40.351	42.949	38.795	38.812	46.400	40.987	38.058
France	46.154	61.239	60.367	57.317	60.858	57.300	59.645	62.907	65.979	59.290	64.873	66.062
Germany	-	-	-	73.414	73.371	77.617	77.619	80.415	76.583	79.573	80.793	66.237
Greece	53.663	53.707	55.993	59.714	70.460	71.848	72.074	68.235	47.251	47.182	45.783	47.697
Hungary	-	-	63.243	58.438	57.673	63.636	61.839	64.268	63.193	61.894	70.250	61.783
Italy	61.880	58.867	66.667	56.944	54.054	62.148	60.969	63.842	67.868	70.520	71.387	67.787
Netherlands	77.725	79.459	73.107	68.722	77.214	63.390	85.592	88.809	75.862	73.295	55.418	88.679
Poland	62.674	69.417	72.943	67.067	79.256	74.177	76.740	71.092	72.605	66.544	76.803	66.879
Portugal	-	-	-	59.859	66.889	79.175	84.362	70.845	77.000	74.214	77.087	71.910
Romania	45.704	43.787	40.551	50.136	61.209	54.717	59.740	48.674	43.266	54.243	59.717	56.090
Slovakia	53.787	55.830	39.574	42.707	51.458	44.684	62.749	64.474	65.720	61.538	68.103	59.275
Slovenia	38.736	34.165	32.976	34.845	33.773	45.779	47.191	41.487	37.391	36.403	33.406	27.223
Spain	69.362	74.515	73.113	81.654	77.635	77.971	73.228	80.175	79.893	79.420	78.446	76.623
Sweden	51.220	43.984	37.797	40.065	43.860	41.369	50.957	50.825	52.381	49.516	46.948	47.463
United Kingdom	63.087	70.509	68.000	70.109	71.244	68.687	69.599	69.679	79.082	69.338	73.165	69.554

Table 4.4. Share of the within component of the Theil index in the decomposition by size classes. % of the within component over total Theil index in each country

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Belgium	99.746	93.534	97.215	97.163	97.852	96.809	94.154	97.486	97.576	97.867	93.822	95.943
Bulgaria	85.637	82.034	78.342	85.784	85.432	88.525	86.924	83.416	88.690	89.933	93.517	96.753
Croatia	89.344	91.011	88.095	90.583	92.243	86.864	90.760	90.909	91.455	89.580	87.109	88.565
Czech Republic	84.091	88.106	93.317	93.506	96.916	99.294	99.437	99.512	99.532	98.750	99.760	97.386
Estonia	75.546	78.251	84.764	84.513	78.304	82.150	89.922	88.656	83.333	85.561	83.362	89.189
Finland	96.599	86.558	83.789	90.184	90.234	95.712	96.581	90.207	94.059	96.800	93.348	90.680
France	91.060	97.706	94.488	92.683	96.783	95.041	91.624	95.990	97.680	90.710	96.317	97.150
Germany	-	-	-	98.796	97.025	98.701	98.889	98.962	98.848	98.531	99.390	90.979
Greece	92.277	92.786	95.880	95.501	97.812	96.774	96.809	96.706	67.413	67.850	64.257	62.007
Hungary	-	-	99.730	98.992	99.010	95.354	99.310	99.752	99.778	96.476	99.750	97.028
Italy	97.389	92.365	92.997	91.111	88.919	95.396	93.878	96.045	98.498	98.844	98.555	98.039
Netherlands	95.893	96.187	95.822	98.385	97.840	97.659	91.013	86.282	99.687	98.694	97.394	85.495
Poland	77.019	87.767	83.861	89.365	89.127	91.681	92.360	90.252	91.597	98.401	93.918	93.631
Portugal	-	-	-	97.418	92.222	96.495	99.794	95.640	95.500	98.323	95.146	98.876
Romania	93.419	89.112	76.846	84.741	93.177	90.000	94.589	80.811	83.811	99.168	95.406	98.077
Slovakia	63.886	72.309	76.312	78.797	89.880	86.595	94.394	93.257	97.159	95.804	99.569	99.574
Slovenia	89.011	77.805	84.182	84.487	85.752	89.935	91.854	87.290	80.652	80.300	76.573	66.788
Spain	97.021	95.874	95.047	96.382	96.658	97.681	96.588	97.668	97.587	97.889	97.995	97.922
Sweden	97.805	87.179	80.508	81.922	84.035	84.970	90.957	92.904	92.611	91.774	93.427	93.453
United Kingdom	94.966	95.659	96.276	97.826	97.409	96.212	97.154	95.773	96.429	98.219	99.197	97.277

Figure 4.5. Theil index in each EU industry

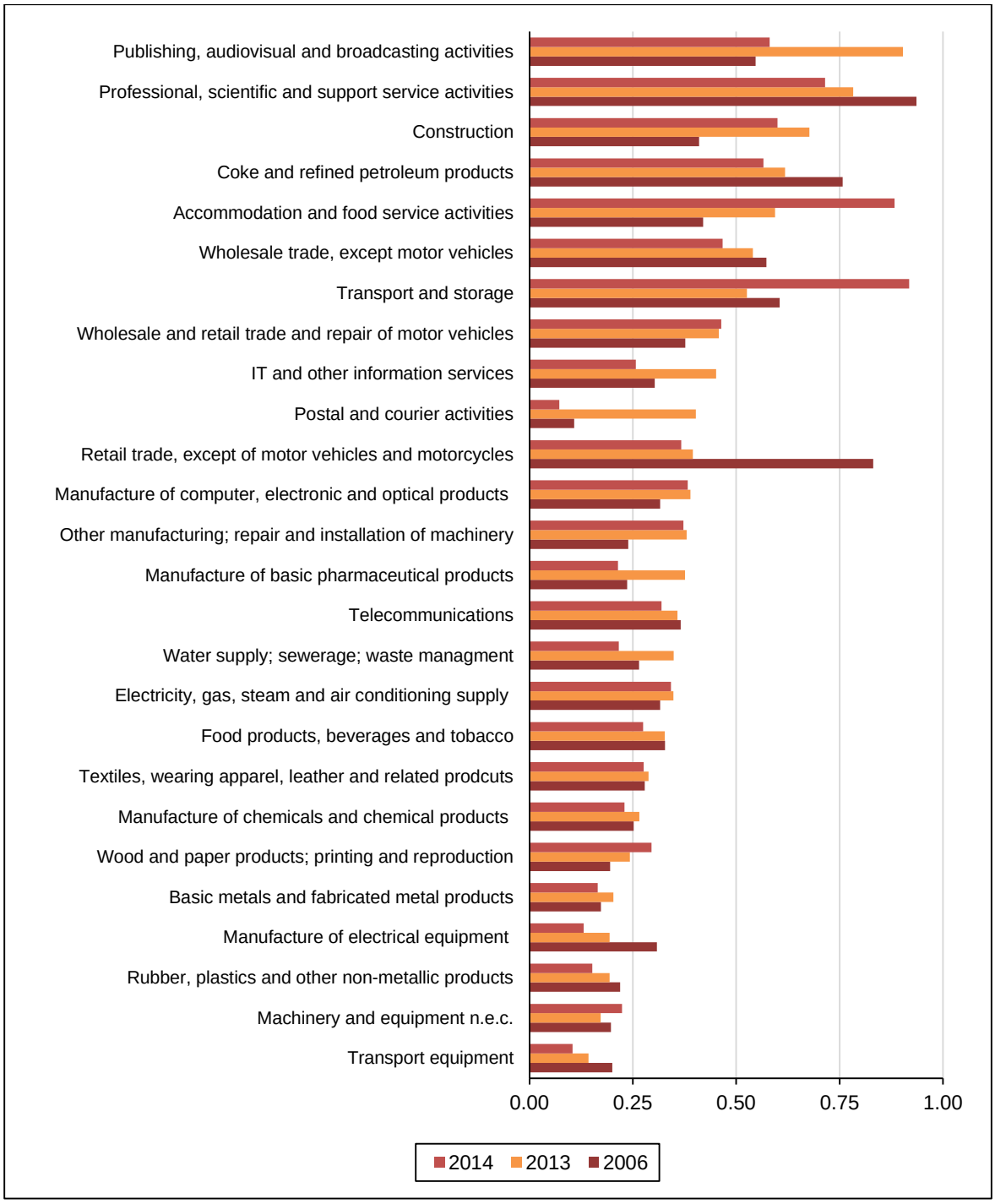
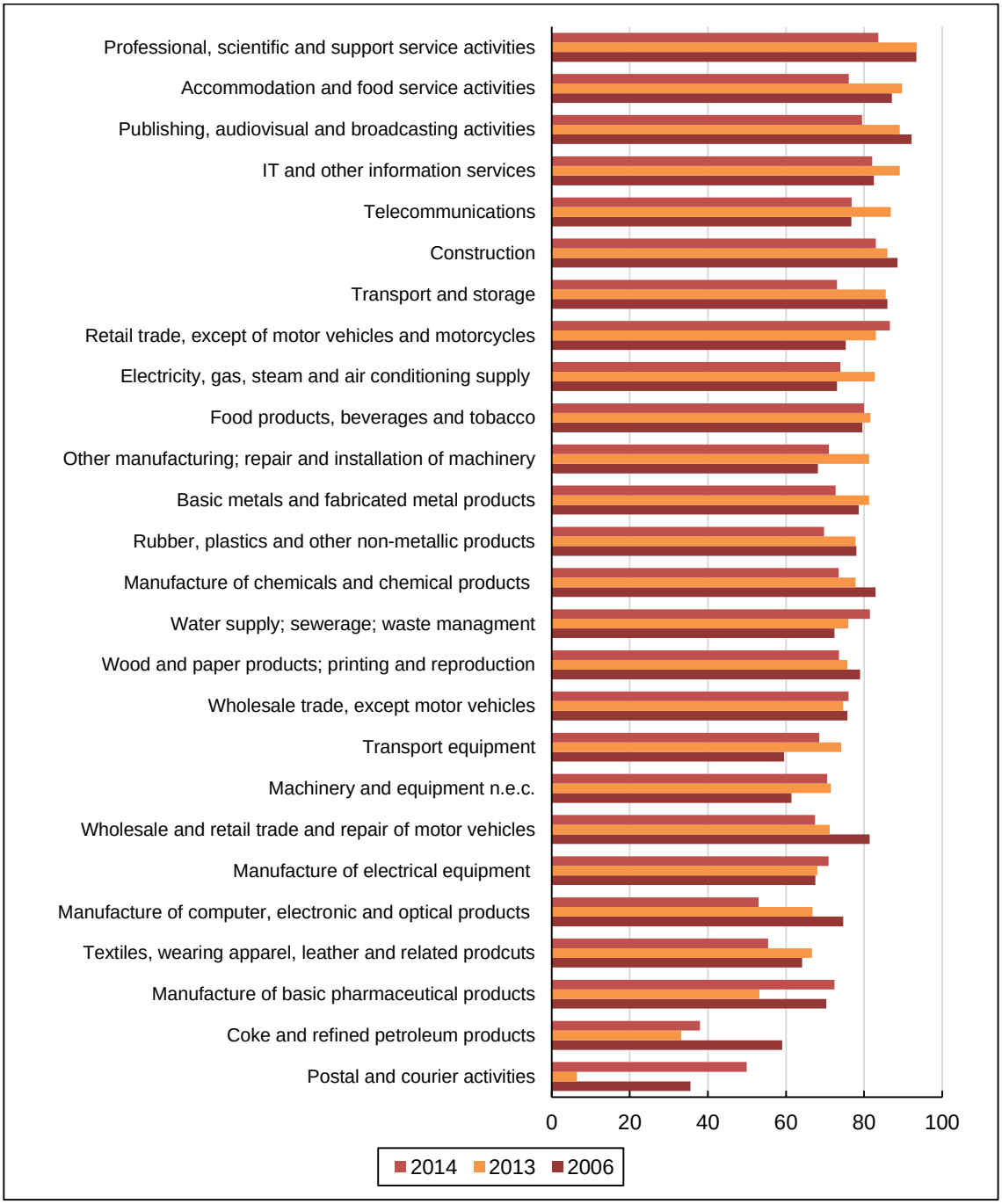


Table 4.5. Theil index by industry and year

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Food products, beverages and tobacco	0.238	0.257	0.252	0.328	0.321	0.328	0.294	0.288	0.306	0.398	0.327	0.275
Textiles, wearing apparel, leather and related prodcuts	0.273	0.283	0.739	0.279	0.272	0.288	0.386	0.675	0.375	0.722	0.288	0.276
Wood and paper products; printing and reproduction of recorded media	0.209	0.176	0.214	0.195	0.307	0.339	0.217	0.207	0.325	0.269	0.243	0.295
Coke and refined petroleum products	0.443	0.337	0.456	0.757	0.344	0.760	0.195	0.608	0.288	0.898	0.618	0.566
Manufacture of chemicals and chemical products	0.295	0.350	0.320	0.252	0.280	0.377	0.360	0.288	0.323	0.298	0.266	0.230
Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.379	0.225	0.247	0.236	0.243	0.231	0.249	0.270	0.304	0.367	0.376	0.214
Rubber and plastics products, and other non-metallic mineral products	0.169	0.176	0.189	0.219	0.188	0.188	0.194	0.175	0.179	0.201	0.194	0.152
Basic metals and fabricated metal products, except machinery and equipment	0.160	0.210	0.192	0.173	0.184	0.179	0.302	0.185	0.224	0.201	0.203	0.165
Manufacture of computer, electronic and optical products	0.420	0.412	0.369	0.316	0.323	0.348	0.401	0.431	0.324	0.363	0.389	0.383
Manufacture of electrical equipment	0.234	0.256	0.229	0.308	0.227	0.326	0.313	0.266	0.217	0.251	0.194	0.131
Machinery and equipment n.e.c.	0.210	0.215	0.229	0.197	0.217	0.189	0.216	0.184	0.173	0.177	0.172	0.224
Transport equipment	0.163	0.308	0.359	0.200	0.180	0.341	0.287	0.284	0.191	0.170	0.143	0.104
Other manufacturing; repair and installation of machinery and equipment	0.254	0.342	0.382	0.239	0.263	0.262	0.259	0.270	0.250	0.359	0.380	0.372
Electricity, gas, steam and air conditioning supply	0.368	0.530	0.412	0.316	0.357	0.417	0.557	0.384	1.071	0.345	0.348	0.342
Water supply; sewerage; waste managment and remediation activities	0.297	0.549	0.384	0.265	0.282	0.269	0.418	0.268	0.315	0.377	0.349	0.216
Construction	0.421	0.464	0.479	0.410	0.475	0.450	0.483	0.488	0.506	0.555	0.677	0.600
Wholesale and retail trade and repair of motor vehicles and motorcycles	0.340	0.348	0.460	0.377	0.390	0.336	0.362	0.364	0.347	0.320	0.458	0.464
Wholesale trade, except of motor vehicles and motorcycles	0.405	0.458	0.624	0.573	0.691	0.930	0.568	0.530	0.569	0.598	0.540	0.467
Retail trade, except of motor vehicles and motorcycles	0.364	0.414	0.400	0.831	0.374	0.390	0.468	0.371	0.418	0.392	0.395	0.367
Transport and storage	0.442	0.713	0.515	0.605	0.721	0.551	0.694	0.670	0.554	0.582	0.526	0.918
Postal and courier activities	0.147	0.099	0.169	0.108	0.118	0.126	0.078	0.129	0.129	0.091	0.402	0.072
Accommodation and food service activities	0.365	0.590	0.440	0.420	0.393	0.400	0.346	0.441	0.425	0.519	0.594	0.883
Publishing, audiovisual and broadcasting activities	0.639	0.567	0.712	0.547	0.642	0.719	0.680	0.575	0.531	0.559	0.903	0.581
Telecommunications	0.470	0.559	0.310	0.366	0.232	0.401	0.506	0.263	0.409	0.226	0.358	0.319
IT and other information services	0.252	0.293	0.299	0.303	0.428	0.317	0.348	0.321	0.323	0.340	0.451	0.257
Professional, scientific, technical, administrative and support service activities	0.601	0.671	0.640	0.936	0.849	1.468	0.696	0.943	0.635	0.878	0.783	0.715

Figure 4.6. Within component of the Theil index in each EU industry (% of total Theil index)

a) Decomposition by country



b) Decomposition by size classes

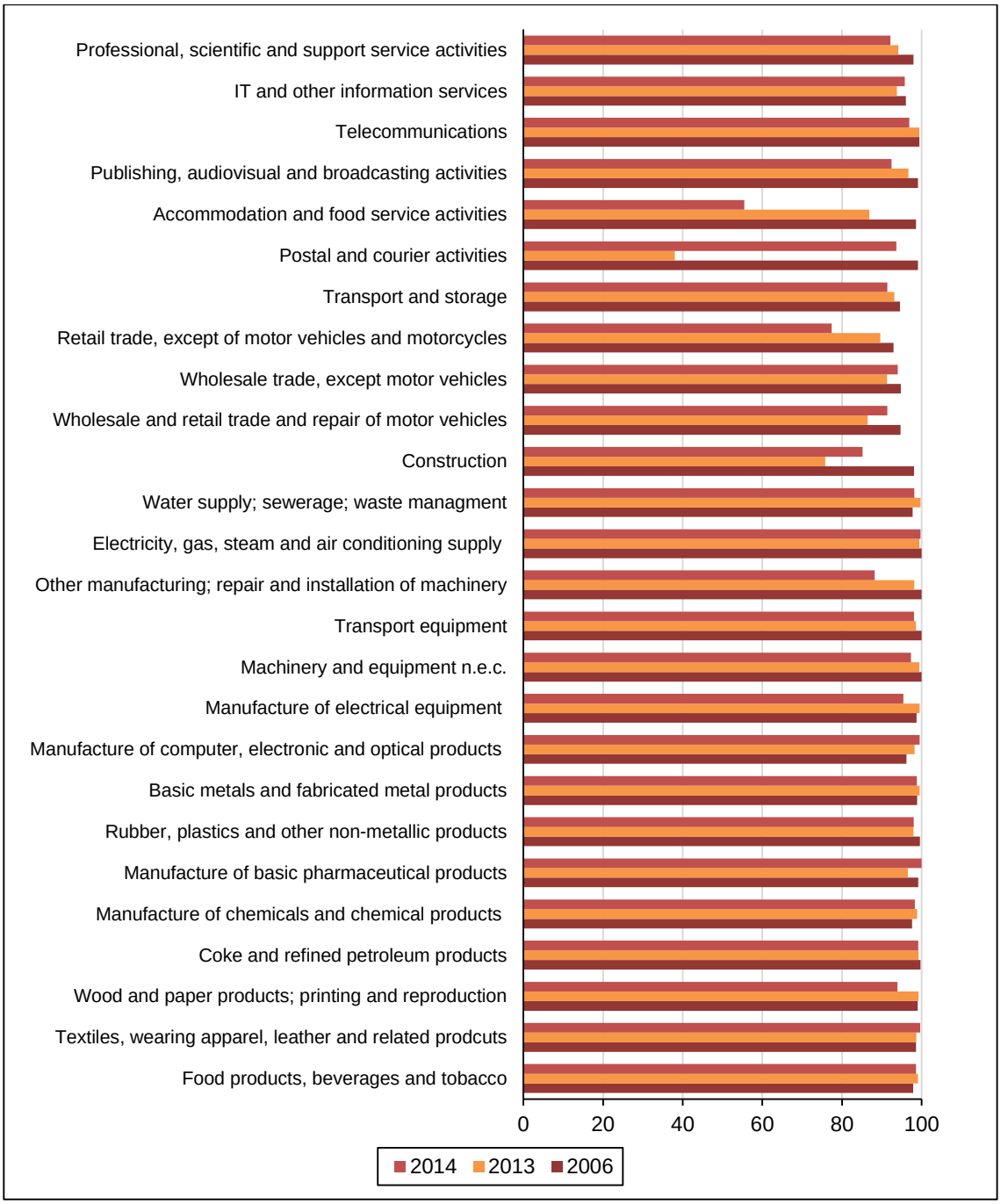


Table 4.6. Share of the within component of the Theil index in the decomposition by country. % of the within component over total Theil index in each industry

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Food products, beverages and tobacco	79.	80.	75.	79.	81.	77.	81.	75.	76.	85.	81.	80.
Textiles, wearing apparel, leather and	69.	68.	38.	64.	70.	69.	73.	66.	59.	66.	66.	55.
Wood and paper products; printing and	77.	83.	84.	78.	65.	65.	76.	77.	78.	79.	75.	73.
Coke and refined petroleum products	15.	34.	48.	59.	49.	40.	31.	41.	43.	34.	33.	37.
Manufacture of chemicals and chemical	72.	64.	74.	82.	73.	81.	81.	81.	73.	71.	77.	73.
Manufacture of basic pharmaceutical	74.	79.	71.	70.	69.	78.	69.	74.	69.	64.	53.	72.
Rubber and plastics products, and other	72.	75.	75.	78.	76.	70.	71.	78.	75.	76.	77.	69.
Basic metals and fabricated metal products,	78.	83.	73.	78.	73.	78.	75.	76.	75.	80.	81.	72.
Manufacture of computer, electronic and	55.	62.	62.	74.	74.	69.	72.	76.	76.	77.	66.	53.
Manufacture of electrical equipment	63.	58.	55.	67.	60.	75.	74.	72.	73.	73.	68.	70.
Machinery and equipment n.e.c.	61.	59.	57.	61.	67.	67.	71.	71.	74.	74.	71.	70.
Transport equipment	63.	70.	69.	59.	59.	81.	69.	65.	70.	75.	74.	68.
Other manufacturing; repair and installation	76.	74.	69.	68.	70.	69.	72.	76.	75.	79.	81.	70.
Electricity, gas, steam and air conditioning	77.	73.	61.	73.	73.	80.	80.	75.	84.	69.	82.	73.
Water supply; sewerage; waste	69.	85.	79.	72.	82.	80.	80.	78.	79.	79.	75.	81.
Construction	84.	87.	87.	88.	87.	86.	83.	84.	83.	85.	85.	83.
Wholesale and retail trade and repair of	84.	81.	76.	81.	84.	83.	82.	80.	83.	80.	71.	67.
Wholesale trade, except of motor vehicles	86.	82.	73.	75.	75.	68.	75.	80.	78.	77.	74.	76.
Retail trade, except of motor vehicles and	83.	84.	84.	75.	86.	79.	80.	81.	81.	82.	83.	86.
Transport and storage	80.	75.	75.	85.	83.	84.	85.	83.	82.	85.	85.	73.
Postal and courier activities	17.	18.	17.	35.	33.	32.	31.	34.	38.	36.	6.4	49.
Accommodation and food service activities	85.	76.	72.	87.	90.	88.	85.	85.	85.	82.	89.	76.
Publishing, audiovisual and broadcasting	91.	91.	88.	92.	89.	86.	86.	91.	88.	89.	89.	79.
Telecommunications	62.	82.	75.	76.	86.	85.	81.	77.	83.	83.	86.	76.
IT and other information services	92.	91.	82.	82.	73.	83.	85.	83.	85.	85.	89.	82.
Professional, scientific, technical,	91.	92.	90.	93.	92.	87.	93.	91.	91.	91.	93.	83.

Table 4.7. Share of the within component of the Theil index in the decomposition by size classes. % of the within component over total Theil index in each industry

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Food products, beverages and tobacco	97.	98.	99.	97.	98.	99.	98.	98.	99.	98.	99.	98.
Textiles, wearing apparel, leather and	95.	92.	92.	98.	98.	100	99.	97.	97.	96.	98.	99.
Wood and paper products; printing and	98.	99.	99.	98.	95.	97.	99.	98.	98.	99.	99.	93.
Coke and refined petroleum products	99.	99.	91.	99.	97.	97.	97.	99.	98.	96.	99.	99.
Manufacture of chemicals and chemical	99.	96.	99.	97.	98.	99.	99.	97.	98.	97.	98.	98.
Manufacture of basic pharmaceutical	98.	96.	99.	99.	98.	96.	97.	98.	98.	98.	96.	100
Rubber and plastics products, and other	99.	99.	99.	99.	100	100	99.	98.	98.	99.	97.	98.
Basic metals and fabricated metal	96.	99.	98.	98.	99.	99.	98.	99.	99.	100	99.	98.
Manufacture of computer, electronic and	98.	92.	94.	96.	94.	97.	94.	98.	97.	96.	98.	99.
Manufacture of electrical equipment	98.	96.	97.	98.	99.	100	98.	96.	100	99.	99.	95.
Machinery and equipment n.e.c.	98.	97.	95.	100	99.	99.	99.	96.	97.	99.	99.	97.
Transport equipment	98.	96.	96.	100	99.	99.	95.	97.	100	99.	98.	98.
Other manufacturing; repair and	99.	98.	98.	100	100	99.	99.	98.	99.	98.	98.	88.
Electricity, gas, steam and air conditioning	99.	99.	99.	100	99.	98.	99.	99.	93.	99.	99.	99.
Water supply; sewerage; waste	94.	95.	96.	97.	96.	98.	98.	98.	98.	98.	99.	98.
Construction	98.	96.	96.	98.	92.	91.	83.	81.	82.	70.	75.	85.
Wholesale and retail trade and repair of	97.	97.	97.	94.	91.	93.	90.	86.	93.	94.	86.	91.
Wholesale trade, except of motor vehicles	99.	97.	94.	94.	92.	87.	94.	94.	93.	92.	91.	94.
Retail trade, except of motor vehicles and	97.	92.	97.	92.	94.	93.	90.	92.	90.	92.	89.	77.
Transport and storage	97.	98.	95.	94.	93.	92.	93.	91.	94.	91.	93.	91.
Postal and courier activities	99.	99.	86.	99.	98.	74.	92.	98.	88.	72.	38.	93.
Accommodation and food service	99.	94.	92.	98.	98.	99.	99.	97.	97.	94.	86.	55.
Publishing, audiovisual and broadcasting	99.	99.	96.	99.	98.	98.	97.	98.	97.	98.	96.	92.
Telecommunications	93.	91.	96.	99.	100	98.	96.	100	98.	99.	99.	96.
IT and other information services	98.	98.	94.	96.	92.	91.	92.	94.	95.	95.	93.	95.
Professional, scientific, technical,	98.	97.	96.	97.	97.	87.	96.	86.	94.	87.	94.	92.

4.2 Dispersion of TFP across EU economies: TFP sigma and beta convergence.

We now address the issue of TFP convergence among EU countries. From the seminal work of Barro and Sala-i-Martin (1992), our analysis of convergence will be based on the concepts of sigma and beta convergence applied to the analysis of TFP. Sigma convergence measures the reduction in the dispersion of the TFP level among different economies over time, whereas beta convergence measures the inverse relationship between a country's growth in TFP and its initial productivity level. These two measures of convergence can be complementary. Beta convergence is a necessary but not sufficient condition for sigma convergence (Sala-i-Martin, 1996).

Beta convergence implies the existence of a mechanism of catching-up operating in the long run, i.e. TFP differences across countries narrow over time. A

distinction should also be made between the concept of absolute (or unconditional) beta-convergence and relative (or conditional) beta-convergence. Absolute beta convergence derives from the neo-classical growth theory models (Solow, 1956) based on diminishing returns to capital, where market forces and exogenous technical progress, freely available also to the poorer regions, facilitate the imitation process and guarantee the convergence result. Thus, absolute beta-convergence is based on the presumption that poorer economies, on average, will grow faster than richer ones over the long term.

The concept of conditional convergence, on the other hand, arises from the "new" endogenous growth theory, with the argument that economies converge to different steady state paths and not to the same steady state equilibrium as neo-classical theory assumes (Barro, 1991). The new endogenous growth models emphasize the role of human capital and innovation, among others, as relevant conditioning factors to ensure convergence. Thus, they postulate that the differences in the steady state paths of different economies are mainly explained by differences in human and physical capital stocks. Conditional convergence then describes the tendency of countries to converge to their own long-run equilibrium paths as a function of a number of conditioning factors (economic, institutional and political variables).

Although the usual analysis of convergence relates to GDP per capita or per worker, the concepts of sigma and beta convergence may also be applied to the analysis of TFP in order to provide insights as to the spread, adoption and convergence of technological progress. It may also be useful to shed light on whether technology is a public good, which may be easily spread across countries, or rather a private good with difficulty spreading across country borders.

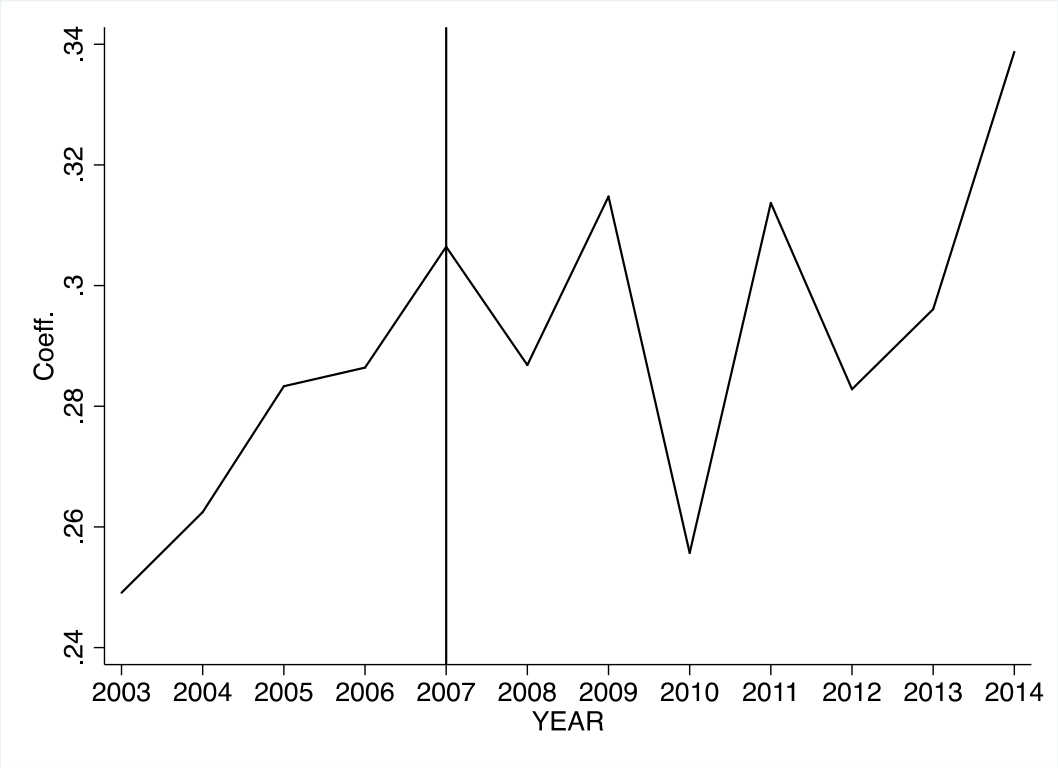
Our analysis of TFP convergence among EU economies covers the period 2003-2014 as a whole, as well as the two different sub-periods of interest (pre-crisis, 2003-2007, and post-crisis, 2007-2014). For the convergence analysis, we will draw on both the growth and level measures of TFP at the country-year level.

To test for the existence of sigma-convergence we examine changes over time in the degree of inequality or dispersion of TFP among countries. A commonly used measure of sigma-convergence is the coefficient of variation of TFP (in logs) at the country level (defined as the standard deviation divided by the sample mean for the TFP variable). A declining value for the coefficient of variation suggests convergence whereas an increasing value indicates divergence.

In Figure 4.2.1 we present the evolution of sigma-convergence among EU countries for the whole period under analysis, 2003-2014. We observe in general an increasing pattern of dispersion of the average levels of TFP among EU state members. However, this visual inspection of the sigma-divergence result is

mainly driven by the period up until 2007, since after 2007 we do not find a clear pattern when excluding the year 2014. Note that in 2014 there is a substantial drop in firms' observations in the Amadeus database, probably because of some limitations and incomplete information still present in the final available year for this database. Hence, results from 2014 should warrant caution.

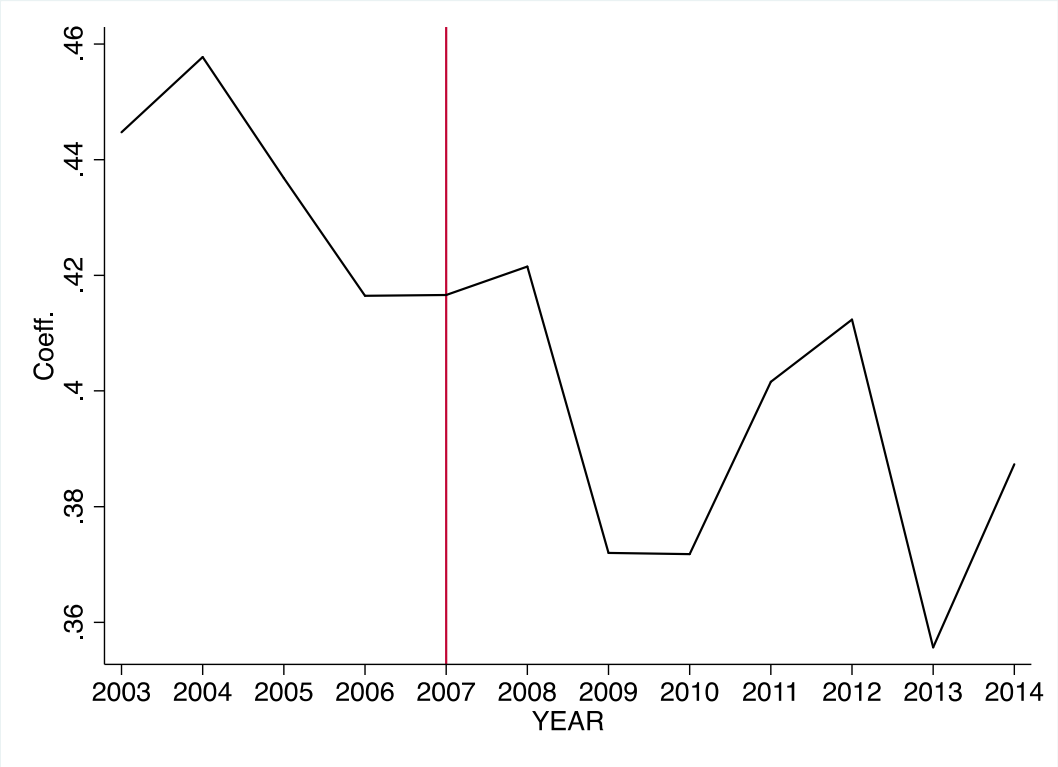
Figure 4.2.1 Sigma-convergence of TFP among EU countries.



Note: Sigma-convergence is measured as the coefficient of variation of TFP (in logs) at the country level, defined as the ratio of the standard deviation over the sample mean.

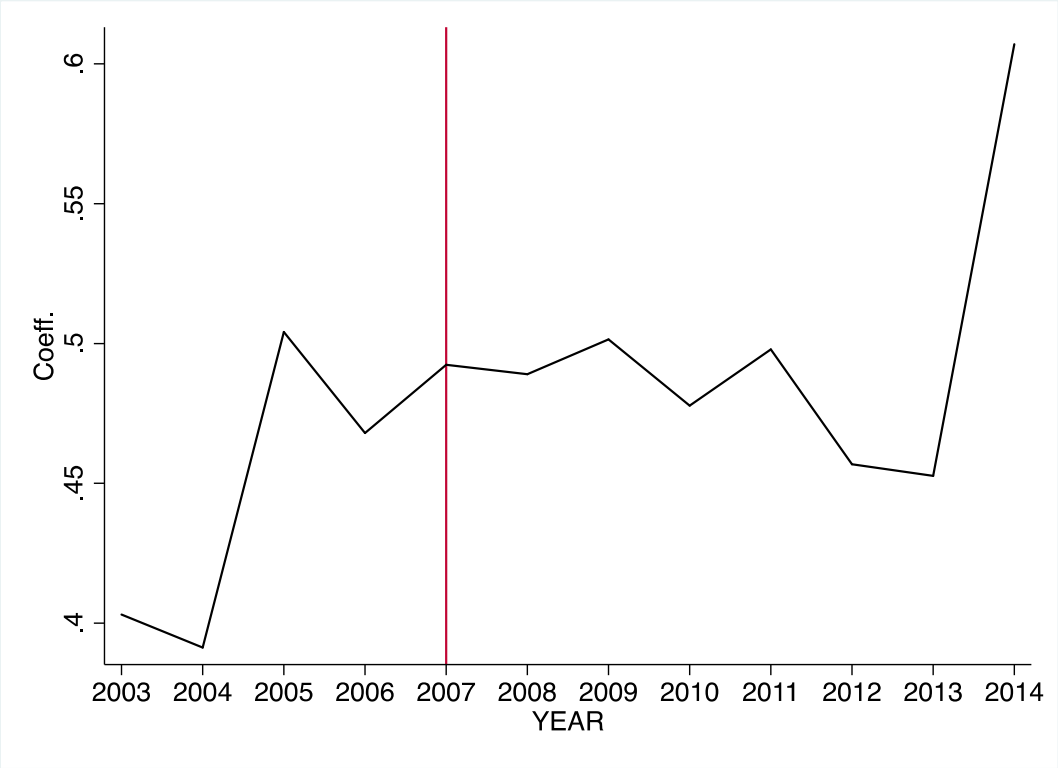
The overall pattern at the economy-wide level may hide a different evolution of sigma convergence by sector. Economies typically encompass sectors at varying levels of TFP. It could be the case that convergence is easier for some activities than for others. Figures 4.2.2 to 4.2.4 represent the patterns of sigma convergence among EU countries for the three main sectors of the economy: Manufacturing, Other Production, and non-financial Market Services. While for Manufacturing we observe a reduction in dispersion (i.e., evidence of sigma convergence), for non-financial Market Services we observe evidence of sigma divergence (even stronger when we exclude information for the year 2014). For Other Production (utilities and construction) we also find a pattern of sigma divergence, but here this is only clear until 2007, with more stability in dispersion of TFP levels among EU countries or even a mild convergence until 2013 (disregarding the very likely anomalous results for 2014).

Figure 4.2.2 Sigma-convergence for TFP among EU countries: Manufacturing.



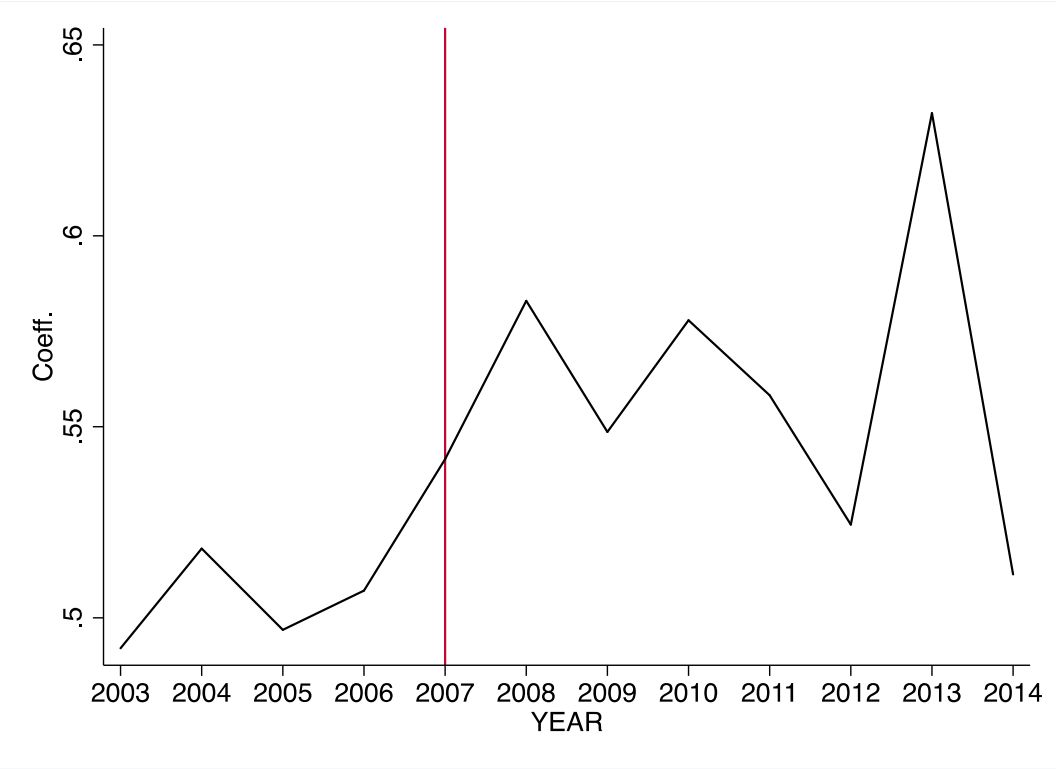
Note: Sigma-convergence is measured as the coefficient of variation of TFP (in logs) at the country level, defined as the ratio of the standard deviation over the sample mean.

Figure 4.2.3 Sigma-convergence for TFP among EU countries: Other Production.



Note: Sigma-convergence is measured as the coefficient of variation of TFP (in logs) at the country level, defined as the ratio of the standard deviation over the sample mean. Other Production corresponds to utilities and construction. The stark increase in 2014 might be due to incomplete data.

Figure 4.2.4 Sigma-convergence of TFP among EU countries: Non-financial Market Services.



Note: Sigma-convergence is measured as the coefficient of variation of TFP (in logs) at the country level, defined as the ratio of the standard deviation over the sample mean. The stark decrease in 2014 might be due to incomplete data.

To expand upon the visual results provided by Figures 4.2.1 to 4.2.4, we regress the value of the coefficient of variation against a trend for the whole period and against a trend starting from 2007, respectively. For the economy-wide aggregated TFP dispersion (in Figure 4.1.1) we find that the trend is positive and statistically significant for the whole period (0.005, with a p-value=0.031). However, this overall trend is mainly driven by the behaviour until 2007, confirming the previous graphical results, since the coefficient associated to the trend starting in 2007, although still positive, has a borderline level of significance that disappears when excluding the year 2014 (0.00015, with a p-value=0.067).

In the case of Manufacturing (in Figure 4.2.2), we find a pattern of sigma convergence, since the coefficient associated with the trend for the whole period is negative and significant (-0.007, with a p-value=0.002). The coefficient is also negative and significant (-0.00002, with a p-value=0.007) for the trend starting in 2007, indicating that there has been sigma convergence also after 2007.

For Other Production (in Figure 4.2.3), we estimate a positive and significant coefficient associated with the general trend (0.009, with a p-value=0.041).

However, as we do not obtain a significant estimated coefficient for the post 2007 trend, we may conclude that divergence results in this industry are driven by behaviour developments prior to 2007.

Finally, for non-financial Market Services (in Figure 4.2.4), we estimate a positive but borderline significant coefficient for the general trend (0.006, with a p-value=0.073) although the significance increases when excluding the year 2014 from the regression. Further, the coefficient for the trend after 2007 is also positive and significant (0.00003, with a p-value=0.018) even when we do not exclude the 2014.

To conclude, both the graphical analysis and the regression results provide evidence of sigma convergence over this period for Manufacturing, sigma divergence for the whole period for non-financial Market Services, and also sigma divergence for Other Production - but only until 2007. Hence, the findings for the economy-wide aggregate (sigma divergence until 2007 and mixed results afterwards) are related to the sigma divergence found for Other Production and non-financial Market Services until 2007, on the one side, and the mixture of sigma convergence for Manufacturing, sigma divergence for non-financial Market Services and non-conclusive results for Other Production, on the other side, after 2007.

We turn now to the estimation of beta-convergence. To test for absolute or unconditional beta-convergence in TFP among EU countries we regress the annual growth in TFP at the country level against the level of TFP in the previous year using the following specification:

$$\Delta \ln TFP_{ct} = a + b \ln TFP_{ct-1} + e_{ct} \qquad (4.2.1)$$

To test for relative or conditional beta-convergence we modify the previous expression to include several “conditioning variables”, that is, a number of variables capturing specific country characteristics:

$$\Delta \ln TFP_{ct} = a + b \ln TFP_{ct-1} + gX_{ct-1} + e_{ct} \qquad (4.2.2)$$

where X_{ct-1} is a vector of structural variables included to control for differences among EU countries. These “conditioning variables” are proxies of the determinants of TFP growth of the individual countries, capturing economic, institutional and political characteristics. We use a number of variables at the EU country level, which are available for the complete period on a yearly basis.

First, we include two variables drawn from Eurostat. The first is a variable capturing the quality of human capital, defined as the percentage of the population aged 15 to 64 years old with *tertiary education*; the second variable we use is the percentage of *R&D expenditure over GDP* (gross domestic expenditure

on R&D). In addition, from the World Bank datasets (http://data.worldbank.org), we use two World Development Indicators: a variable measuring the degree of trade openness, calculated as the ratio of the sum of imports plus exports over GDP *(X+M/GDP)* and, finally, we use the domestic credit provided by the financial sector as a percentage of GDP, *Credit/GDP*, as a proxy for the development of the financial sector.

Second, we use three variables to control for the economic and regulatory environment faced by firms, obtained from the rankings reported in *Doing Business*, a dataset provided by the World Bank (http://www.doingbusiness.org). The three variables are measured as indicators of the distance to frontier (DTF) scores, capturing the gap between a particular economy's performance and best practice:[13] *DTF registering property* measures the ease in the procedures necessary for a business to purchase a property from another business and to transfer the property title; *DTF paying taxes* measures the ease in the administrative burden of paying taxes and contributions; and, finally, *DTF resolving insolvencies* captures the ease in resolving insolvency proceedings involving domestic entities (time, cost and outcomes), as well as the strength of the legal framework applicable to liquidation and reorganization proceedings. Thus, by construction, we expect a higher value of these three indicators to imply greater ease in conducting business and so to have a positive impact on TFP growth.

Finally, we use information from the Worldwide Governance Indicators (WGI), (see www.govindicators.org), a dataset from the World Bank summarizing views on the quality of governance provided by a large number of enterprise, citizen and expert survey respondents in each country. The Worldwide Governance Indicators report on different dimensions of governance at the country level, which are useful as a tool for broad cross-country comparisons and for evaluating broad trends over time. The indicators that we use are Government Effectiveness, Regulatory Quality, Rule of Law and Control of Corruption. *Government Effectiveness* captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. *Regulatory Quality* reflects the perceptions of the ability of the government to formulate and implement sound policies and regulations that allow and promote private sector development. The indicator *Rule of Law* captures the perceptions of the extent to which agents have confidence in and abide by the rules of society and, in particular, the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. Finally, *Corruption Control* captures perceptions

[13] For example, a value (score) of 75 in DTF in 2009 means an economy was 25 percentage points away from the frontier constructed from the best performances across all economies and across time. A score of 80 in DTF in 2016 would indicate the economy is improving.

of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. Given the high correlation among these governance indicators, in the estimations below we introduce only one of these four variables in each specification.

The results of the estimations of equations (4.2.1) and (4.2.2) are reported in the following tables. Table 4.2.1 presents the estimation results of both unconditional and conditional beta-convergence for the whole period under analysis, 2003-2014, whereas Table 4.2.2 and Table 4.2.3 show the estimation results for the pre-crisis and post-crisis periods respectively.

In general, and for the period as a whole, the estimation results show an inverse correlation between the previous TFP level and the subsequent TFP growth. The coefficients of $lnTFP_{t-1}$ are negative and statistically significant in all specifications of Table 4.2.1, providing evidence of beta convergence for EU countries: EU countries with low levels of TFP undergo, in general, a more rapid growth in TFP than those with high levels of TFP. These results also indicate that, the further away from the frontier a country is in terms of its TFP level, the more rapid the growth in its TFP.

The estimation results on unconditional beta convergence (i.e. with no controls included), corresponding to equation (4.2.1) above, are reported in column (1) of Tables 4.2.1 to 4.2.3. The coefficient of TFP is negative and significant at a 10% level for the whole period, and significant at a 5% level for the post-crisis period. These results thus support the existence of a pattern of unconditional beta convergence during the whole period 2003-2014 and, especially after 2007, since the coefficient is non-significant for the pre-crisis years. Thus, the results suggest the existence of an automatic catching-up mechanism operating in the long run inducing EU countries to converge to the same steady state path of TFP growth.

The results on conditional beta-convergence are reported in columns (2) to (5) of Tables 4.2.1 to 4.2.3. Compared to unconditional beta-convergence, the coefficients on TFP are also negative and of larger magnitude, and provide evidence of convergence among EU countries for the whole period, especially during the post-crisis period. Again, there is no evidence of convergence during the pre-crisis years, with non-significant coefficients on the TFP variable. Thus, our results provide evidence of a process of TFP convergence among EU countries during the post-crisis years, and also indicate that conditional beta-convergence in TFP is greater than unconditional beta-convergence, a result which is in line with existing empirical evidence in the growth literature, suggesting that convergence is greater among similar countries. That is, convergence in TFP among EU countries seems to be higher when we control for a number of economic, institutional and political characteristics at the country

level, suggesting the possibility of a tendency of EU countries to converge to their own long-run TFP growth equilibrium paths.

As regards the variables controlling for country characteristics, in general, the results indicate the importance of some country-level economic and institutional characteristics in fostering TFP growth. In particular, R&D intensity (measured by the ratio of R&D expenditures as a percentage of GDP) seems to be relevant in promoting TFP growth, especially in the period after 2007). The variable capturing distance to the frontier in terms of resolving insolvencies also shows a positive and significant effect on TFP growth for the whole period. Finally, some indicators of the quality of governance at the country level have a positive and significant impact on TFP growth, with some differences among indicators between the two sub-periods.

Table 4.2.1. Beta convergence, 2003-2014.

Dep. Variable: TFP Growth	(1)	(2)	(3)	(4)	(5)
$lnTFP_{t-1}$	-0.057*	-0.265***	-0.246***	-0.283***	-0.251***
	(0.034)	(0.055)	(0.051)	(0.054)	(0.055)
R&D Exp./GDP		0.116	0.196**	0.106	0.156
		(0.088)	(0.072)	(0.068)	(0.091)
(X+M)/GDP		0.000	-0.000	-0.000	0.000
		(0.001)	(0.001)	(0.001)	(0.001)
Credit/GDP		-0.001	-0.001	-0.002*	-0.002
		(0.001)	(0.001)	(0.001)	(0.001)
Tertiary Educ.		-0.017	-0.018	-0.019	-0.017
		(0.013)	(0.013)	(0.014)	(0.013)
DTF registering property		-0.001	-0.003	-0.002	-0.002
		(0.002)	(0.002)	(0.002)	(0.002)
DTF paying taxes		-0.002	0.000	-0.002	-0.001
		(0.005)	(0.005)	(0.004)	(0.005)
DTF resolving insolvencies		0.005**	0.006**	0.006*	0.006**
		(0.002)	(0.003)	(0.002)	(0.003)
Gov. Effectiveness		0.341**			
		(-0.121)			
Reg. Quality			0.253*		
			(0.128)		
Rule of Law				0.421**	
				(0.161)	
Corruption Control					0.172
					(0.107)
Constant	0.261**	0.933***	0.758**	1.113***	0.935**
	(0.123)	(0.311)	(0.287)	(0.311)	(0.347)
Observations	231	231	231	231	231
R-squared	0.019	0.167	0.145	0.177	0.143

Notes: Dependent Variable is TFP growth, defined as the difference between $lnTFP_t$ and $lnTFP_{t-1}$ at the country level. OLS estimates with robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4.2.2 Beta convergence. Pre-crisis period, 2003-2007.

Dep. Variable: TFP Growth	(1)	(2)	(3)	(4)	(5)
$lnTFP_{t-1}$	0.061	-0.052	-0.052	-0.082	-0.061
	(0.037)	(0.053)	(0.055)	(0.059)	(0.057)
R&D Exp./GDP		0.084	0.134***	0.080	-0.008
		(0.063)	(0.047)	(0.059)	(0.101)
(X+M)/GDP		0.001	0.001	0.001	0.001
		(0.002)	(0.002)	(0.002)	(0.001)
Credit/GDP		0.000	0.000	-0.000	-0.000
		(0.002)	(0.002)	(0.002)	(0.001)
Tertiary Educ.		-0.007	-0.004	-0.006	-0.009
		(0.013)	(0.013)	(0.014)	(0.013)
DTF registering property		0.003	0.002	0.002	0.00114
		(0.002)	(0.002)	(0.002)	(0.001)
DTF paying taxes		-0.004	-0.004	-0.005	-0.006*
		(0.004)	(0.004)	(0.004)	(0.003)
DTF resolving insolvencies		0.001	0.002	0.002	-0.000
		(0.003)	(0.003)	(0.003)	(0.002)
Gov. Effectiveness		0.197			
		(0.114)			
Reg. Quality			0.170		
			(0.110)		
Rule of Law				0.251*	
				(0.132)	
Corruption Control					0.392*
					(0.188)
Constant	-0.109	0.0442	-0.00854	0.241	0.478
	(0.126)	(0.276)	(0.272)	(0.286)	(0.280)
Observations	76	76	76	76	76
R-squared	0.051	0.309	0.293	0.321	0.340

Notes: Dependent Variable is TFP growth, defined as the difference between ln TFP_t and $lnTFP_{t-1}$ at the country level. OLS estimates with robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4.2.3. Beta convergence. Post-crisis period, 2007-2014.

Dep. Variable: TFP Growth	(1)	(2)	(3)	(4)	(5)
$lnTFP_{t-1}$	-0.113**	-0.355***	-0.344***	-0.371***	-0.330***
	(0.054)	(0.071)	(0.067)	(0.068)	(0.070)
R&D Exp./GDP		0.239***	0.296***	0.212***	0.315***
		(0.084)	(0.079)	(0.063)	(0.098)
(X+M)/GDP		0.001	0.001	0.000	0.001
		(0.001)	(0.001)	(0.002)	(0.001)
Credit/GDP		-0.001	-0.001	-0.001	-0.001
		(0.001)	(0.001)	(0.001)	(0.001)
Tertiary Educ.		-0.019	-0.021	-0.023	-0.017
		(0.021)	(0.022)	(0.022)	(0.020)
DTF registering property		-0.001	-0.002	-0.002	-0.001
		(0.002)	(0.003)	(0.002)	(0.002)
DTF paying taxes		0.001	0.003	0.001	0.003
		(0.007)	(0.007)	(0.006)	(0.007)
DTF resolving insolvencies		0.004	0.004	0.004	0.006
		(0.004)	(0.004)	(0.003)	(0.004)
Gov. Effectiveness		0.236**			
		(0.112)			
Reg. Quality			0.204		
			(0.163)		
Rule of Law				0.368	
				(0.221)	
Corruption Control					-0.003
					(0.109)
Constant	0.428**	0.942*	0.753*	1.079**	0.667
	(0.188)	(0.465)	(0.398)	(0.394)	(0.454)
Observations	155	155	155	155	155
R-squared	0.062	0.204	0.202	0.220	0.195

Notes: Dependent Variable is TFP growth, defined as the difference between $lnTFP_t$ and $lnTFP_{t-1}$ at the country level. OLS estimates with robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

From the values of the estimated coefficients on the level of TFP from the previous tables we may compute the speed of convergence, i.e. the rate at which EU countries close the gap between their initial TFP levels and their common (or respective) TFP steady states. In Table 4.2.4 we present the results concerning the estimated coefficients for beta convergence (β) corresponding to the different specifications of Tables 4.2.1 to 4.2.3, together with the annual implied speed of convergence. The implied speed of beta convergence (b) is calculated according to the formula $b= \log(1-\beta)$.

The results of Table 4.2.4 indicate that the annual speed of unconditional beta convergence among EU countries, given by specification (1), is about 5 per cent for the whole period, 2003-2014. However, when looking at sub-periods, there is

evidence of unconditional convergence only for the post-crisis period (with an annual speed of convergence of about 11 per cent).

Regarding conditional beta-convergence, given by specifications (2) to (5), the implied annual speed of convergence for the whole period analysed ranges from 22 per cent to 25 per cent, depending on the estimated specification. However, if we consider separately the sub-periods before and after 2007, our results reveal that conditional beta convergence for the post-crisis period ranges from 28 to 31 per cent per year. For the pre-crisis period, although coefficients on TFP are also negative, they are not statistically significant.

These results are in line with other studies of TFP convergence, such as Miller and Upadhyay (2002), who find evidence for both unconditional and conditional beta-convergence in TFP for a sample of developed and developing countries.[14]

Table 4.2.4. Implied speed of beta-convergence

Specification	Period	Estimated coefficients β	s.e.	Implied speed of convergence b	R^2	Obs.
(1)	2003-2014	-0.057*	(0.034)	-0.056*	0.019	231
(1)	2003-2007	0.061	(0.037)	0.063	0.051	76
(1)	2008-2014	-0.113**	(0.054)	-0.107**	0.062	155
(2)	2003-2014	-0.265***	(0.055)	-0.235***	0.167	231
(2)	2003-2007	-0.052	(0.053)	-0.050	0.309	76
(2)	2008-2014	-0.355***	(0.071)	-0.304***	0.204	155
(3)	2003-2014	-0.246***	(0.051)	-0.220***	0.145	231
(3)	2003-2007	-0.052	(0.055)	-0.050	0.293	76
(3)	2008-2014	-0.344***	(0.067)	-0.296***	0.202	155
(4)	2003-2014	-0.283***	(0.054)	-0.249***	0.177	231
(4)	2003-2007	-0.082	(0.059)	-0.079	0.321	76
(4)	2008-2014	-0.371***	(0.068)	-0.316***	0.22	155
(5)	2003-2014	-0.251***	(0.055)	-0.224***	0.143	231
(5)	2003-2007	-0.061	(0.057)	-0.059	0.34	76
(5)	2008-2014	-0.330***	(0.070)	-0.286***	0.195	155

Notes: Values in column β are the coefficient estimates of TFP_{t-1} in specifications (1) to (5) of Tables 5.1.3 to 5.1.5. The implied speed of beta convergence (b) is calculated according to the formula b= log(1-β). Control variables included in specifications (2) to (5) are the same as those in Tables 5.1.3 to 5.1.5. *** significant at 1%, ** significant at 5%, and * significant at 10%.

Further analysis reveals that the speed of beta-convergence is not uniform across sectors. Tables 4.2.5 to 4.2.7 report the annual rate of convergence for

[14] Most of the existing literature has analysed convergence of GDP per capita and fewer studies test for convergence in TFP. The speed of absolute or unconditional beta-convergence in GDP per capita among OECD economies has consistently been found to be about 2 per cent per year (Barro and Sala-i-Martin, 1993).

Manufacturing, Other Production, and non-financial Market Services respectively. Interestingly, the speed of beta convergence differs across sectors, with different patterns also corresponding to different sub-periods. First, we observe that for Manufacturing there is both unconditional and conditional beta-convergence only during the pre-crisis years (with values of about 11 per cent and 40 per cent per year, respectively). Second, for Other Production there is evidence of unconditional and conditional beta-convergence for the whole period (around 15 per cent and 20 per cent, respectively), although conditional beta-convergence is evident particularly during the post-crisis period. Finally, there is no evidence of any type of beta-convergence for non-financial Market Services.

Table 4.2.5. Implied speed of beta convergence for Manufacturing.

Specification	Period	Estimated coefficients β	s.e.	Implied speed of convergence b	R^2	Obs.
(1)	2003-2014	-0.113	(0.121)	-0.107	0.024	222
(1)	2003-2007	-0.120**	(0.055)	-0.113**	0.027	76
(1)	2008-2014	-0.105	(0.145)	-0.100	0.021	146
(2)	2003-2014	-0.256	(0.177)	-0.228	0.103	222
(2)	2003-2007	-0.504***	(0.160)	-0.408***	0.286	76
(2)	2008-2014	-0.217	(0.164)	-0.196	0.085	146
(3)	2003-2014	-0.257	(0.176)	-0.229	0.101	222
(3)	2003-2007	-0.503***	(0.155)	-0.407***	0.285	76
(3)	2008-2014	-0.218	(0.162)	-0.197	0.085	146
(4)	2003-2014	-0.276	(0.178)	-0.244	0.108	222
(4)	2003-2007	-0.542***	(0.154)	-0.433***	0.305	76
(4)	2008-2014	-0.235	(0.157)	-0.211	0.09	146
(5)	2003-2014	-0.25	(0.178)	-0.224	0.098	222
(5)	2003-2007	-0.512***	(0.167)	-0.414***	0.295	76
(5)	2008-2014	-0.203	(0.156)	-0.185	0.087	146

Notes: Values in column β are the coefficient estimates of TFP_{t-1} in specifications (1) to (5) of Tables 5.1.3 to 5.1.5 estimated using only observations in manufacturing. Values in column β are the implied speed of beta convergence, calculated according to the formula b= log(1-β). Control variables included in specifications (2) to (5) are the same as those in Specifications (2) to (5) in Tables 5.1.3 to 5.1.5. *** significant at 1%, ** significant at 5%, and * significant at 10%.

Table 4.2.6. Implied speed of convergence for Other Production.

Specification	Period	Estimated Coefficients β	s.e.	Implied speed of convergence b	R^2	Obs.
(1)	2003-2014	-0.165**	(0.073)	-0.153**	0.066	224
(1)	2003-2007	-0.147*	(0.081)	-0.137*	0.039	76
(1)	2008-2014	-0.175	(0.125)	-0.161	0.086	148
(2)	2003-2014	-0.225***	(0.081)	-0.203***	0.111	224
(2)	2003-2007	-0.196	(0.149)	-0.179	0.110	76
(2)	2008-2014	-0.247**	(0.113)	-0.221**	0.161	148
(3)	2003-2014	-0.226***	(0.079)	-0.204***	0.111	224
(3)	2003-2007	-0.195	(0.149)	-0.178	0.110	76
(3)	2008-2014	-0.249**	(0.112)	-0.223**	0.157	148
(4)	2003-2014	-0.231***	(0.078)	-0.208***	0.113	224
(4)	2003-2007	-0.205	(0.148)	-0.186	0.115	76
(4)	2008-2014	-0.252**	(0.112)	-0.225**	0.156	148
(5)	2003-2014	-0.248***	(0.079)	-0.222***	0.118	224
(5)	2003-2007	-0.26	(0.160)	-0.231	0.161	76
(5)	2008-2014	-0.252**	(0.109)	-0.225**	0.155	148

Notes: Values in column β are the coefficient estimates of TFP_{t-1} in specifications (1) to (5) of Tables 5.1.3 to 5.1.5 estimated using only observations corresponding to Other sectors (construction and utilities). Values in column β are the implied speed of beta convergence, calculated according to the formula b= log(1-β). Control variables included in specifications (2) to (5) are the same as those in specifications (2) to (5) in Tables 5.1.3 to 5.1.5. *** significant at 1%, ** significant at 5%, and * significant at 10%.

Table 4.2.7. Implied speed of convergence for non-financial Market Services.

Specification	Period	Estimated Coefficients β	s.e.	Implied speed of convergence b	R^2	Obs.
(1)	2003-2014	-0.157	(0.111)	-0.146	0.060	231
(1)	2003-2007	-0.077	(0.079)	-0.074	0.030	76
(1)	2008-2014	-0.195	(0.152)	-0.178	0.076	155
(2)	2003-2014	-0.189	(0.126)	-0.173	0.088	231
(2)	2003-2007	-0.124	(0.102)	-0.117	0.076	76
(2)	2008-2014	-0.235	(0.167)	-0.211	0.119	155
(3)	2003-2014	-0.192	(0.128)	-0.176	0.094	231
(3)	2003-2007	-0.130	(0.108)	-0.122	0.077	76
(3)	2008-2014	-0.239	(0.170)	-0.215	0.127	155
(4)	2003-2014	-0.192	(0.124)	-0.176	0.087	231
(4)	2003-2007	-0.125	(0.097)	-0.118	0.074	76
(4)	2008-2014	-0.237	(0.163)	-0.212	0.120	155
(5)	2003-2014	-0.187	(0.127)	-0.172	0.087	231
(5)	2003-2007	-0.137	(0.095)	-0.128	0.077	76
(5)	2008-2014	-0.234	(0.167)	-0.21	0.117	155

Notes: Values in column β are the coefficient estimates of TFP_{t-1} in specifications (1) to (5) of Tables 5.1.3 to 5.1.5 estimated using only observations corresponding to services. Values in column β are the implied speed of beta convergence, calculated according to the formula b= log(1-β). Control variables included in Specifications 2 to 5 are the same as those in specifications (2) to (5) in Tables 5.1.3 to 5.1.5. *** significant at 1%, ** significant at 5%, and * significant at 10%.

Summary and policy implications

Our results show evidence of sigma convergence for the manufacturing sector as well as sigma divergence for non-financial market services over the whole period; we also find evidence of sigma divergence in other production but only until 2007. The economy-wide results (sigma divergence until 2007 and less-clear results afterwards) can be related to the sigma divergence found in other production and non-financial market services until 2007, together with the mix of sigma convergence for manufacturing and sigma divergence for non-financial market services.

Hence, similarly to the Theil index analysis performed earlier in this report, we find evidence of convergence in manufacturing and divergence in non-financial market services. Additionally, and again in common with the Theil index analysis, there is less dispersion in TFP in manufacturing than in non-financial market services (compare the coefficients of variation of TFP in Figures 4.2.1 and 4.2.3).

The results of the beta convergence analysis point to the existence of both conditional and unconditional beta-convergence, that is, there is greater TFP growth in those EU countries with lower initial levels of TFP, especially after 2007. These findings are not necessarily inconsistent with the ones obtained in the analysis of sigma convergence, the increase in dispersion of TFP levels across countries over time (sigma-divergence) not only depends on the differential rates of growth in TFP across countries (beta-convergence) but also on the different initial levels of TFP. That is, the existence of beta-convergence may not fully reflect changes in the dispersion of TFP levels but other factors affecting TFP differentials across countries may be at play.[15] Moreover, while beta convergence focuses on uncovering possible catching-up processes, sigma convergence simply refers to a reduction of disparities among countries' TFPs over time.

The analysis has also revealed that beta convergence is not uniform across industries. For manufacturing, the results provide evidence on both unconditional and conditional beta-convergence during the pre-crisis years. For non-financial market services, there is no evidence of any type of beta-convergence. Finally, for other production there is evidence of unconditional and conditional beta-convergence for the whole period, although conditional beta-convergence occurs mostly during the post-crisis period.

Comparing results from the sigma and beta convergence analysis for manufacturing, non-financial market services, and other production, we conclude that there exists evidence of convergence in manufacturing (both sigma and beta convergence), some evidence of sigma divergence in non-financial market

[15] For a discussion of these convergence concepts, see Sala-i-Martin (1996).

services, and an opposite result of sigma divergence and beta convergence for other production.

The comparison of the results between unconditional and conditional beta-convergence is interesting from a policy perspective. Our findings suggest that there is, in general, technological convergence among EU economies, both in absolute terms (that is, regardless of country specific characteristics, as captured by unconditional beta-convergence) and in relative terms (that is, conditioning on country characteristics, as captured by conditional beta-convergence), and especially in manufacturing and other production. The results do not provide evidence on beta convergence among non-financial market services. Evidence on unconditional convergence in TFP may be associated with the view that technology is a public good that spreads easily across countries. The result that conditional TFP convergence (that is, convergence conditional on a number of economic and institutional characteristics at the country level) is much stronger than unconditional convergence among EU countries, and in particular in manufacturing seems to suggest the possibility that EU countries tend to converge to their own long-run TFP growth equilibrium paths. However the existence of both unconditional and conditional beta convergence is not infeasible.

The catching-up from unconditional beta convergence is expected to be an exogenous process of imitation. However, the one implied by conditional beta convergence is likely to be more closely related to countries' active policies to facilitate this catching-up. Therefore, our findings suggest that there is room for policy intervention affecting structural variables to strengthen the speed of convergence among EU economies. In particular, country-level R&D intensity (the ratio of R&D expenditures as a percentage of GDP) seems to be relevant in promoting TFP growth. The ease in resolving insolvencies also shows a positive and significant effect on TFP growth for the whole period, indicating that there is a policy role in facilitating bankruptcy procedures and the exit of inefficient firms (lowering exit cost). Finally, policies aimed at improving the quality of governance at the country level may also have a positive impact on TFP growth.

The disparity between results in terms of convergence/divergence found for Manufacturing as compared with non-financial Market Services, may also suggest paying attention to pro-competitive policies and more liberalization affecting Services.

5. An empirical characterisation of the best-performing firms in the EU using Amadeus

The literature studying catching-up mechanisms to the frontier adopts two main perspectives: the macroeconomic and the microeconomic approach. In the macro approach, the unit of analysis is usually the country or the region, and the focus has been placed on the process of reaching the frontier (Barro and Sala-i-Martín, 1992). The objective is usually to identify the global frontier at the country or region level, and to test whether productivity growth is related to the existing gap in relation to the global frontier (see Sala-i-Martín, 1996; Griffith *et al*., 2004a; Acemoglu *et al.*, 2006; Kneller and Stevens, 2006; Aghion *et al*., 2008; Amable *et al.*, 2010, among others). Under this approach, it is usually assumed that all firms in a given country or region catch-up and converge towards the frontier, ignoring the heterogeneity across firms and that growth may be influenced by mechanisms of selection and reallocation, as well as uncertainty (Jovanovic 1982; Melitz 2003).

The micro approach, on the other hand, aims to overcome some of the aforementioned limitations (Griffith *et al.*, 2004b; Acemoglu *et al.*, 2007; Alvarez and Crespi, 2007; Bartelsman *et al*., 2008; Bartelsman *et al.*, 2014, Andrews *et al.*, 2015; Ding *et al*., 2016, among others). The unit of analysis is now the firm, and it is based on the identification of a national frontier (or industry frontier) that reflects the most advanced technology within a country (or within an industry) and assesses how a firm's distance to this frontier affects its performance. With few exceptions (see Bartelsman *et al.,* 2008; Iacovone and Crespi, 2010; or Andrews *et al.,* 2015), the literature on firm-level convergence processes assumes that the national best-practice frontier is a good proxy for the global frontier. Therefore, although some micro studies based on a single country are able to address the issue of firm-level heterogeneity, and they are potentially helpful in understanding whether convergence effects differ across types of firms, they may not correctly identify the 'true' frontier.

In light of these considerations, micro data for all (potentially relevant) countries is useful in identifying the global frontier, which may differ from the national frontier firm. The small literature that uses firm-level data in a multi-country analysis, suggests that the productivity growth of laggard firms is more strongly related to the productivity developments at the national frontier, than to those at the global frontier (Bartelsman *et al.*, 2008; Van der Wiel *et al.*, 2012; Iacovone and Crespi, 2010, Andrews *et al*., 2015).[16]

[16] With the exception of Andrews *et al.* (2015), the rest of studies use a small number of countries to identify the global frontier firm. For example, Bartelsman *et al.* (2008) focus on the United States and five European economies. Iacovone and Crespi (2010) and Van der Wiel *et al.* (2008)

Therefore, in this study we rely mainly on the "micro" approach. We look at EU members individually and also derive the "EU frontier firms" considering the EU as a whole. Particularly, following Andrews *et al*. (2015), for measuring the productivity frontier we use an absolute number of firms. Another approach to defining the productivity frontier is to take the top 5% of firms in terms of productivity levels, within each industry and year. However, the tendency for the number of firms in ORBIS and AMADEUS to expand over time leads to the adoption of a definition of frontiers based on a fixed number of firms. More specifically, frontier firms are identified using an absolute number of firms: the top 100 globally most productive firms at the EU level (within each industry and year), and the top 10 most productive firms for the national frontier (within each country, industry and year). However, as a robustness check we have also used both the top 5% most productive firms at the EU and national levels. The results are qualitatively similar for the four definitions of frontiers and are available upon request.

A growing number of studies stress the high degree of heterogeneity in productivity levels (that is persistent across time) across countries, and across firms of narrowly defined sectors (see Haltiwanger *et al.*, 2007). Firm productivity differences within industries are even more pronounced than those between industries (Foster *et al.*, 2001). The underlying factors behind the existence of these productivity differentials, as well as the reasons for their persistence have attracted the attention of numerous studies (Syverson, 2011).

In this section, we identify the frontier firms and explore what determines the distance to the frontier. Following Arnold *et al.* (2008), Gal (2013) and Andrews *et al.* (2015), the analysis concentrates on the set of firms with more than 20 employees as this helps obtain better coverage and a more balanced sample. Arnold *et al.* (2008) point out that AMADEUS does not have satisfactory coverage of firms with less than 20 employees; therefore, the resampling procedure targets the size-sector-country distribution of the true population of firms with 20 employees and more. A similar problem is highlighted by Andrews *et al.* (2015) for ORBIS, who also exclude firms with less than 20 employees.[17]

5.1 The EU-wide Frontier firms.

To analyse the "frontier-firms" in more depth, we describe cross-sectional differences in key characteristics between "frontier" and "non-frontier" firms along a number of measurable dimensions. This part of the analysis is purely

analyse Mexico and The Netherlands, respectively, and use the data from Bartelsman *et al.* (2008) to identify the global frontier. However, a small sample of countries casts doubts about the correct identification of the global frontier.

[17] A key drawback of ORBIS is that it is a selected sample of larger and more productive firms, which tends to result in smaller and younger firms being under-represented in some economies.

descriptive. The main dimensions considered include: age, employment, value added, capital intensity, earnings[18], profits and average wage per employee. A test of difference in means over these dimensions determines the extent to which frontier firms (either EU or national) differ significantly from the non-frontier firms.

Table 5.1.1 reports differences in average characteristics at aggregate level for the top 100 EU frontier firms and for the top 10 national frontier firms relative to non-frontier firms along a number of firm characteristics over the period 2003 to 2014. Additionally, this table provides cross-sectional differences in average characteristics for the year 2006 (pre-crisis) and 2013 (post-crisis), respectively. Table 5.1.1 also shows these differences over the total period by the three aggregate sectors: Manufacturing, Other Production industries and non-financial Market Services. In all cases the differences in means between frontier and non-frontier firms are based on a Solow TFP productivity measure.

On average, relative to non-frontier firms, EU frontier firms are older[19], larger, have higher mean values of value added, earnings and profits, and pay higher average wages per employee than non-frontier firms. However, they are relatively less capital intensive. By sector, EU-frontier firms are older in Manufacturing, but younger in Other Production industries and non-financial Market Services (A result obtained by Andrews et al., 2015). EU-frontier firms are also less capital intensive in Other Production industries and non-financial Market Services, but not significantly different from non-frontier in Manufacturing. However, independently of sector, EU frontier firms are larger, have higher mean value added, earnings and profits, and pay higher average wages per employee than non-frontier firms.

Comparing the reported statistics pre-crisis (2006) and post-crisis (2013), non-frontier firms became relatively older and more capital intensive. Additionally, non-frontier firms experienced a drop in value added, earnings and profits. No significant changes are observed in terms of employment and wages, though in previous periods non-frontier firms underwent an important process of external adjustments. In contrast, EU frontier firms increased in size, earnings and wages from 2006 to 2013. However, they marginally decreased value added and profits.

Comparing national frontier firms with the non-frontier ones, the former have a relatively higher mean value of value added, earnings and profits, but they are less capital intensive than non-frontier firms[20]. By sector, national-frontier firms

[18] Earnings are measured by EBITDA (*earnings before interest, taxes, depreciation and amortization*).

[19] Although the significant difference in age is lost over time.

[20] In a comparative analysis across countries, national frontiers are also significantly older than non-frontier firms, except in Ireland, and larger in terms of employment except in Ireland and Slovakia. Not in all countries, national frontiers are relatively less capital intensive. In Bulgaria, Czech Republic, Ireland, Netherlands and Portugal national frontiers are, on average, significantly more capital intensive than non-frontiers.

are also younger, larger, have a relatively higher mean value of value added, earnings and profits in all three sectors: Manufacturing, Other Production industries and Market services. While in Manufacturing national frontier firms are not significantly different from non-frontier in terms of capital intensity, they are relatively more intensive in Services and less capital intensive in Other Production industries. As previously stated, from 2006 to 2013 non-frontier firms became on average relatively older, more capital intensive and experienced a drop in value added, earnings and profits, while their size and average wages remained relatively constant. In contrast to EU-frontier firms, national frontier firms, although continuing to be larger in size, value added, earnings and profits than non-frontier firms, experienced a fall in employment, value added, earnings and profits from 2006 to 2013. However they became more capital intensive and also increased average wages.

Table 5.1.2 reports differences in average characteristics by industry for the top 100 EU-frontier firms relative to non-frontier firms over the period 2003 to 2014. Table 5.1.3 and 5.1.4 show cross-sectional differences for the year 2006 (pre-crisis) and 2013 (post-crisis), respectively.

On average, manufacturing firms at the EU productivity frontier are relatively older (over 3 years on average). However, in utilities and most market service industries, EU-frontier firms are relatively younger (with the exceptions of wholesaling, postal services and professional service activities). This result is similar to that obtained by Andrews *et al.* (2015).

With regards to employment, EU-frontier firms are, on average, larger in the following industries: food, paper, pharmaceuticals, construction, postal activities, and accommodation. For the remaining industries, EU-frontier firms are smaller or not significantly different in size relative to non-frontier firms. Comparing the 2006 and 2013 averages, we observe that over time the average size of non-frontier firms has decreased after the crisis in most industries. Though EU-frontier firms did better in terms of layoffs than non-frontier firms, the average size of frontier firms in several industries decreased as we compare 2006 and 2013 averages. The decline in average size of EU-frontier firms is relevant in the following industries: food, coke, rubber, electronic equipment, electricity, wholesaling, retailing and computer programming.

Regarding value added, EU-frontier firms have larger mean values of value added than non-frontier firms. Overall in manufacturing and non-financial market services, the value added of frontier firms is 3 times larger than that of non-frontier firms. In most industries, non-frontier firms witnessed a decline in value added from 2006 to 2013. In those industries in which the average employment of EU-frontier firms fell, value added also declined. In the remaining industries, value added of EU-frontier firms improved. With regards to capital intensity, EU-frontier firms are less capital intensive than non-frontier firms, with the exception

of transport and postal services. Non-frontier firms became more capital intensive if we compare the average values from 2006 to 2013. This is in part explained by the fact that they became smaller. In contrast, in most sectors EU frontier firms became less capital intensive, with the exceptions of the food, chemicals, pharmaceuticals, machinery, motor vehicles, furniture, transport, publishing and telecommunications.

With very few exceptions, average earnings and profits of EU-frontier firms are larger than those of non-frontier firms. In most industries, non-frontier firms faced a decline in earnings and profits comparing average values from 2006 with those in 2013. In the case of EU-frontier firms, we observe more heterogeneity. In industries, where value added fell, earnings and profits of EU-frontier firms also declined. In other sectors, earning and profits of frontier firms increased. EU-frontier firms also pay on average higher average wages per employee relative to non-frontier firms. Comparing the mean values from 2006 to those in 2013, we observe that in most industries, non-frontier firms increased average wages per employee. In most manufacturing industries, EU-frontier firms also increased wages, with the exceptions of the textiles, machinery, motor vehicles and furniture industries. In other sectors, such as water supply, wholesaling, postal services, communication, computer programming and professional services, wages decreased.

Table 5.1.1: Means and differences in means of firm characteristics: Frontier firms vs. non-frontier firms.

FRONTIER	*Age*		*Employment*		*Value Added*		*Capital intensity*		*EBITDA*		*Profits*		*Wage p.e.*	
	NF	*F*	*NF*	*F*	*NF*	*F*	*NF*	*F*	*NF*	*F*	*NF*	*F*	*NF*	*F*
AVERAGE 2003-2014														
EUROPEAN FRONTIER TOP 100	22.5	23.1 ***	130.7	227.0 ***	6844	30023 ***	67.2	40.5 ***	2334	11283 ***	918	11000 ***	30.8	59.1 ***
NATIONAL FRONTIER TOP 10	23.2	20.2	130.4	190.1	6785	20422 ***	66.9	62 **	2255	9547 ***	876	7340 ***	30.9	43.5 ***
PRE-CRISIS: 2006														
EUROPEAN FRONTIER TOP 100	22.3	23.9 ***	127.3	213.5 ***	6820	26750 ***	60.6	27.9 ***	2363	9800 ***	1037	8675 ***	30.9	58.1 ***
NATIONAL FRONTIER TOP 10	22.4	19.2 ***	126.6	196.5 ***	6727	20666 ***	60.3	57.9	2262	10049 ***	969	7528 ***	31.0	41.2 ***
POST-CRISIS: 2013														
EUROPEAN FRONTIER TOP 100	25.4	25.5	129.4	219.0 ***	6753	25983 ***	75.3	29.4 ***	2242	11107 ***	813	8320 ***	31.9	66.0 ***
NATIONAL FRONTIER TOP 10	25.5	21.6 ***	129.3	175.1 ***	6689	17759 ***	75.1	61.4 *	2184	8262 ***	775	5498 ***	31.9	47.6 ***
BY SECTORS (2003-2014)														
Manufacturing														
EUROPEAN FRONTIER TOP 100	25.2	29.0 ***	127.7	153.1 ***	6779	30912 ***	45.8	45.3	2276	15222 ***	819	11998 ***	29.6	57.7 ***
NATIONAL FRONTIER TOP 10	25.3	23.4 ***	127.3	152.3 ***	6738	20102 ***	45.7	46.6	2206	10751 ***	747	8386 ***	29.7	40.0 ***
Other Production Industries														
EUROPEAN FRONTIER TOP 100	22.1	19.4 ***	142.6	332.0 ***	6907	29947 ***	76.9	36.7 ***	2184	6586 ***	921	9795 ***	31.6	64.1 ***
NATIONAL FRONTIER TOP 10	22.2	17.3 ***	142.5	238.3 ***	6865	19839 ***	77.2	47.0 ***	2110	7443 ***	904	5921 ***	31.6	48.4 ***
Market Services														
EUROPEAN FRONTIER TOP 100	21.2	19.6 ***	97.2	163.0 ***	6796	26452 ***	87.8	33.3 ***	3013	11423 ***	1162	11090 ***	31.4	47.5 ***
NATIONAL FRONTIER TOP 10	21.3	18.1 ***	96.2	169.9 ***	6624	23896 ***	85.1	180.8 ***	2896	12281 ***	1111	8208 ***	31.4	39.9 ***

Note: F is the average of frontier firms; NF is the average of non-frontier (all other) firms. EUROPEAN FRONTIER TOP 100 corresponds to the average of the top 100 EU most productive (Solow TFP) firms in each year and industry. NATIONAL FRONTIER TOP 10 corresponds to the average of the top 10 most productive (Solow TFP) firms in each country, year and industry. Test in mean differences with *** significant at 1%, ** significant at 5%, and * significant at 10%.

Table 5.1.2: Means and differences in means of firm characteristics: EU-frontier firms (Top 100) vs. non-frontiers. (Average 2003-2014)

Industry	*Age*		*Employment*		*VA*		*Capital*		*EBITDA*		*Profits*		*Wages p.e.*	
	NF	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***
Manuf. of food, beverages and tobacco	26.3	31.5***	125.4	221.3***	6227	52650***	65.1	45.9***	2521	24466***	972	24966***	25.2	56.1***
Manuf. of textiles, wearing apparel, leather	22.7	26.6***	94.7	76.9***	2599	9609***	24.5	11.4***	755	5873***	247	3666***	20.1	45.1***
Manuf. of wood, paper, printing	25.9	27.0*	92.4	100.5*	4612	17788***	51.9	19***	1642	9652***	473	7519***	27.2	47.1***
Manuf. of coke and refined petroleum prod.	27.0	37.7***	402.4	248.7***	40528	84641***	328.6	330.8	18680	41164***	3531	27727***	38.7	79.3***
Manuf. of chemicals and chemical prod.	29.6	33.6***	141.2	155.1	11972	40949***	88.6	38.1***	4896	16224***	1824	14934***	40.4	65.8***
Manuf. of pharmaceutical products	31.2	36.1***	308.1	359.0**	29876	75201***	78.6	31.6***	13220	47262***	5669	31210***	41.7	68.2***
Manuf. of rubber, plastic and non-metallic	24.9	29.5***	113.0	109.5	5933	18561***	60.6	31.5***	2159	8878***	750	8345***	29.2	49.4***
Manuf. of basic and fabricated metal prod.	25.0	27.4***	98.5	76.7**	5254	12758***	41.1	30.6***	1700	6820***	623	5355***	32.1	54.4***
Manuf. of computer, electronic and optical	23.3	25.0***	195.0	97.7***	11076	13293	28.7	5.4***	3033	5080***	1304	4218***	34.9	64.5***
Manuf. of electrical equipment	25.5	25.9	175.3	118.8*	8356	14952***	33.1	11.9***	2710	5209***	1130	5355***	30.9	53.5***
Manuf. of machinery and equipment n.e.c.	27.1	27.7	124.0	117.6	7011	20901***	32.5	8.5***	2139	9555***	916	7289***	36.5	61.9***
Manuf. of motor vehicles, trailers	23.2	26.2***	404.8	198.3***	23381	24546	41.7	16.7***	6160	10205***	1441	9452***	31.4	49.4***
Manuf. of furniture; jewellery, musical prod.	23.3	23.1	104.6	109.9	4771	16004***	27.5	8.1***	1392	7504***	528	6343***	28.3	56.9***
Electricity, gas, steam and air cond. Supply	24.2	19.6***	313.2	262.0	57040	56484	777.1	82.1***	38276	25157**	13730	26592***	44.1	47.9***
Water supply; sewerage, waste management	20.1	18.0***	147.4	124.1**	9232	9768	175.2	11.9***	4091	2918	1130	1901***	30.5	42.6***
Construction	21.2	21.1	79.4	102.8***	3822	13105***	40.3	6.1**	1005	6194***	511	5170***	30.9	52.1***
Wholesale and retail trade of motor vehicles	24.7	26.2***	76.5	79.4	3728	15963***	37.4	14.9***	1010	8814***	374	6751***	32.0	64.6***
Wholesale trade, except of motor vehicles	25.3	27.3***	82.9	64.4***	5178	21681***	39.6	7.1***	1810	14519***	925	11898***	35.1	84.2***
Retail trade, except of motor vehicles	20.9	18.1***	232.3	92.4*	7395	6644	29.2	5.8***	2355	2913	1002	2252**	21.6	43.2***
Transport and storage	23.6	17.0***	156.4	155.4	8256	14199***	87.1	279***	2476	4575***	609	3869***	32.1	52.7***

Postal and courier activities	13.2	19.5***	895.0	2420.2***	17752	123505***	9.3	10.5*	804	13477***	-543	8511***	14.3	35.3***
Accommodation and food service activities	18.7	15.6***	116.0	207.2***	3184	6419***	79.9	4.2***	853	1058	164	924***	21.3	34.0***
Publishing, motion picture, video, television	25.4	24.0**	139.1	83.2***	9799	17618***	35.6	27.6	3025	7270***	1461	5807***	39.8	88.1***
Telecommunications	14.9	14.3	475.0	161.7***	75635	24134***	204.3	16.7***	51237	11095***	18456	12684	39.4	53.8***
Computer programming, consultancy	15.9	13.8***	141.4	94.1***	9646	13053***	17.5	9.6*	1964	4594***	885	4223***	45.0	78.0***
Professional, scientific and technical activities	18.3	19.8***	190.5	171.3	8826	76028***	41.1	24.1*	1962	2044	1174	46337***	36.4	123.7***

Note: EU-F: EU-frontier firms corresponds to the average of the top 100 EU most productive (Solow TFP) firms in each year and industry. NF: Non-frontier firms is the average of all other firms. Test in mean differences with *** significant at 1%, ** significant at 5%, and * significant at 10%.

Table 5.1.3: Means and differences in means of firm characteristics: EU-frontier firms (top 100) vs. non-frontiers (Pre-crisis 2006).

Industry	*Age*		*Employment*		*VA*		*Capital*		*EBITDA*		*Profits*		*Wages p.e.*	
	NF	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***	***NF***	***EU_F***
Manuf. of food, beverages and tobacco	25.8	31.1*	124.7	223.5***	6180	44867***	58.8	25.2***	2427	23126***	943	18152***	24.9	52.6***
Manuf. of textiles, wearing apparel, leather	22.6	24.3	92.9	68.4**	2656	9012***	22.1	13.6**	794	5314***	260	3419***	20.4	47.0***
Manuf. of wood, paper, printing	24.9	30.5***	93.2	88.0	4538	9815***	46.3	11.6***	1649	4409***	501	2802***	25.7	45.4***
Manuf. of coke and refined petroleum prod.	24.1	36.1**	287.4	240.6	21759	84900	248.0	383.7	10012	49224	1631	32942	30.9	70.4***
Manuf. of chemicals and chemical prod.	28.5	29.4	138.2	112.4	11550	17074	80.1	27.0***	4663	7321	1633	5686***	39.9	63.0***
Manuf. of pharmaceutical products	30.7	32.2	318.0	328.7	33668	58371	73.9	16.8***	14722	33274	7393	12664	41.3	59.6***
Manuf. of rubber, plastic and non-metallic	23.9	30.8***	111.3	154.9	6037	21344***	52.4	33.6***	2296	9595***	935	8283***	28.6	50.4***
Manuf. of basic and fabricated metal prod.	24.0	24.8	98.3	83.7	5533	17715***	34.9	20.1***	2087	11081***	988	7805***	31.4	50.4***
Manuf. of computer, electronic and optical	22.3	22.6	194.0	82.2*	10307	9244	25.1	5.2***	3411	3957	1555	3068	31.5	59.5***
Manuf. of electrical equipment	24.7	25.6	172.4	173.2	8531	23064***	27.4	12.2***	2848	5635***	1324	9190***	31.0	52.0***
Manuf. of machinery and equipment n.e.c.	26.1	29.9*	121.5	83.2*	7036	9632	27.4	6.5***	2221	3762*	964	2589***	37.2	65.1***
Manuf. of motor vehicles, trailers	22.2	29.8***	392.5	162.9	21945	21586	38.9	16.0***	5342	8264	1330	8243*	30.5	52.7***
Manuf. of furniture; jewellery, musical prod.	22.2	22.6	101.4	92.0	4798	12662**	24.2	7.8***	1450	5625**	548	3888***	28.7	64.5***
Electricity, gas, steam and air cond. Supply	22.5	21.6	307.4	238.9	58136	59265	599.1	65.3***	36392	24282	15745	24800	41.9	45.5
Water supply; sewerage, waste management	18.7	20.3	142.6	114.8	9884	11044	159.7	20.9**	4438	3878	1430	2077	31.9	43.7***
Construction	20.0	23.6**	78.1	84.0	3938	13608***	33.9	12.1	1131	7799***	748	5810**	30.8	49.7***
Wholesale and retail trade of motor vehicles	23.7	24.5	75.6	96.0	3874	23096***	33.2	20.1**	1104	13556***	451	10185***	32.4	73.2***
Wholesale trade, except of motor vehicles	24.4	25.1	82.7	49.9	5653	16865***	35.1	6.6***	2069	9231***	1120	9713***	36.2	84.6***
Retail trade, except of motor vehicles	20.5	18.4	215.9	84.9	7255	6045	27.4	11.6***	2356	2183	1253	2412	20.4	43.6***

Transport and storage	23.1	15.6***	153.6	143.5	8252	8501	70.8	1.2*	2360	1358	593	1403	33.2	48.3***
Postal and courier activities	11.4	19.1***	885.3	2370.8	15519	134321	10.0	9.6	1964	12021	738	8149	12.8	34.8***
Accommodation and food service activities	18.1	14.3***	122.2	109.4	3491	4386	73.6	2.3***	991	723	306	830	21.8	33.1***
Publishing, motion picture, video, television	25.1	23.1	134.9	72.2*	9865	12454	40.4	3.0*	3210	5469	1641	3462	39.4	69.7***
Telecommunications	13.6	14.6	425.0	102.0	69139	16300	209.2	9.4**	52491	8002	19995	8117	33.6	48.2***
Computer programming, consultancy	15.3	13.9	135.2	107.4	8884	12231	14.8	1.9**	1573	3678*	824	3567***	44.4	83.0***
Professional, scientific and technical activities	17.7	20.6*	188.6	165.5	8519	50557***	36.6	6.9	1863	-2277**	979	29148***	36.4	123.9***

Note: EU-F: EU-frontier firms corresponds to the average of the 100 EU most productive (Solow TFP) firms in each year and industry. NF: Non-frontier firms is the average of all other firms. Test in mean differences with *** significant at 1%, ** significant at 5%, and * significant at 10%.

Table 5.1.4: Means and differences in means of firm characteristics: EU-frontier firms (top 100) vs. non-frontiers (Post-crisis: 2013).

Industry	*Age*		*Employment*		*VA*		*Capital*		*EBITDA*		*Profits*		*Wages p.e.*	
	NF	*EU_F*	*NF*	*EU_F*	*NF*	*EU_F*	*NF*	*EU_F*	*NF*	*EU_F*	*NF*	*EU_F*	*NF*	*EU_F*
Manuf. of food, beverages and tobacco	28.6	31.1	122.1	173.1	6101	43373***	73.8	59.8	2403	21994***	902	21476***	26.7	56.8***
Manuf. of textiles, wearing apparel, leather	23.9	25.2	84.5	60.9	2457	6113***	25.4	7.9***	707	3173***	277	2233***	20.9	44.1***
Manuf. of wood, paper, printing	28.8	28.0	90.2	88.5	4866	12626***	59.2	11.3***	1625	6666***	426	5142***	30.9	53.6***
Manuf. of coke and refined petroleum prod.	29.0	42.8**	483.3	160.8***	52803	61634	364.2	214.3**	15125	26243	-487	9646	37.3	83.7***
Manuf. of chemicals and chemical prod.	31.9	37.9**	133.0	107.7	11259	23599***	96.4	29.2***	4602	11876***	1639	10795***	41.4	67.6***
Manuf. of pharmaceutical products	32.8	39.7**	285.7	429.1*	29026	105814***	84.5	28.5***	12419	73230***	5227	27371***	46.4	66.2***
Manuf. of rubber, plastic and non-metallic	27.6	31.0*	112.0	101.5	5990	18292***	66.5	31.7***	2041	6828***	651	8603***	31.6	56.2***
Manuf. of basic and fabricated metal prod.	27.4	27.6	93.6	71.7	5049	9109**	47.1	13.1***	1380	3637***	363	3237***	35.6	61.5***
Manuf. of computer, electronic and optical	25.9	30.0**	176.0	98.6	11245	12999	31.1	4.5***	3292	4675	1403	3173*	40.8	74.5***
Manuf. of electrical equipment	28.2	28.6	163.4	121.0	8041	13541**	38.4	8.3**	2483	5026**	952	4389***	32.2	56.4***
Manuf. of machinery and equipment n.e.c.	29.9	29.7	127.5	117.5	7521	18328***	37.6	8.3***	2288	10647***	1039	8218***	38.3	57.8***
Manuf. of motor vehicles, trailers	25.4	24.1	375.3	215.8	23350	24030	45.1	23.5***	7266	7512	1800	8684	34.5	48.6***
Manuf. of furniture; jewellery, musical prod.	26.1	24.0	105.7	139.2	4852	21713***	31.7	9.0***	1411	12742***	497	9655***	28.5	52.8***
Electricity, gas, steam and air cond. Supply	27.0	20.3**	281.2	156.8	48688	22312	875.0	29.3***	34835	11563	10126	8495	46.7	47.8
Water supply; sewerage, waste management	21.8	18.3**	138.9	170.6	8108	13737	194.3	11.1**	3556	4623	886	1897	28.7	39.9***
Construction	24.2	22.3	76.0	159.6***	3469	20030***	50.6	1.1	771	9264***	317	6972***	30.9	53.7***
Wholesale and retail trade of motor vehicles	27.7	31.0*	80.6	67.9	3842	11795***	42.0	6.7***	935	6567***	311	4593***	32.9	67.2***
Wholesale trade, except of motor vehicles	28.5	29.4	85.0	76.8	5080	20082***	45.2	1.9***	1657	14079***	759	10982***	36.7	78.3***

Retail trade, except of motor vehicles	22.4	18.6**	246.7	68.9	7933	5803	30.7	2.8***	2372	2325	974	2209	23.8	45.3***
Transport and storage	24.8	18.6***	146.4	152.0	7486	8979	98.8	3.0	2272	1294	542	671	31.4	55.7***
Postal and courier activities	13.3	22.0***	450.5	2125.1	7762	95734	7.9	10.6	446	22166	-281	14456	13.8	33.3***
Accommodation and food service activities	20.1	17.9	108.1	233.9*	2942	5215	85.3	0.7***	790	375	157	286	20.9	31.4***
Publishing, motion picture, video, television	28.2	24.6	138.5	84.9	9408	30917***	37.6	259.6***	2823	5713	858	6197***	40.2	265.2***
Telecommunications	17.9	15.1**	318.4	168.2	62662	26043	227.4	12.7***	42176	16816	12936	12402	51.0	59.5**
Computer programming, consultancy	17.9	14.8***	145.5	83.4	10603	11771	23.0	1.0	2060	4520**	930	4037***	46.9	78.8***
Professional, scientific and technical activities	19.6	17.0*	188.9	308.6	8897	51591***	42.7	3.1	1988	5059**	1225	28273***	36.5	101.8***

Note: EU-F: EU-frontier firms corresponds to the average of the 100 EU most productive (Solow TFP) firms in each year and industry. NF: Non-frontier firms is the average of all other firms. Test in mean differences with *** significant at 1%, ** significant at 5%, and * significant at 10%.

5.1.5 The EU-Frontier by country of origin

Table 5.1.5 shows the fraction of firms in the EU Frontier that correspond to different countries in three selected years (2006, 2013 and 2014). The information is provided separately for Manufacturing, non-financial Market Services and Other Production, but also for the total across these sectors.

Looking at the country composition of the EU Frontier for all three sectors combined, we can conclude that the countries with higher participation are Germany, France, UK, Italy, Spain, Sweden and Belgium. If we further look at changes over time (from 2006 to 2013/2014[21]) for these countries, countries which increase their presence in the EU Frontier are France, Italy, Sweden and Belgium. The other three countries decrease their presence.

The same countries appear as leaders integrating the Frontier in Manufacturing and non-financial Market Services. The only differences are that now Denmark also has a notable participation in non-financial Market Services, and that the participation of Belgium in non-financial Market Services, although relevant, decreases over time.

In Other Production, again Germany, France, UK, Italy, Spain and Sweden have a notable presence. However, Belgium disappears from the top ranking, and the Czech Republic is present in 2006. Additionally, and in contrast to the findings for Manufacturing, non-financial Market services and for the combined sectors, Germany and the UK increase their presence from 2006 to 2013.

[21] For several countries, there is a relevant drop in observations and coverage in Amadeus from the year 2013 to 2014 (Germany, for instance, is a clear example; see Table 2.1 in this report). For this reason, and for the sake of robustness, we present information both for 2013 and 2014. However, in case of discrepancy, we rely on 2013 results.

Table 5.1.5. The percentage of firms in the EU Frontier by country origin in selected years.

	Total			Manufacturing			Non-financial Market Services			Other Production		
Country	2006	2013	2014[4]	2006	2013	2014[4]	2006	2013	2014[4]	2006	2013	2014[4]
Austria	0.0	0.5	0.1	0.0	0.6	0.0	0.0	0.4	0.2	0.0	0.0	0.0
Belgium	5.6	6.5	8.4	5.5	8.5	11.4	6.7	5.3	5.7	2.0	1.3	4.3
Bulgaria	0.2	0.5	1.2	0.2	0.2	0.5	0.3	0.7	2.0	0.0	1.0	2.0
Croatia	0.2	0.3	0.3	0.2	0.2	0.1	0.1	0.4	0.6	0.3	0.3	0.7
Czech Republ.	2.4	1.4	1.2	1.4	1.2	1.1	2.5	1.4	0.9	6.3	2.3	2.7
Denmark	0.0[1]	2.7	4.2	0.0[1]	1.6	2.2	0.0[1]	4.6	7.2	0.0[1]	1.3	2.7
Estonia	0.4	0.4	0.4	0.1	0.2	0.0	0.8	0.8	0.8	0.3	0.0	0.7
Finland	1.2	1.2	2.4	0.9	1.2	2.5	1.9	1.4	2.8	0.3	0.3	0.7
France	16.2	17.0	19.5	13.7	13.8	18.3	19.3	21.9	22.0	16.3	14.3	16.7
Germany	18.6	12.7	2.5[4]	25.0	17.3	3.2	12.3	6.5	0.9	11.7	13.3	5.0
Greece	0.9	0.6	0.6	1.0	0.7	0.8	0.9	0.6	0.5	0.3	0.0	0.0
Hungary	0.3	1.2	1.5	0.6	1.1	1.2	0.1	1.1	1.4	0.0	1.7	3.0
Ireland	0.2	0.2	0.0	0.0	0.1	0.0	0.4	0.3	0.0	0.0	0.3	0.0
Italy	9.8	13.0	17.0	14.7	19.4	26.2	4.0	5.8	7.4	8.0	9.3	9.3
Netherlands	1.6	1.4	0.5	2.0	2.0	0.9	1.3	0.7	0.0	1.0	1.0	0.3
Poland	1.6	0.5	0.0	0.5	0.2	0.0	2.4	0.3	0.0	3.7	2.0	0.0
Portugal	2.0	1.7	2.8	1.2	1.7	2.1	2.8	1.7	2.9	3.0	1.7	5.3
Romania	0.8	1.4	3.4	0.8	0.8	3.1	0.5	1.8	3.9	2.0	2.7	3.3
Slovakia	3.3	1.0	1.8	2.6	0.6	1.2	4.9	1.5	1.8	0.7	1.0	4.3
Slovenia	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Spain	13.5	12.0	10.3	11.7	10.8	9.6	12.6	11.3	9.3	24.0	19.0	17.0
Sweden	5.3	9.0	11.8	3.8	5.8	8.0	7.5	12.7	16.4	4.3	10.3	13.0
Unit. Kingdom	16.0	15.0	10.0	14.1	11.9	7.9	18.7	18.6	13.1	15.7	16.7	9.0

Notes: 1) Denmark has no coverage in Amadeus for the year 2006 in the sample used for TFP measurement (see Table 2.1 in this report). 2) The same happens for all the years (2003-2014) for Cyprus and Lithuania. 3) Also Latvia, Luxembourg and Malta have not been considered because of insufficient observations in the database. 4) For several countries there is a relevant drop in observations and coverage from the year 2013 to 2014 (Germany, for instance, is a clear example; see Table 2.1 in this report).

5.2. The National Frontier firms

Table 5.2.1 reports differences in average characteristics by industry for the top 10 national-frontier firms[22] relative to non-frontier firms over the period 2003 to 2014. Table 5.2.2 and 5.2.3 show cross-sectional differences for the years 2006 (pre-crisis) and 2013 (post-crisis), respectively.

On average, firms at the national productivity frontier are relatively younger (3 years on average)[23]. This is the case for both manufacturing, where the age gap is over 2 years, and for services, with an age gap of over 3 years. With regards to employment, national-frontier firms are, on average, larger than non-frontier firms in the following industries: food, paper, coke, rubber, construction, wholesaling and, accommodation. For the remaining industries, national-frontier firms are smaller or not significantly different in size relative to non-frontier firms. Over time, we observe that the average size of non-frontier firms has decreased during the crisis, with some exceptions, particularly, in services. We also observe the decline in average size of national frontier firms in some manufacturing industries (food, coke, computers, electrical equipment and motor vehicles). In electricity, construction and some service industries, the average size of the national-frontier firms has also decreased comparing 2006 and 2013 averages.

With regards to value added, national-frontier firms have higher value added than non-frontier firms. Overall in manufacturing and services, the value added of frontier firms is two times larger than that of non-frontier firms. In several industries, non-frontier firms and national-frontier firms witnessed a decline in value added from 2006 to 2013. However, national-frontier firms increased value added in the following industries: textiles, paper, chemicals, pharmaceuticals, machinery, furniture, water supply, wholesale trade, retailing, publishing, computer programming and professional services. With regards to capital intensity, national-frontier firms are on average less capital intensive than non-frontier firms. Non-frontier firms became more capital intensive if we compare the average values from 2006 to 2013. This is in part explained by the fact that they became smaller. In contrast, there are some industries in which national-frontier firms became less capital intensive.

With very few exceptions, average earnings and profits of national-frontier firms are larger than those of non-frontier firms. In several industries, non-frontier firms and national-frontier firms experienced a decline in earnings and profits from 2006 to 2013. In contrast, national-frontier firms increased

[22] The top-10 national frontier firms correspond to the average of the 10 most productive (Solow TFP) firms in each country, year and industry.
[23] In all countries analysed, with the exception of Ireland, national frontier firms are significantly younger relative to non-frontier firms.

earnings and profits in the following industries: paper, chemicals, machinery, furniture, wholesale trade, postal services and computer programming.

National-frontier firms pay on average higher average wages per employee relative to non-frontier firms, with very few exceptions. Comparing the values from 2006 to those in 2013, we observe that in the manufacturing sector, non-frontier firms and national frontier firms increased average wages per employee. On the other hand, non-frontier firms decreased wages in water supply, wholesaling, postal services and accommodation, while frontier firms did so in wholesaling, postal services, accommodation, computer programming and professional services.

Table 5.2.1: Means and differences in means of firm characteristics: National-frontier firms (top 10) vs. non-frontiers (Average 2003-2014).

Industry	*Age*		*Employment*		*VA*		*Capital*		*EBITDA*		*Profits*		*Wages p.e.*	
	NF	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*
Manuf. of food, beverages and tobacco	26.3	26.4	125.3	175.5***	6189	29673***	65.1	57.0***	2468	15165***	932	13774***	25.2	39.7***
Manuf. of textiles, wearing apparel, leather	22.8	22.3	94.4	96.4	2593	6230***	24.7	14.2***	753	3343***	237	2297***	20.3	39.7***
Manuf. of wood, paper, printing	26.1	21.5***	91.6	120.7***	4444	15860***	51.5	48.8	1513	9267***	382	6474***	27.3	34.1***
Manuf. of coke and refined petroleum prod.	32.7	35.9**	235.1	329.7**	46179	88462***	279.3	362.7	19189	44627***	3768	31667***	62.0	71.2
Manuf. of chemicals and chemical prod.	29.9	26.5***	142.3	133.2	12129	24026***	88.6	64.4***	4812	11503***	1751	9097***	41.1	44.0***
Manuf. of pharmaceutical products	32.6	29.1***	322.3	288.8*	33551	44154***	80.0	45.3***	14594	28810***	4805	23653***	44.5	47.6*
Manuf. of rubber, plastic and non-metallic	24.9	24.7	112.6	126.1**	5806	16868***	60.1	64.0**	2042	9938***	667	7521***	29.2	37.5***
Manuf. of basic and fabricated metal prod.	25.0	20.8***	98.5	90.9	5230	10222***	41.1	38.6**	1670	5936***	594	4609***	32.2	38.9***
Manuf. of computer, electronic and optical	23.8	19.7***	196.0	138.1**	11331	9865	29.1	13.2***	2973	4573***	1231	3366***	35.9	40.3***
Manuf. of electrical equipment	25.7	23.0***	175.1	150.3	8270	12598***	33.1	23.8***	2576	5572***	1016	4569***	31.2	38.9***
Manuf. of machinery and equipment n.e.c.	27.3	21.3***	124.1	116.4	7015	13419***	32.6	19.1***	2106	6659***	892	4637***	36.7	43.3***
Manuf. of motor vehicles, trailers	23.4	21.6***	410.0	236.4***	23346	24408	41.9	27.1***	5801	12849***	1079	10094***	31.7	36.0***
Manuf. of furniture; jewellery, musical prod.	23.4	19.6***	104.5	112.9	4749	10848***	27.6	13.0***	1366	5128***	502	4118***	28.3	41.9***
Electricity, gas, steam and air cond. Supply	24.4	20.0***	305.7	331.7	56345	60969	774.0	431.5***	37928	33499	13462	21917***	44.3	44.7
Water supply; sewerage, waste management	20.3	16.0***	149.5	106.7***	9421	6866***	178.7	46.4***	4157	2589***	1128	1530*	30.7	33.8***
Construction	21.2	18.3***	79.4	90.5**	3822	7951***	39.7	90.2***	1007	3096***	510	2678***	30.9	41.1***
Wholesale and retail trade of motor vehicles	24.8	21.0***	76.4	83.2*	3700	10365***	37.5	22.2***	989	5349***	357	3857***	32.0	48.3***
Wholesale trade, except of motor vehicles	25.4	21.7***	83.0	63.1***	5162	14054***	39.7	13.1***	1794	9007***	913	6895***	35.0	66.2***

Retail trade, except of motor vehicles	21.0	16.0***	233.6	94.7***	7401	6740	29.2	20.4***	2341	3427*	985	2565***	21.5	33.7***
Transport and storage	23.7	17.4***	157.0	125.0*	8269	10240*	86.7	197.8***	2460	4299***	597	2633***	32.0	42.3***
Postal and courier activities	14.4	17.6***	1131.4	1933.0	52603	79807	9.1	10.3*	4876	8297	3244	4331	19.3	27.5***
Accommodation and food service activities	18.8	14.2***	115.6	176.0***	3166	5530***	80.5	14.4***	851	1044*	158	788***	21.3	25.3***
Publishing, motion picture, video, television	25.9	20.0***	141.8	86.9***	10152	10509	36.8	21.0***	3150	4014*	1513	3165***	40.6	57.6***
Telecommunications	14.7	15.2	421.6	435.2	67454	67500	207.4	87.4***	44448	45988	16165	21179	45.7	44.3***
Computer programming, consultancy	16.1	13.1***	143.7	88.1***	9709	10378	17.6	13.1	1923	3763***	851	2924***	44.6	66.0***
Professional, scientific and technical activities	18.3	15.2***	190.9	150.7*	8931	29825***	41.2	25.1***	1945	3385***	1230	16339***	36.4	76.3***

Note: NAT-F: National frontier firms corresponds to the average of the 10 most productive (Solow TFP) firms in each country, year and industry. NF: Non-frontier firms is the average of all other firms. Test in mean differences with *** significant at 1%, ** significant at 5%, and * significant at 10%.

Table 5.2.2: Means and differences in means of firm characteristics: National-frontier firms (Top 10) vs. non-frontiers (Pre-crisis 2006).

Industry	***Age***		***Employment***		***VA***		***Capital***		***EBITDA***		***Profits***		***Wages p.e.***	
	NF	***NAT_F***	***NF***	***NAT_F***	***NF***	***NAT_F***	***NF***	***NAT_F***	***NF***	***NAT_F***	***NF***	***NAT_F***	***NF***	***NAT_F***
Manuf. of food, beverages and tobacco	25.9	24.5	124.1	205.7***	6100	29379***	58.8	44.4**	2359	16094***	876	12783***	25.0	37.2***
Manuf. of textiles, wearing apparel, leather	22.6	20.7	92.8	85.6	2663	5598***	22.2	15.1***	795	3024***	246	2380***	20.6	28.2***
Manuf. of wood, paper, printing	25.1	19.8***	92.9	103.7	4331	14170***	45.9	44.3	1483	8642***	397	5165***	25.8	32.0***
Manuf. of coke and refined petroleum prod.	31.0	33.4	180.1	298.7	34845	84911	240.9	404.7	18269	49153	970	37205	60.9	56.7
Manuf. of chemicals and chemical prod.	28.8	24.8**	139.0	114.3	11592	13736	79.6	60.2**	4618	6628	1507	5377***	40.7	41.8
Manuf. of pharmaceutical products	32.5	25.1***	329.9	281.2	35793	40808	75.6	33.2***	14178	27879	5243	18256**	44.4	40.9
Manuf. of rubber, plastic and non-metallic	24.0	24.3	111.6	122.3	5965	17002***	51.7	74.2***	2183	11088***	853	8263***	28.7	36.2***

Manuf. of basic and fabricated metal prod.	24.1	16.8***	98.2	93.3	5516	12610***	34.5	53.5***	2058	8422***	962	5988***	31.5	34.9***
Manuf. of computer, electronic and optical	22.7	17.8***	190.6	171.6	10200	10814	25.1	15.6***	3186	5855*	1354	4237***	32.7	34.6
Manuf. of electrical equipment	24.9	23.2	169.8	207.8	8368	17920***	26.7	29.4	2627	7157***	1146	7622***	31.5	35.2***
Manuf. of machinery and equipment n.e.c.	26.3	20.9***	121.3	110.2	7015	9034	27.4	15.2***	2183	4335***	924	3169***	37.5	40.9***
Manuf. of motor vehicles, trailers	22.5	21.1	390.3	309.2	21176	32486	38.9	27.6**	5048	10900*	593	15051***	30.9	35.2***
Manuf. of furniture; jewellery, musical prod.	22.3	18.2***	101.7	85.5	4836	7364	24.3	11.3***	1465	2976	550	2138***	28.9	42.5***
Electricity, gas, steam and air cond. Supply	22.8	19.9	302.4	301.4	57574	62159	568.6	499.3	35403	35936	15306	23043	42.2	42.1
Water supply; sewerage, waste management	19.0	15.3***	144.4	101.0	10122	6961	163.6	30.9***	4566	2258	1414	1993	32.2	32.5
Construction	20.0	19.0	78.2	70.6	3946	7663**	34.0	11.8	1138	3506***	745	3491	30.8	38.1***
Wholesale and retail trade of motor vehicles	23.8	21.9	75.9	76.1	3870	13517***	33.2	28.5	1089	7901***	439	5766***	32.4	52.2***
Wholesale trade, except of motor vehicles	24.4	19.4***	82.8	55.4	5651	11047***	35.2	12.3***	2063	6031***	1112	5763***	36.2	60.1***
Retail trade, except of motor vehicles	20.6	15.4***	217.0	89.4	7257	6546	27.3	31.9	2335	3596	1237	2806	20.4	33.1***
Transport and storage	23.2	16.2***	154.4	103.3	8231	9594	69.9	93.2	2306	5071	558	3025	33.2	41.1***
Postal and courier activities	14.0	16.2	197.1	2394.3	7347	111858	9.8	9.8	792	10369	235	6791	18.5	26.6***
Accommodation and food service activities	18.2	13.0***	122.1	117.2	3472	4800	73.9	25.9***	980	1363	290	1346***	21.8	26.6***
Publishing, motion picture, video, television	25.4	20.8***	136.1	91.3*	10009	9724	41.6	9.4**	3216	4297	1598	2970	40.5	44.4**
Telecommunications	14.1	13.1	418.1	246.3	56700	69761	196.2	121.6	40046	58224	13169	30714	35.1	38.5
Computer programming, consultancy	15.5	13.0***	137.8	84.7	9042	8236	14.8	8.6*	1579	2502	847	1813**	44.1	69.1***
Professional, scientific and technical activities	17.8	14.4***	188.4	199.0	8597	21142***	36.7	10.6	1816	4016*	1045	7998***	36.4	76.6***

Note: NAT-F: National frontier firms corresponds to the average of the 10 most productive (Solow TFP) firms in each country, year and industry. NF: Non-frontier firms is the average of all other firms. Test in mean differences with *** significant at 1%, ** significant at 5%, and * significant at 10%.

Table 5.2.3: Means and differences in means of firm characteristics: National-frontier firms (top 10) vs. non-frontiers (Post-crisis 2013).

Industry	*Age*		*Employment*		*VA*		*Capital*		*EBITDA*		*Profits*		*Wages p.e.*	
	NF	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*	*NF*	*NAT_F*
Manuf. of food, beverages and tobacco	28.7	26.1	122.5	129.3	6126	21605***	73.9	61.9	2379	12276***	891	10605***	26.8	37.8***
Manuf. of textiles, wearing apparel, leather	23.9	23.6	83.6	102.4*	2405	5888***	25.6	9.1***	691	2389***	248	2148***	21.0	28.3***
Manuf. of wood, paper, printing	29.0	22.3***	89.0	122.4***	4630	14934***	58.9	47.0*	1444	8966***	312	5717***	30.9	39.5***
Manuf. of coke and refined petroleum prod.	33.9	42.2	228.0	275.1	36489	74133	317.7	219.0	12995	29633	1306	10231	68.0	71.8
Manuf. of chemicals and chemical prod.	32.3	29.3*	133.5	114.7	11248	16985**	96.3	67.7**	4488	9322***	1536	7072***	42.0	45.6**
Manuf. of pharmaceutical products	34.2	31.9	297.5	324.0	31401	63275**	87.1	44.5***	13141	43533***	5356	16657***	49.2	47.5
Manuf. of rubber, plastic and non-metallic	27.7	26.1	111.4	128.8	5849	16435***	66.8	43.1***	1911	8804***	557	7478***	31.7	40.8***
Manuf. of basic and fabricated metal prod.	27.4	22.7***	93.4	96.6	5005	9567***	47.2	28.0***	1342	4732***	339	3122***	35.7	42.4***
Manuf. of computer, electronic and optical	26.5	22.6***	177.1	131.5	11492	9975	31.7	14.6***	3213	4584	1292	3111***	41.8	47.4***
Manuf. of electrical equipment	28.4	25.3**	163.0	148.9	7995	11097**	39.0	17.6**	2415	4461***	906	3056***	32.4	40.8***
Manuf. of machinery and equipment n.e.c.	30.1	22.5***	127.9	112.1	7534	11866***	37.8	18.8***	2282	6148***	1011	5067***	38.5	43.3***
Manuf. of motor vehicles, trailers	25.5	24.0	377.4	276.9	22818	30326	45.3	33.3**	6504	16926**	1320	10913**	34.7	38.4***
Manuf. of furniture; jewellery, musical prod.	26.2	21.5***	105.5	128.1	4795	14064***	31.9	14.8***	1374	7577***	464	5572***	28.4	44.2***
Electricity, gas, steam and air cond. Supply	27.5	20.6***	268.1	296.9	48191	38520	857.4	558.7	35242	20835	9772	11411	46.9	46.1
Water supply; sewerage, waste management	22.0	17.6***	140.8	127.4	8368	7034	199.3	38.0**	3676	2345	868	1617	28.8	33.0***
Construction	24.3	18.7***	76.5	65.1	3534	4899	49.8	95.4	802	1748***	337	1426***	30.9	41.4***
Wholesale and retail trade of motor vehicles	27.9	22.3***	80.2	87.9	3808	8305***	42.4	16.1***	918	3865***	293	2702***	32.9	49.1***
Wholesale trade, except of motor vehicles	28.5	22.9***	85.2	64.3	5069	12407***	45.4	7.2***	1646	7913***	748	6121***	36.5	70.1***
Retail trade, except of motor vehicles	22.5	16.8***	248.3	81.0	7926	7450	30.8	14.9***	2371	2400	947	3011*	23.8	33.8***
Transport and storage	24.8	19.6***	146.9	121.0	7507	6966	99.5	24.3	2281	1328	537	876	31.4	42.2***
Postal and courier activities	13.0	19.4***	559.1	1512.7	8615	65655	6.9	10.1	12	15017	-336	9469	15.4	26.0***

Accommodation and food service activities	20.2	14.0***	107.7	180.1	2926	4728*	86.2	5.7***	789	653	153	427	21.0	22.3*
Publishing, motion picture, video, television	29.0	21.1***	142.9	83.9**	9926	16060	39.8	127.0*	2966	3227	888	3164**	41.3	143.6***
Telecommunications	17.7	16.7	327.4	219.5	65208	37750	246.3	71.9***	44042	24678	13782	10676	52.0	53.1
Computer programming, consultancy	18.2	13.5***	147.8	89.4*	10705	9848	23.1	11.4	2020	3626**	901	2622***	46.6	64.6***
Professional, scientific and technical activities	19.6	15.5***	189.8	164.9	8943	22935***	43.0	3.6**	1992	2957	1232	11666***	36.4	71.1***

Note: NAT-F: National frontier firms corresponds to the average of the 10 most productive (Solow TFP) firms in each country, year and industry. NF: Non-frontier firms is the average of all other firms. Test in mean differences with *** significant at 1%, ** significant at 5%, and * significant at 10%

5.3 Persistence of frontier and non-frontier firms

To analyse firms' persistence, both in the EU and National frontiers, we report in Tables 5.3.1-5.3.6 the percentage of firms staying in the corresponding frontier, and the percentage remainingaway from the frontier, after several years. More specifically, we report the percentage remaining after one, two and five years. We present results for both the total across sectors and for aggregated industries. The data obtained for each individual industry has been aggregated into three broad groups: Manufacturing, Other Production, and non-financial Market Services. The information in these tables refers to three different samples. The first sample follows frontier, F, (non-frontier, NF) firms in 2003. The second sample follows F (NF) firms in 2006. Finally, the third sample also follows F (NF) firms in 2006 but restricting the sample to a balanced panel of firms that remain in the Amadeus database from 2006 to 2013. The purpose of experimenting with these three samples is to provide a robustness check as regards the analysis of persistence using Amadeus. As has already been shown in Table 2.1 of this report, for several countries coverage improves from 2006 onwards. This is the case for countries such as Germany, Portugal, Ireland, Hungary and Austria. However, there is a decline in coverage for several countries in 2014, which is likely to be due to the existence of still incomplete and preliminary data for the latest available year in Amadeus.

Looking at Table 5.3.1 for persistence in the EU frontier, we see that the percentage of firms that manage to remain in the EU frontier after one year ranges from 40.35% (in sample 1) to 50.12% (in sample 2) to 66.14% (in sample 3). Sample 2 minimizes coverage problems for several countries before the year 2006 (present in sample 1). Additionally, sample 3 (as regards samples 1 and 2) eliminates the effect of exit of firms from Amadeus in the computation of persistence. In the following therefore, we mainly base our analysis and comments regarding persistence on sample 3 results. In this sample, results after five years indicate that 41.36% of firms are still in the EU frontier. In general, persistence is higher among frontier Manufacturing firms than among Market Services (this result appears in the three samples and it is also obtained by Andrews *et al.*, 2015, using the OECD-ORBIS productivity database from Gal, 2013; these authors consider Manufacturing and Market Services, but do not consider Other Production).[24]

Table 5.3.2, for persistence in the National frontiers, reveals that the percentage of firms that manage to remain in the National frontier after one year fluctuates from 46.14% (in sample 1) to 52.21% (in sample 2) and to 60.92% (in sample 3). Focusing on sample 3 results, 36.08% of National frontiers firms are still in this frontier after five years. In samples 1 and 2, again we find that persistence is higher among frontier Manufacturing firms than among non-financial Market Services. For sample 3, this result is obtained only when we measure long-run persistence (after five years).

[24] Andrews *et al.* (2015), also using a Solow-residual based total factor productivity measure, find that around half of the firms manage to remain at the global frontier from one year to the next, and after five years, less than 20% of firms are still there. These results are quite similar to the ones we obtain for persistence both at the EU and National frontiers in our samples 1 and 2. In sample 3, persistence is higher due to the fact that balancing the sample we avoid the effects of attrition in the Amadeus database when calculating the percentage of firms staying in the frontier after several years.

Results are more erratic for Other Production, since for the National frontiers they are either in the middle or lower level of persistence (as regards Manufacturing and non-financial Market Services), but for the EU Frontier they are either in the middle or the ones with higher persistence.

Looking at Tables 5.3.3 and 5.3.4 for persistence in the EU and National non-frontiers, respectively, we see that the percentage of firms that remain at the EU non-frontier after one year is 97.07% (according to sample 3). Results after five years indicate that 80.94% of EU non-frontier firms still have EU-non frontier status. The corresponding percentages forNational non-Frontiers are 96.84% and 80.89%, respectively.

For the non-frontier status, in general, the intermediate level of persistence is for Other Production (independently of the sample and independently of considering EU or National non-frontiers). For the balanced sample (sample 3) the higher persistence in this status is for Services. However, for samples 1 and 2 it is for Manufacturing.

If we focus on sample 3 (balanced panel), after five years' persistence in the frontier status, there is evidence of higher persistence for the EU frontier firms than for the National frontier firms (the percentage of firms that remain in the frontier after five years is 41.36% in the first case and 36.08% in the second case). The comparable percentages for Manufacturing are 41.88% and 38.24%, respectively. For Other Production, these stand at 53.33% and 31.96% and, for non-financial Market Services, at 35.59% and 34.23%. However, persistence in the non-frontier status is quite similar independent of the definition of frontier firms (EU or National). For sample 3, looking at persistence after five years, 80.94% of non-frontier firms by the EU definition (and and 80.89% by the National definition) remain in this status. The corresponding percentages for Manufacturing are 79.38% and 79.24%, respectively. For Other Production, these stand at 80.33% and 80.55% and, for non-financial Market Services, at 82.39% and 82.32%.

Table 5.3.1: Persistence in the EU Frontier (Top 100 EU).

Percentage of firms staying in the frontier after several years

	Sample 1			**Sample 2**			**Sample 3**		
	Number of years			***Number of years***			***Number of years***		
Industry	**1**	**2**	**5**	**1**	**2**	**5**	**1**	**2**	**5**
Total	40.35%	23.12%	9.31%	50.12%	34.42%	17.38%	66.14%	54.32%	41.36%
Manufacturing	42.31%	24.00%	10.46%	52.77%	37.31%	20.23%	65.70%	55.23%	41.88%
Other Production	45.00%	27.33%	10.00%	50.00%	33.67%	17.67%	68.89%	60.00%	53.33%
Market Services	36.40%	20.70%	7.60%	46.70%	30.90%	13.60%	66.10%	50.00%	35.59%

Notes: 1) Top 100 EU frontier firms are the top 100 most productive (Solow TFP) firms in each year and industry at the EU level. 2) Sample 1 follows F firms in 2003. Sample 2 follows F firms in 2006. Finally, Sample 3 also follows F firms in 2006 but restricting the sample to a balanced panel of firms that stay in Amadeus database since 2006 to 2013.

Table 5.3.2: Persistence in the National Frontier (Top 10 National).

Percentage of firms staying in the frontier after several years

	Sample 1			Sample 2			Sample 3		
	Number of years			*Number of years*			*Number of years*		
Industry	**1**	**2**	**5**	**1**	**2**	**5**	**1**	**2**	**5**
Total	46.14%	28.28%	15.28%	52.21%	38.51%	22.20%	60.92%	51.11%	36.08%
Manufacturing	48.67%	30.54%	17.17%	53.20%	39.98%	25.51%	60.29%	48.77%	38.24%
Other Production	45.67%	27.16%	17.91%	52.87%	40.54%	22.13%	55.67%	53.61%	31.96%
Market Services	43.03%	25.72%	12.02%	50.76%	36.05%	18.08%	63.85%	53.85%	34.23%

Notes: 1) Top 10 frontier firms are the top 10 most productive (Solow TFP) firms in each year and industry at the national level. 2) Sample 1 follows F firms in 2003. Sample 2 follows F firms in 2006. Finally, Sample 3 also follows F firms in 2006 but restricting the sample to a balanced panel of firms that stay in Amadeus database since 2006 to 2013.

Table 5.3.3: Persistence in the non-EU Frontier (non-Top 100 EU).

Percentage of firms staying away from the frontier after several years

	Sample 1			Sample 2			Sample 3		
	Number of years			*Number of years*			*Number of years*		
Industry	**1**	**2**	**5**	**1**	**2**	**5**	**1**	**2**	**5**
Total	83.53%	64.76%	49.04%	88.97%	76.65%	60.12%	97.07%	89.95%	80.94%
Manufacturing	84.17%	65.86%	51.90%	90.95%	78.62%	63.45%	97.14%	88.98%	79.38%
Other Production	85.07%	64.59%	48.76%	88.89%	76.84%	58.40%	97.35%	90.09%	80.33%
Market Services	82.61%	64.02%	47.08%	87.48%	75.08%	58.08%	96.93%	90.70%	82.39%

Notes: 1) Non-Top 100 EU are all firms below the top 100 most productive (Solow TFP) firms in each year and industry at the EU level. 2) Sample 1 follows non-F firms in 2003. Sample 2 follows non-F firms in 2006. Finally, Sample 3 also follows non-F firms in 2006 but restricting the sample to a balanced panel of firms that stay in Amadeus database since 2006 to 2013.

Table 5.3.4: Persistence in the non-National Frontier (non-Top 10 National).

Percentage of firms staying away from the frontier after several years

	Sample 1			Sample 2			Sample 3		
	Number of years			*Number of years*			*Number of years*		
Industry	**1**	**2**	**5**	**1**	**2**	**5**	**1**	**2**	**5**
Total	83.27%	64.47%	48.62%	88.64%	76.28%	59.78%	96.84%	89.74%	80.89%
Manufacturing	83.77%	65.42%	51.21%	90.44%	78.04%	62.83%	96.78%	88.67%	79.24%
Other Production	84.85%	64.28%	48.46%	88.69%	76.59%	58.14%	97.24%	90.07%	80.55%
Market Services	82.45%	63.85%	46.81%	87.25%	74.84%	57.93%	96.79%	90.52%	82.32%

Notes: 1) Non-Top 10 firms are all firms below the top 10 most productive (Solow TFP) firms in each year and industry at the national level. 2) Sample 1 follows non-F firms in 2003. Sample 2 follows non-F firms in 2006. Finally, Sample 3 also follows non-F firms in 2006 but restricting the sample to a balanced panel of firms that stay in Amadeus database since 2006 to 2013.

In Tables 5.3.5 (persistence in the frontier) and 5.3.6 (persistence in the non-frontier) we perform the same analysis as before, but at a more disaggregated industry level. However, results are only presented for sample 3. Results in Table 5.3.5 indicate that Manufacturing industries such as Manufacturing of textiles, wearing apparel, leather; Manufacturing of wood, paper, printing; Manufacturing of coke and refined petroleum products; Manufacturing of chemicals and chemical products; and Manufacturing of pharmaceutical products show high persistence in the frontier status after five years, both with respect to EU and National frontiers. Additionally, the following industries show high persistence after five years according to the National frontiers: Manufacturing of food, beverages and tobacco; and Manufacturing of motor vehicles and trailers.

Finally, there is also high persistence in the EU frontier for Manufacturing of electrical equipment. As regards Other Production, higher persistence is observed for utilities and lower persistence for Construction (very low persistence after five years), both for the EU and the National frontiers. In the case of Services, and also for both frontiers, a high rate of persistence is obtained for Transport and storage; Postal and courier activities; and Publishing, motion picture, video and television. For the EU frontier this is also the case for Telecommunications. And for National frontiers, this is apparent for Computer programming and consultancy.

Results in Table 5.3.6 regardingpersistence in the non-frontier status, indicate that it is the same industries, independently of the definition of frontier, that show higher persistence in this status.In Manufacturing these industries are: Manufacturing of food, beverages and tobacco; Manufacturing of chemicals and chemical products; Manufacturing of rubber, plastic and non-metallic products; Manufacturing of computer, electronic and optical; Manufacturing of electrical equipment; Manufacturing of machinery and equipment; and Manufacturing of furniture, jewelry, and musical products. In Other Production this applies for Electricity, gas, steam and air conditioning supply. Finally, in Services, higher persistence in the non-frontier status is found for Wholesale trade, except of motor vehicles; Computer programming, consultancy; and professional, scientific and technical activities.

Table 5.3.5: Persistence in the Frontier (balanced sample).

Percentage of firms staying in the frontier after several years

	Frontier measure					
	Top 10 National			**Top 100 EU**		
	Number of years			***Number of years***		
Industry	**1**	**2**	**5**	**1**	**2**	**5**
Total	60.92%	51.11%	36.08%	66.14%	54.32%	41.36%
Manuf. of food, beverages and tobacco	51.72%	34.48%	44.83%	68.42%	52.63%	31.58%
Manuf. of textiles, wearing apparel, leather	64.29%	53.57%	50.00%	57.89%	47.37%	47.37%
Manuf. of wood, paper, printing	52.17%	47.83%	47.83%	52.94%	52.94%	64.71%
Manuf. of coke and refined petroleum prod.	76.19%	71.43%	38.10%	92.86%	89.29%	60.71%
Manuf. of chemicals and chemical prod.	72.97%	67.57%	56.76%	71.43%	64.29%	46.43%
Manuf. of pharmaceutical products	77.42%	61.29%	48.39%	72.41%	62.07%	62.07%
Manuf. of rubber, plastic and non-metallic	44.12%	44.12%	20.59%	50.00%	55.00%	20.00%
Manuf. of basic and fabricated metal prod.	48.65%	29.73%	24.32%	48.00%	36.00%	36.00%
Manuf. of computer, electronic and optical	64.29%	42.86%	35.71%	80.00%	45.00%	25.00%
Manuf. of electrical equipment	58.70%	41.30%	32.61%	78.57%	64.29%	42.86%
Manuf. of machinery and equipment n.e.c.	42.42%	51.52%	30.30%	50.00%	50.00%	25.00%
Manuf. of motor vehicles, trailers	72.41%	44.83%	41.38%	35.71%	21.43%	14.29%
Manuf. of furniture; jewelry, musical prod.	65.63%	53.13%	34.38%	61.11%	44.44%	38.89%
Electricity, gas, steam and air cond. supply	72.97%	67.57%	48.65%	72.41%	68.97%	62.07%
Water supply; sewerage, waste management	54.55%	60.61%	36.36%	72.73%	63.64%	54.55%
Construction	33.33%	25.93%	3.70%	40.00%	0.00%	0.00%
Wholesale and retail trade of motor vehicles	82.14%	71.43%	32.14%	93.33%	60.00%	20.00%
Wholesale trade, except of motor vehicles	47.37%	47.37%	21.05%	50.00%	37.50%	25.00%
Retail trade, except of motor vehicles	51.35%	40.54%	27.03%	43.75%	25.00%	25.00%
Transport and storage	60.71%	50.00%	35.71%	78.57%	50.00%	50.00%
Postal and courier activities	76.19%	66.67%	71.43%	81.25%	75.00%	43.75%

Accommodation and food service activities	37.04%	37.04%	25.93%	61.54%	53.85%	30.77%
Publishing, motion picture, video, television	72.00%	52.00%	36.00%	58.33%	50.00%	58.33%
Telecommunications	79.17%	66.67%	20.83%	71.43%	57.14%	50.00%
Computer programming, consultancy	70.97%	67.74%	48.39%	42.86%	42.86%	14.29%
Professional, scientific and technical activities	65.00%	40.00%	25.00%	33.33%	0.00%	0.00%

Notes: 1) Top 10 frontier firms are the top 10 most productive (Solow TFP) firms in each year and industry at the national level. Top 100 EU frontier firms are the top 100 most productive (Solow TFP) firms in each year and industry at the EU level. 2) Balanced sample corresponds to sample 3, which follows F firms in 2006 but restricting the sample to a balanced panel of firms that stay in Amadeus database since 2006 to 2013.

Table 5.3.6: Persistence in the non-Frontier (balanced sample).

Percentage of firms staying away from the frontier after several years

	Frontier measure					
	Non-Top 10 National			**Non-Top 100 EU**		
	Number of years			***Number of years***		
Industry	**1**	**2**	**5**	**1**	**2**	**5**
Total	96.84%	89.74%	80.89%	97.07%	89.95%	80.94%
Manuf. of food, beverages and tobacco	96.64%	89.52%	80.55%	96.78%	89.82%	80.89%
Manuf. of textiles, wearing apparel, leather	96.21%	87.37%	73.06%	96.66%	87.80%	73.43%
Manuf. of wood, paper, printing	96.70%	88.26%	77.40%	97.01%	88.31%	77.43%
Manuf. of coke and refined petroleum prod.	92.86%	64.29%	21.43%	85.71%	57.14%	0.00%
Manuf. of chemicals and chemical prod.	96.03%	89.47%	83.17%	95.68%	89.46%	82.97%
Manuf. of pharmaceutical products	94.62%	86.56%	77.96%	95.74%	87.23%	75.00%
Manuf. of rubber, plastic and non-metallic	96.85%	89.24%	79.58%	97.32%	89.71%	79.97%
Manuf. of basic and fabricated metal prod.	97.10%	87.67%	77.19%	97.36%	87.93%	77.50%
Manuf. of computer, electronic and optical	94.69%	89.76%	81.10%	97.48%	89.92%	80.81%
Manuf. of electrical equipment	96.28%	86.96%	80.52%	96.93%	87.29%	80.45%
Manuf. of machinery and equipment n.e.c.	96.76%	86.99%	79.52%	96.58%	86.97%	79.42%
Manuf. of motor vehicles, trailers	96.51%	88.36%	78.46%	97.44%	89.74%	78.92%
Manuf. of furniture; jewelry, musical prod.	98.21%	92.15%	84.25%	98.67%	92.49%	84.09%
Electricity, gas, steam and air cond. supply	97.15%	90.16%	88.34%	97.46%	91.88%	87.06%
Water supply; sewerage, waste management	94.62%	86.00%	75.85%	95.39%	85.12%	75.60%
Construction	97.61%	90.62%	80.56%	97.62%	90.64%	80.44%
Wholesale and retail trade of motor vehicles	96.38%	90.47%	82.26%	96.63%	90.89%	82.46%
Wholesale trade, except of motor vehicles	97.40%	91.70%	84.47%	97.51%	91.82%	84.67%
Retail trade, except of motor vehicles	96.96%	90.34%	82.15%	97.19%	90.69%	82.46%
Transport and storage	95.98%	89.29%	79.25%	96.22%	89.57%	79.43%
Postal and courier activities	84.62%	76.92%	69.23%	72.22%	50.00%	50.00%
Accommodation and food service activities	96.14%	89.74%	80.34%	96.44%	90.03%	80.29%
Publishing, motion picture, video, television	95.64%	86.15%	76.67%	96.28%	87.59%	75.93%
Telecommunications	95.45%	90.00%	75.45%	93.33%	85.00%	70.83%
Computer programming, consultancy	96.86%	90.92%	83.17%	96.83%	91.11%	82.86%
Professional, scientific and technical activities	97.08%	90.61%	83.14%	97.15%	90.68%	83.22%

Notes: 1) Non-Top 10 firms are all firms below the top 10 most productive (Solow TFP) firms in each year and industry at the national level. Non-Top 100 EU are all firms below the top 100 most productive (Solow TFP) firms in each year and industry at the EU level. 2) Balanced sample corresponds to sample 3, which follows non-F firms in 2006 but restricting the sample to a balanced panel of firms that stay in Amadeus database since 2006 to 2013.

Another proxy for persistence in the frontier (or non-frontier) status is the average number of years a firm belongs to the frontier (or remains away from the frontier). We have calculated these mean values for all the frontier (non-frontier) firms defined either as EU or National frontiers (non-frontiers) during the period 2003-2014, but using information on firms that belong to the balanced sample from 2006 to 2013. For firms

that belong to the frontier for at least one year (either to the EU or to the National frontier), we find that for around 30% of sample years they belong to the frontier, and the mean number of years they remain there is around 3. Furthermore, for firms that do not belong to the frontier for at least one year, we find that in about 98% of sample years they have non-frontier status, and the mean number of years they remain in this status is around 10.5.

Summary and policy implications

From the descriptive analysis, we observe that relative to non-frontier firms, EU- and National-frontier firms are larger, have higher mean value added, earnings and profits, and pay higher average wages per employee. This holds by aggregate sectors and for the pre-crisis (2006) and post-crisis period (2013). While EU-frontier firms are relatively older in manufacturing, EU- and National-frontier firms are younger in other production and in non-financial market services. Discrepancies by sector are also found in terms of capital intensity. EU- and National-frontier firms are less capital intensive in other production industries, but not significantly different from non-frontier firms in manufacturing. In market services, however, while EU-frontier firms are relatively less capital intensive, National-frontier firms are more capital intensive than non-frontier firms. From 2006 to 2013, both frontier and non-frontier firms went through important adjustments, with a high degree of heterogeneity across industries.

According to the results on the country composition of the EU-Frontier, the countries with the highest participation are Germany, France, UK, Italy, Spain, Sweden and Belgium. This holds in 2006 and does not change by 2013/2014. Additionally, it also holds when considering manufacturing, non-financial market services, and other production separately. There seems to be substantial persistence over time in the country composition of the EU-Frontier, which probably represents the difficulty some countries face in the ability of their National Frontiers to catch-up/surpass the EU-Frontiers.

From our analysis of persistence of firms in the Frontier/Non-Frontier status, we observe first that generally, persistence is higher among frontier manufacturing firms than among frontier firms in non-financial market services, independently of the definition of frontier. Results for other production are more erratic. Second, there is higher persistence for the EU frontier firms than for the National frontier firms. Third, and regarding the non-frontier status, a higher persistence is found for services and lower persistence for manufacturing (the intermediate level is for other production). This holds independently of the definition of non-frontier firms. Fourth, differently to persistence in the frontier status, persistence in the non-frontier status is quite similar among manufacturing, other production and non-financial market services, independently of the definition of non-frontier firms. Finally, persistence is much higher in the non-frontier than in the frontier status; 41.36% (36.08%) of EU (National) frontier firms remains in the frontier after five years. In contrast, 80.94% (80.89%) of EU (National) non-frontier firms remain away from the best practice after five years. The results imply that it is harder for firms in non-financial market services to remain in the

frontier, compared to those in manufacturing, and it is also more difficult for National than for EU frontier firms. The latter could indicate that it is easier for laggard firms to catch-up/exceed the National leaders than it is for the National frontier firms to approach the EU frontier firms.

6. Determinants of TFP growth and Catching up to the Frontier.

6.1 Analysis at country level using Amadeus database

There is much scope to boost productivity and reduce inequality by fostering the productivity of laggard firms within industries, via better diffusion of knowledge and better allocation of talent (OECD, 2015).[25] This is highly important for policy in countries with more skewed industrial structures where more firms linger far from technological excellence. Therefore, it is crucial to understand the factors determining the distance-to-frontier of laggard firms (both to the national or to the EU frontier).

With this aim in mind, we test how firms' characteristics (such as size –as measured by the number of employees–, age, capital and skilled labour –as measured by the average wage per worker) may influence a firm's relative position to the frontier.[26] We estimate a model with the distance to the frontier (or technology gap) on the left hand side and firms' characteristics and other controls (such as industry, country and year dummies) on the right hand side, such as:

$$\ln \frac{TFP_{icjt}}{TFP^{F}_{jt}} = \alpha + \beta' Z_{icjt} + \gamma' controls + \varepsilon_{icjt}$$

(6.1.1)

where subscript *i* denotes firm, subscript *c* country, subscript *j* a particular industry and *t* the time period. The distance to the frontier of a particular laggard firm is calculated as the log of the ratio of its own TFP over the average TFP of the frontier firms belonging to the same industry and for each particular year (and also from the same country in case of defining National frontiers).

The estimation results obtained by Ordinary Least Squares (OLS) are presented in Tables 6.1.1 and 6.1.2. All standard errors in Tables 6.1.1 and 6.1.2 are calculated as robust standard errors clustered by country-industry. All regressions are run only with non-frontier firm distances. Results were similar when also including frontier firms in the regressions, in which case the corresponding log value for the dependent variable was set to zero. Coefficient estimates for the regressors have the interpretation of elasticities since both the dependent variable and the regressors are in log form.

[25] As previously shown through the Theil index analysis in this report, analysing firms' TFP dispersion grouping firms by industries, the most relevant component is the within industry dispersion (with respect to the between industry dispersion component).

[26] Note that in this report we use wages as a proxy for skills. Although we acknowledge this is far from perfect, this is the best available measure in the Amadeus database for this purpose. We are also aware of papers that use information on wages to control for differences in the quality of the workforce (Gopinath *et al.*, 2015). Still, results obtained for this variable should be treated with some caution.

In Table 6.1.1 we use the definition of global (EU) frontier as the top 100 firms in terms of productivity per industry and year. Table 6.1.2 uses the definition of National frontier as the top 10 firms per industry, country and year. Alternatively, we also used the definition of frontiers as the 5% top firms in terms of productivity for EU (global) frontiers and National frontiers respectively, which provides very similar results. These results are not presented in the report but can be obtained from the authors upon request. In addition, given that the results reported in Tables 6.1.1 and 6.1.2 are very similar both qualitatively and quantitatively (that is, both in terms of the signs and magnitudes of coefficients), we discuss them simultaneously.

In Column (1) of Tables 6.1.1 and 6.1.2 we estimate the regression in expression (5.1.1) above. Wwe find that larger and more labour skilled firms decrease the distance to the frontier. For instance, a one per cent increase in employment reduces the distance to the frontier by 0.33 per cent. In addition, older firms and firms with higher capital increase the distance to the frontier.[27]

In Column (2) we include the same regressors and controls than in Column (1), but we also interact regressors with a dummy variable taking a value of 1 for the years 2008-2014 (post-crisis years). Hence, the first group of estimates in this column correspond to the reference category, pre-crisis years (2003-2007). We obtain the same patterns than in Column (1) for pre-crisis years. For post-crisis years, results indicate that larger and more labour skilled firms decrease the distance to the frontier (in a similar magnitude to that in the pre-crisis period). Also firms with higher capital increase the distance to the frontier (in a similar magnitude to that in the pre-crisis period when using EU frontiers, and less than in pre-crisis years when using national frontiers). Finally, in post-crisis years the role of firm age becomes smaller, which means that the effect of age turns out to be smaller in explaining firms' divergence to the frontier.

In Column (3) we include the same regressors and controls than in Column (1), but we also interact regressors with a dummy for non-financial Market Services and a dummy for Other Production. Hence, the first group of estimates in this column correspond to the reference category, Manufacturing. The same patterns of results as in Column (1) are obtained for manufacturing firms. For non-financial Market Services, there is both a stronger effect of firm size in explaining convergence to the frontier, and a stronger effect of capital and age in explaining divergence from the frontier. Furthermore, for Other Production, there is a stronger effect of firm size and age (although for age only when using EU frontiers) and a smaller effect of labour skill in explaining convergence to the frontier, but a stronger effect of capital in explaining divergence from the frontier.

[27] Conway *et al.* (2015) for New Zealand show the results of a logistic regression of frontier versus laggard firms within industries and find that frontier firms are more likely to be younger.

Finally, in Column (4), regressors are interacted both with dummies of pre-crisis and post-crisis years, and dummies corresponding to Manufacturing, non-financial Market Services, and Other Production. Hence, in this final column coefficients have a direct interpretation and do not need to be interpreted with regard to reference categories. For Manufacturing, we find that larger and more labour skilled Manufacturing firms decrease the distance to the frontier in both the pre and post-crisis periods (these effects being slightly stronger for the post-crisis period). However, both older firms and firms with higher capital increase the distance to the frontier in both periods. As for firms in non-financial Market Services, the role of size in decreasing the distance to the frontier is stronger during the pre-crisis years (although also relevant in the post-crisis period). Similarly, more labour skilled firms approach the frontier in both periods. In addition, age increases the distance to the frontier in pre-crisis years but is non-relevant for post-crisis years. As for capital, in both periods an increase in capital in non-financial Market Services justifies a higher divergence from the frontier. In summary, for firms in non-financial Market Services, we find in general that the effects of the regressors are slightly stronger during the pre-crisis period. Finally, for Other Production, larger and more labour skilled firms decrease the distance to the frontier in both the pre and post-crisis periods. However, older firms increase the distance to the frontier only in the post-crisis years. In addition, firms with higher capital increase the distance to the frontier in both periods. For Other Production we find that in general the effects of the regressors are somewhat stronger during the post-crisis period.

Summary and policy implications

From the analysis of the determinants of the TFP gap between frontier and non-frontier firms within industries we observe that, in general, larger and more labour skilled firms are closer to the frontier. In contrast, the older and more capital intensive firms are further away from the frontier. If we look at the results separately for manufacturing, non-financial market services and other production, we observe some different traits. Firstly, in manufacturing, the role of size and skills in fostering convergence to the frontier becomes stronger during the post-crisis years (2008-2014). Secondly, for services, the effect of variables explaining convergence or divergence from the frontier is stronger in the pre-crisis period (2003-2007); and thirdly for other production, the corresponding effect of variables is stronger in the post-crisis period. These general results are robust to the definition of frontiers as EU or National frontiers.

According to the general results in this and previous sections, frontier firms seem to be less capital intensive and, at the same time, more labour skilled than the non-frontier counterparts in their industry. These results, at least partly, can provide some support to the misallocation of capital hypothesis, where capital is allocated to less productive firms. If this was the case, the reallocation of capital towards more productive firms. could boost productivity further. Authors such as Olley and Pakes (1996) found that the deregulation of the telecommunications equipment industry was accompanied by a reallocation of capital which translated into significant productivity improvements.

Gopinath *et al.* (2015) use a firm-level dataset extracted from AMADEUS that covers manufacturing firms in Spain between 1999 and 2012 to document a deterioration in the efficiency of capital allocation across Spanish manufacturing firms. They develop a model of heterogeneous firms facing financial frictions, investment adjustment costs and risk in capital accumulation. Firms may choose in a period a capital stock that may not be optimal ex-post (after productivity is realized). Hence, misallocation of capital may arise even in an undistorted economy in which the capital stock is chosen under uncertainty and becomes productive in the next period. But also misallocation of capital may come from distortions such as financial frictions and investment adjustment costs. In their model, under the absence of borrowing constraints, risk in capital accumulation, and investment adjustment costs, there would not be misallocation of capital since more productive firms would choose higher capital stocks.

In the Spanish case, they demonstrate how a decline in the real interest rate (that is, a decline in the cost of capital) directs capital inflows to less productive firms under the presence of financial frictions (and adjustment costs). In particular, they show that the cross-sectional correlation between capital and firm productivity decreased over time, suggesting that capital inflows were increasingly directed toward less productive firms. Furthermore, as regards the correlation between firm productivity and the capital-labour ratio, they obtain that this correlation is positive (and low) in the data while negative (and close to zero) according to the model. They justify this difference between the data and the model by the fact that the model produces a stronger correlation between productivity and labour than observed in the data. In relation to this, note that in this report we find in our data that in general non-frontier firms are not only cross-sectionally smaller (as measured by employment), but are also relatively more affected by the crisis in terms of employment layoffs than their frontier counterparts (see subsections 6.2.1 to 6.2.3 in this report). This, together with the fact that capital may be costly to reduce in an economic downturn (for instance, because of indivisibilities, sunk costs and adjustment costs), may also contribute to the explanation regarding why non-frontier firms seem to be more capital intensive than frontier ones.

Gopinath *et al.* (2015) also present in their paper analysis for some of the countries included in this report, namely Italy (1999-2012), Portugal (2006-2012), Germany (2006-2012), and France (2000-2012). They find that similarly to Spain, there is also a decline in productivity very likely related to capital misallocation in Italy and Portugal. Results for France are less robust. Finally, they do not observe a declining trend in Germany.

Dias *et al.* (2014) find that allocative efficiency in the Portuguese economy strongly deteriorated during the 1996-2011 period and that there was an important role for capital distortions. As they mention: *"The list of potential distortions that may affect firms in the economy is long and varied. For instance, non-competitive banking systems may offer favorable interest rates on loans to some producers based on non-economic factors, leading to a misallocation of credit across firms. Or, financial institutions may be unable or unwilling to provide credit to firms that are highly productive but have no credit history or insufficient guarantees, preventing these firms from expanding their activities*.

In contrast, some small or medium-sized firms may have access to cheaper capital through special lines of credit. Governments may offer subsidies, special tax deals or lucrative contracts to specific producers. Enforcement activity of tax collection may focus on large and more productive firms implying a subsidy to small potentially less productive ones". In summary, the authors provide examples that favour some firms relative to others, independent of their relative efficiency. In this direction, they also add that the increasing role of capital distortions may indicate that the financial sector might have contributed to the survival of relatively inefficient firms.

Overall, the evidence on the misallocation of capital points towards the need to implement policies that stimulate competition and a more competitive banking system, with a reduction in informational asymmetries between lenders and borrowers (that generate borrowing constraints), analyzing carefully government subsidies or special tax deals to some producers (when, for instance, enforcement activity of tax collection is focused on large and more productive firms), and also the implementation of policies affecting the risk in capital accumulation (reducing uncertainty for firms' investment decisions) and alleviating investment adjustment costs.

Table 6.1.1 Distance to the EU Frontier (top 100 most productive firms)

	(1)	(2)	(3)		(4)
VARIABLES	$\ln\frac{TFP_{icjt}}{TFP^{F}_{jt}}$	$\ln\frac{TFP_{icjt}}{TFP^{F}_{jt}}$	$\ln\frac{TFP_{icjt}}{TFP^{F}_{jt}}$	VARIABLES	$\ln\frac{TFP_{icjt}}{TFP^{F}_{jt}}$
Employment	0.332***	0.341***	0.239***	Employment Man. 2003-2007	0.209***
	(0.009)	(0.013)	(0.005)		(0.007)
				Employment Man. 2008-2014	0.263***
					(0.005)
Age	-0.0160***	-0.0279***	-0.0106***	Age Man. 2003-2007	-0.0123***
	(0.004)	(0.007)	(0.003)		(0.004)
				Age Man. 2008-2014	-0.0112***
					(0.003)
Capital	-0.338***	-0.347***	-0.249***	Capital Man. 2003-2007	-0.234***
	(0.008)	(0.011)	(0.004)		(0.005)
				Capital Man. 2008-2014	-0.261***
					(0.003)
Wage	0.873***	0.875***	0.877***	Wage/worker Man. 2003-2007	0.858***
per worker	(0.013)	(0.016)	(0.014)		(0.014)
				Wage/worker Man. 2008-2014	0.892***
					(0.014)
Employment times			0.124***	Employment Serv. 2003-2007	0.396***
Dummy Services			(0.011)		(0.014)
				Employment Serv. 2008-2014	0.340***
					(0.012)
Age times			-0.0118*	Age Serv. 2003-2007	-0.0321***
Dummy Services			(0.006)		(0.009)
				Age Serv. 2008-2014	-0.00786
					(0.006)
Capital times			-0.126***	Capital Serv. 2003-2007	-0.397***
Dummy Services			(0.011)		(0.014)
				Capital Serv. 2008-2014	-0.360***
					(0.009)
Wage/worker times			-0.00235	Wage/worker Serv. 2003-2007	0.893***
Dummy Services			(0.013)		(0.015)
				Wage/worker Serv. 2008-2014	0.861***
					(0.019)
Employment times			0.0724***	Employment Other 2003-2007	0.277***
Dummy Other			(0.013)		(0.018)
				Employment Other 2008-2014	0.357***
					(0.012)
Age times			0.0215*	Age Other 2003-2007	-0.0128
Dummy Other			(0.011)		(0.013)
				Age Other 2008-2014	-0.0108**
					(0.005)
Capital times			-0.0828***	Capital Other 2003-2007	-0.326***
Dummy Other			(0.008)		(0.009)

				Capital Other 2008-2014	-0.348***
					(0.007)
Wage/worker times			-0.0467***	Wage/worker Other 2003-2007	0.814***
Dummy Other			(0.016)		(0.015)
				Wage/worker Other 2008-2014	0.878***
					(0.022)
Employment times		-0.0141			
Dummy 2008-2014		(0.013)			
Age times		0.0199**			
Dummy 2008-2014		(0.008)			
Capital times		0.0157			
Dummy 2008-2014		(0.010)			
Wage/worker times		-0.00415			
Dummy 2008-2014		(0.022)			
Constant	-3.505***	-3.453***	-3.808***		-3.761***
	(0.068)	(0.076)	(0.057)		(0.055)
Observations	2,244,987	2,244,987	2,244,987		2,244,987
R-squared	0.821	0.821	0.826		0.831

Notes: All specifications include industry, country and year dummies. Robust standard errors clustered by country-industry in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6.1.2. Distance to the National Frontier (top 10 most productive firms)

	(1)	(2)	(3)		(4)
VARIABLES	$\ln\frac{TFP_{icjt}}{TFP^{F}_{jt}}$	$\ln\frac{TFP_{icjt}}{TFP^{F}_{jt}}$	$\ln\frac{TFP_{icjt}}{TFP^{F}_{jt}}$	VARIABLES	$\ln\frac{TFP_{icjt}}{TFP^{F}_{jt}}$
Employment	0.331***	0.341***	0.239***	Employment Man. 2003-2007	0.216***
	(0.009)	(0.012)	(0.005)		(0.007)
				Employment Man. 2008-2014	0.259***
					(0.005)
Age	-0.0145***	-0.0258***	-0.00774***	Age Man. 2003-2007	-0.0118***
	(0.003)	(0.006)	(0.003)		(0.004)
				Age Man. 2008-2014	-0.00753**
					(0.003)
Capital	-0.337***	-0.349***	-0.249***	Capital Man. 2003-2007	-0.241***
	(0.008)	(0.011)	(0.004)		(0.005)
				Capital Man. 2008-2014	-0.258***
					(0.004)
Wage	0.868***	0.873***	0.876***	Wage/worker Man. 2003-2007	0.861***
per worker	(0.013)	(0.014)	(0.014)		(0.015)
				Wage/worker Man. 2008-2014	0.885***
					(0.015)
Employment times			0.121***	Employment Serv. 2003-2007	0.388***
Dummy Services			(0.011)		(0.014)
				Employment Serv. 2008-2014	0.340***
					(0.011)
Age times			-0.0112*	Age Serv. 2003-2007	-0.0308***
Dummy Services			(0.006)		(0.009)
				Age Serv. 2008-2014	-0.00543
					(0.005)
Capital times			-0.123***	Capital Serv. 2003-2007	-0.393***
Dummy Services			(0.012)		(0.014)
				Capital Serv. 2008-2014	-0.358***
					(0.009)
Wage/worker times			-0.00773	Wage/worker Serv. 2003-2007	0.884***
Dummy Services			(0.014)		(0.015)
				Wage/worker Serv. 2008-2014	0.854***
					(0.020)
Employment times			0.0790***	Employment Other 2003-2007	0.296***
Dummy Other			(0.013)		(0.015)
				Employment Other 2008-2014	0.348***
					(0.014)
Age times			0.00868	Age Other 2003-2007	-0.00401
Dummy Other			(0.008)		(0.011)

				Age Other 2008-2014	-0.0192***
					(0.006)
Capital times			-0.0852***	Capital Other 2003-2007	-0.337***
Dummy Other			(0.008)		(0.010)
				Capital Other 2008-2014	-0.340***
					(0.008)
Wage/worker times			-0.0434***	Wage/worker Other 2003-2007	0.822***
Dummy Other			(0.015)		(0.017)
				Wage/worker Other 2008-2014	0.860***
					(0.021)
Employment times		-0.0150			
Dummy 2008-2014		(0.011)			
Age times		0.0187***			
Dummy 2008-2014		(0.007)			
Capital times		0.0205**			
Dummy 2008-2014		(0.008)			
Wage/worker times		-0.00980			
Dummy 2008-2014		(0.017)			
Constant	-3.041***	-2.988***	-3.349***		-3.295***
	(0.068)	(0.073)	(0.057)		(0.056)
Observations	2,215,895	2,215,895	2,215,895		2,215,895
R-squared	0.820	0.820	0.825		0.828

Notes: All specifications include industry, country and year dummies. Robust standard errors clustered by country-industry in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

6.2. Analysis using EFIGE firm database: The role of public policies

After the collapse of the financial markets in the period between 2007 and 2008, leading to a major global recession, there has been increasing interest in understanding the conditions that enable firms to better accommodate demand shocks and economic fluctuations. In Europe, concerns about firms' ability to recover from the crisis are motivated by some structural characteristics that may make European companies more vulnerable, for example, their inherently small size, their higher specialisation in mature and traditional production, and a moderate or low technological base. Altomonte et al. (2013) find that those firms that engaged more intensively in innovation and internationalisation activities suffered considerably less from the collapse of the financial markets.

Altomonte et al. (2016) investigate the determinants of productivity in a large sample of manufacturing firms from seven EU countries (EFIGE database), in a period immediately after the crisis. These authors found a robust positive link between the exporting status of the firm and its productivity performance, but a negative association between the age and financial constraints faced by businesses. Recognising the distinction between levels and growth rates, Foster et al. (2013) show that productivity growth between 2008 and 2009 was systematically higher for the most productive firms; these were firms that had, on average, a larger proportion of highly educated workers and a greater commitment to knowledge generating activities (primarily R&D-based). Aiello and Ricotta (2016) study the determinants of productivity dispersion in the EU manufacturing sector. They find that about 85% of the heterogeneity in TFP performance can be explained by company features (size, type of management, group affiliation, innovation and human capital); the remaining 15% depends more on idiosyncratic localisation factors, which are either country-specific or region-specific (10% and 5%, respectively).

Verschelde et al. (2016) apply a semi-parametric stochastic frontier technique to EU company-level data to investigate the portion of TFP growth that can be attributed to efficiency changes and that which can be attributed to the narrowing of the technology gap (between 2002 and 2009). Their results corroborate earlier evidence on the lack of TFP convergence within the EU. The increase in productivity dispersion does not appear to be strictly related to the depth of the crisis. The implications are broader, and suggest that laggards may be persistently unable to achieve the efficiency levels of frontier firms and that technology transfers from the latter may not be sufficient to promote productivity growth far from the frontier. The technological capabilities and human capital endowments of the laggards may not maximise the process of technology transfers from the frontier, i.e. absorptive capacity, an issue popularized by Cohen and Levinthal (1989); Griffith et al. (2004), Van der Wiel (2008).[28]

This may open avenues for policy initiatives that specifically target firms lagging behind the leaders. The nature and extent of these policies could vary in relation to their distance to

[28] Rincon-Aznar et al. (2014) report firm-level evidence on the role of absorptive capacity in technologically turbulent periods characterised by the advent of new technologies.

the frontier (i.e. the productivity gap). Consistent with this pattern, Andrews et al. (2015) analyse the impact of a large array of public policies on firm productivity growth, documenting that: (i) product market liberalisation has significant benefits very close and very far from the frontier, whilst firms in the middle of productivity distribution are un-affected by pro-competition policies; (ii) strong labour protection is more harmful the wider is the productivity gap; (iii) university-firm research collaborations are particularly useful for laggard firms.[29] The latter paper shows that global frontier technologies can have a widespread diffusion amongst laggards once they have been adapted to country-specific circumstances by the national frontier firms. This observation could explain the rapid diffusion of the newest technologies across countries but the slow implementation within countries (Comin and Mestieri 2013).

The severity of the crisis has raised concerns about which tools governments can exploit to mitigate the adverse effects of the fall of the markets and to rapidly (and stably) restore the growth process. Much of the attention of policy-makers has been devoted to the regulatory setting and, especially, the need to reform the financial market (OECD 2012, ch. 1). However, the effects of such regulatory interventions are only likely to be felt in the long-run. Hence, from a policy-making perspective, there is a need to identify which policy instruments are capable of increasing firm resistance to the crisis and stimulating their productivity performance in the short and the medium run. Brautzsch et al. (2015) study the macroeconomic effects of an R&D subsidy programme granted in Germany during the crisis period. Using input-output multipliers, they show that the counter-cyclical effects of direct funding to research are quantitatively important in terms of employment, value added and income outcomes. Microeconomic effects of the greater base of R&D subsidies dispensed to German companies during the crisis of 2008-10 have been studied by Hud and Hussinger (2015). Prammer (2011) presents a review of the effects of tax discipline on economic growth and discusses how the recent crisis has induced the EU member states to make the fiscal setting more homogenous across countries and become more conducive to growth. In this regard, using data from 11 EU countries between 1996 and 2005, Gemmell et al. (2016) document that, for small firms, higher rates of corporate taxation affect firm productivity convergence by reducing the post tax returns to investments.

6.2.1 Analytical framework

We study the impact of a large set of public policies on productivity growth of EU firms using a harmonized dataset for seven European countries that provides rich company-level information. More specifically, our analysis relates productivity growth between 2008 and 2014 to a set of structural characteristics of the companies as observed at the beginning of the sample period (2008).

[29] Earlier evidence on the linkage between product market regulations on productivity growth within a distance-to-frontier framework can be found in Arnold et al. (2008). See Aristei et al. (2015a) and (2015b) for an assessment of the factors stimulating R&D engagement and technological collaborations, based on EFIGE data.

Following the latest developments in the firm-level productivity literature (see for instance Syverson 2011), we implement a regression analysis in which productivity growth at the firm level is modeled as a function of: (i) the distance to the EU (global) frontier; and (ii) the distance to the national frontier, and (iii) the distance between national and global frontier companies. The distance-to-frontier framework allows us to analyze whether the impact of public policies on productivity growth is direct or rather indirect, i.e. as facilitating the catch-up process of the laggards, for example by enabling technology transfers from the frontier. In order to identify the impact of public policies we control for a large set of firm characteristics (technological capabilities, education level of the workforce, etc.) and contextual factors (the existence of geographical knowledge spillovers, etc.).

Our baseline specification explains productivity advancements of the firm as a result of productivity growth experienced by the leading firms, that move the frontier outwards, the distance between the frontier and laggards (in productivity terms) as well as the technology transfers enabled by certain firm characteristics (Griffith et al., 2004)

$$\Delta \ln TFP_i^{2008-2014} = \alpha_1 \Delta \ln TFP_{G,F}{}^{2008-2014} + \alpha_2 GAP_{G,i}^{2008} +$$

$$+\alpha_3 Public\_support_i^{2008} + \alpha_4 Public\_support_i^{2008} * GAP_{G,i}^{2008} + \epsilon_i \quad (6.2.1)$$

where *i* denotes laggard firms and *F* denotes the frontier firm; productivity growth is measured as the average annual rate of change in total factor productivity between 2008 and 2014.

As is standard in this branch of the literature, we assume the existence of a unique frontier at the EU level for each of the thirteen two-digit manufacturing sectors covered by the dataset. Therefore, $GAP_{G,i}$ refers to the distance of a typical firm *i* to the global frontier firm as measured in 2008, $GAP_{G,i}=\ln(TFP_G/TFP_i)$[30]. In essence, frontier firms are identified as those with the highest levels of TFP, measured at the beginning of the sample period. Laggard firms will be identified as those falling behind the frontier in terms of TFP levels.

As a key contribution of the analysis, the model specification is designed to verify whether firms that benefited from some types of public support (direct funding/tax credit for machinery investments, R&D, export, etc.) experienced greater productivity outcomes and, if any, the impact of public policies changed with the firm distance to technological frontier. The latter evidence would indicate that public policies have non-linear effects on productivity growth, which constitutes a largely unexplored issue in the literature[31]. As we detail below, we consider a wide range of policy instruments and seek to ascertain which of these measures is more conducive of technology advances and productivity improvements in periods of market turbulence.

[30] Industry subscripts omitted for sake of simplicity.
[31] See Minniti and Venturini (2015) for an industry-level analysis on this type of effects associated with fiscal incentives to R&D.

We refine the baseline specification by breaking the gap effect into two components ($GAP_{G,i}$): that associated with the convergence of the laggards towards the national frontier ($GAP_{N,i}$), and that reflecting the distance of the national frontier firm to the global productivity frontier ($GAP_{G,N}$). Put differently, the gap effect is disentangled into a between-country and a within-country effect. The extended version of the distance-to-frontier specification is therefore shaped as follows (see Andrews et al. 2015, p. 24):

$$\Delta \ln TFP_i^{2008-2014} = \alpha_1 \Delta \ln TFP_{G,F}{}^{2008-2014} + \alpha_2 \Delta \ln TFP_{N,F}{}^{2008-2014} + \alpha_3 GAP_{G,N}^{2008} + \alpha_4 GAP_{N,i}^{2008} +$$

$$+\alpha_5 Public\_support_i^{2008} + \alpha_6 Public\_support_i^{2008} * GAP_{G,N}^{2008} * + \alpha_7 Public\_support_i^{2008} * GAP_{N,i}^{2008} +$$

$$+Controls_i^{2008} + \epsilon_i. \quad (6.2.2)$$

$GAP_{G,N}$ denotes the productivity distance (in logs) between the national frontier (denoted by N) and the global frontier (denoted by G), taken at 2008. As introduced above, the global frontier is identified as the firm with the highest TFP level in each industry of the EFIGE sample, $GAP_{G,N}$= ln ($TFP_{G,F}/TFP_{N,F}$).[32]

$GAP_{N,i}$ indicates the productivity distance between a domestic firm and the national frontier firm, $GAP_{N,i}$= ln ($TFP_{N,F}/TFP_{i,}$), measured at 2008. α_1 and α_2 capture the effect of TFP growth at the global and the national frontier on the productivity performance of followers. When market leaders move the productivity frontier outwards this creates opportunities for further TFP increases in laggard firms. α_3 and α_4 show whether firms far from the global and national frontier experience faster or slower TFP growth. α_5 captures the direct impact of public policies, whilst α_6 and α_7 inform whether firms that benefited from public support were able to growth faster (or slower) when they were far (or close) to the global and the national frontier.

This specification rationalizes the idea that the diffusion of global technologies within countries is channeled through the adoption (and adaptation) by the national leaders, which make these technologies available to domestic companies. This part of the analysis aims to contribute to the emerging literature investigating the link between the productivity performance of laggards and the diffusion of existing technologies from national frontier firms.

Controls include sector and country-specific fixed effects, a large set of firm characteristics (age, size, management, ownership structure, group affiliation, etc.) and indicators of market conditions prevailing between 2008 and 2009 (demand conditions, etc.), to be detailed below. Since our main purpose is to identify whether public policies have direct productivity effects, and/or enable technology transfers from the frontier, our empirical specification includes interactions between the gap terms and other firm-specific

[32] To neutralize the effect of outliers, the overall productivity distribution has been censored at the 95 percentile (366 obs). We obtain similar results if we adopt a stricter censoring of the distribution, i.e. at the 99 percentile (74 obs).

characteristics found in the literature to promote technology transfers, primarily workers' education and R&D input (Griffith et al. 2004, Madsen et al 2010). Accounting for these factors is crucial to exclude the possibility that the impact estimated for the public policy variables is biased because of omitted variables' problems.

The cross-sectional nature of the survey data, which are available only for the period 2008-09, prevent us from properly accounting for idiosyncratic firm fixed effects in the specification introduced above. If the explanatory variables are correlated with time-invariant, unobserved firm characteristics and these are not accounted for in the analysis, estimation may yield biased parameters. However, in the empirical analysis below, we are able to partly circumvent this risk by estimating a panel data version of Eqs. (6.2.1) and (6.2.2), based on yearly observations from 2008 and 2014, but excluding policy variables and firm-level controls. Such panel estimates will hence be compared with cross-sectional estimates of Eqs. (6.2.1) and (6.2.2) so as to exclude possible misspecification bias.

In identifying the direct or mediated effects of public support we take account of a range of firm characteristics. We account for some structural features: firm size (in terms of employment brackets, e.g. "with less than 50 employees, between 50 and 250, over 250"), age ("less than 6 years old", "between 6 and 20 years", and "over 20 years"), type of ownership and management style (e.g. family control, internal or external management), group affiliation/position (e.g. national or foreign, headquarter or controlled), mergers and acquisition (e.g. newly incorporated firms, nature of main shareholders), occupational structure (e.g. share of graduates, share of workers under training,), financial factors (i.e. the extent to which firms depend on external finance, the number of banks, etc.), degree of internationalisation (e.g. FDI, the exporting status), cyclical conditions (e.g. drop in sales, investment and innovation). As productivity growth and technology transfers are commonly driven by innovation and R&D efforts, we pay particular attention to this dimension of firm activity. We explore whether the firm introduced product or process innovation over the period under assessment, whether it engaged in formal and routinised research tasks (i.e. whether the firm undertook R&D projects) and the intensity of the company engagement in these activities (measured either as the share of research expenses over company sales or the employment share accounted for by researchers). Furthermore, in order to gauge the technological capabilities of the firm we look at whether the company patented innovations during the period of analysis and whether it made use of other IPRs tools such as industrial design, copyright and trademarks. We also consider a more general indicator of innovation outcomes consisting of the percentage share of sales that can be ascribed to innovative products brought to the market.

A crucial issue in this type of analysis is understanding whether productivity growth of laggards is driven by technology transfers from the frontier, or rather is induced by diffusion of technological knowledge ornew business practices across firms localised in a given area. Proximity factors usually take the form of Marshallian external economies and knowledge spillovers. We assess the former effect by looking at the sectoral distribution of companies located in the same administrative area. The influence of knowledge spillovers is investigated by looking at the number of innovating firms in a particular region, either defined in terms of the firm status of R&D performer or of patentee, and also in terms of

the intensity of R&D expenses over total sales. By exploiting information on firm location (at NUTSII level) we will therefore be able to distinguish both types of external effects associated with geographic proximity. Accounting for other forms of regional effects (public infrastructure, institutional quality, etc.) is beyond the scope of this study, due to a lack of suitable administrative data. The bulk of regional variables will be defined in terms of the mean values (peer effects).

Firms are classified into thirteen industry categories, corresponding to two-digit codes of the NACE Rev. 1 classification. We identify as the frontier the firm with the highest level of productivity in each of these groupings at the level of the overall EU (i.e. the seven countries under assessment) or for each single nation. The former will be denoted as *global frontier firm*, the latter will be referred to as *national frontier firm*. The full list of the variables (and relative description) that are used in the regression is displayed in Table A.12 of the Appendix of the present study.

6.2.2. Descriptive statistics

Table 6.2.1 reports the value of the industry productivity gap calculated as a simple mean over the total sample of firms, looking at different percentiles of the distribution. More specifically, the table displays the productivity level of laggards compared to the industry frontier in the EFIGE sample, which we consider the global frontier in our study. The latter is benchmarked to 100. The results suggest that the productivity distribution is largely skewed. Taken as a whole, the productivity of the typical (average) firm was 25% of that of the leader. Slightly higher values are found for firms from Spain, France, Germany and Hungary (26-27%). The results for the latter country may be reflecting the fact that large firms are significantly over-represented in the EFIGE sample. This is also the case for Austria (see Forster et al. 2013).

A clearer picture of productivity dispersion arises when looking at the gap at different points of the distribution. For the overall sample, the median firm is at 22% of the productivity level achieved by the frontier firm, with Austria and the UK having a much lower median value (18-19%).

At the 75th percentile, non-frontier firms have productivity levels 31% of that of the global leader. At the 95th percentile, the productivity gap narrows significantly but continues to be important (50%).

Table 6.2.1. Productivity gap to the global frontier (Frontier=100)

	Mean ($GAP_{G,i}$)	p5	p25	p50	p75	p95
Austria	19	5	12	19	24	37
France	26	11	18	23	31	50
Germany	26	10	17	23	31	55
Hungary	26	10	17	22	32	54
Italy	24	9	16	21	29	46
Spain	27	11	18	24	32	52
UK	23	6	13	18	27	53
Total	**25**	**10**	**17**	**22**	**31**	**50**

NOTE: statistics by country at 2008.

Table 6.2.2 displays the productivity gap from the global frontier distinguishing firms by sector. It shows that productivity dispersion is very heterogeneous across industries. Manufacture of Coke (cat. 23) denotes a relatively more homogenous pattern as the productivity level of the average firm amounts to 57% that of the frontier firm. Productivity distribution within Paper (cat. 21t22) and Food and beverages (cat. 15t16) look similar as either the mean or the median productivity are around 34-37% and 31% of the value achieved by the global leader.

Table 6.2.2. Productivity gap to the global frontier (Frontier=100)

ind	Mean ($GAP_{G,i}$)	p5	p25	p50	p75	p95
15t16	34	17	25	31	40	62
17t19	17	5	10	15	21	38
20	15	8	12	14	17	25
21t22	37	16	24	31	43	100
23	57	13	38	52	86	100
24	27	13	20	25	31	45
25	19	9	14	17	22	31
26	32	14	22	30	38	55
27t28	24	12	18	22	28	43
29	23	12	18	22	27	39
30t33	29	8	19	26	37	56
34t35	30	9	23	29	36	54
36t37	18	9	14	17	20	30
Total	**25**	**10**	**17**	**22**	**31**	**50**

NOTE: statistics by industry at 2008.

Next to the average gap from the global (EU-EFIGE) frontier ($GAP_{G,i}$), Table 6.2.3 contains information, for each country, on the distance between the national and the global frontier ($GAP_{G,N}$) and the average gap to the national leaders ($GAP_{N,i}$). On average, the

productivity level of the national leader amounts to 84% of the global frontier whilst, as expected, the average distance of the laggards to national leaders is much larger.

Firms lagging behind reach only 32% of the productivity level of the domestic frontier in their sector of activity. Notably, when national leaders stay closer to the global frontier, the within-country dispersion of productivity levels is much wider. In Spain and France, industry leaders closely follow the productivity pattern of the EU leading firms (89-90%). However, within country, the average gap of laggards is particularly pronounced and these firms reach productivity levels considerably lower than national leaders (30-31%). Comparable distances to national leaders are shown by Italian firms. At the other end of the distribution we find Austria, but estimates for this country should be interpreted with caution given the low number of observations in the EFIGE sample and the representativeness problems of this national sample.

Table 6.2.3. Productivity gap between national and global frontier, and from national frontier (Frontier=100)

	$GAP_{G,i}$	$GAP_{G,N}$	$GAP_{N,i}$
Austria	19	23	86
France	26	89	30
Germany	26	67	40
Hungary	26	63	47
Italy	24	85	30
Spain	27	90	31
UK	23	62	43
Total	**25**	**84**	**32**

NOTE: statistics by country at 2008.

Table 6.2.4 breaks down, by industry, the gap to the global frontier into the component associated with the gap of national leaders to the EU frontier firms and the component associated with the gap of laggards to national frontier firms. Interestingly, the table shows that there is wide dispersion across and within countries in low-tech industries such as Textiles (15t16) and Basic metals and Fabricated metal products (27t28). In such sectors, laggards reach only 25-26% of the productivity levels of national leaders. Within-country dispersion is narrower in Transport equipment, as the average value of productivity levels of laggards amounts to 42% of that of the leading companies at country level.

Table 6.2.4. Productivity gap between national and global frontier, and from national frontier (Frontier=100).

	$GAP_{G,i}$	$GAP_{G,N}$	$GAP_{N,i}$
15t16	34	99	35
17t19	17	72	25
20	15	52	32
21t22	37	100	37

23	57	86	65
24	27	86	33
25	19	59	39
26	32	91	36
27t28	24	97	26
29	23	80	32
30t33	29	80	37
34t35	30	77	42
36t37	18	67	33
Total	**25**	**84**	**32**

NOTE: statistics by industry at 2008.

Table 6.2.5 provide details on the key characteristics of frontier firms that can be concluded from the EFIGE survey. The table compares the value found for the industry frontier at the global level of the EU and those for national frontier firms. Further details on firm characteristics are provided in Table A.12 of the Appendix. Table 6.2.5 illustrates that all types of frontier firms receive some benefit from public support. In particular, 32% of the EU leading firms benefit from public support for capital investment and, almost all (99%), undertake R&D projects in collaboration with public research centres and Universities. A much lower proportion of such companies access public support for export or had public sector participation (2.5%). It should be noted that Austria diverges from the global pattern with a considerably higher proportion of national leading companies accessing public support for R&D (66%). The caveats discussed above concerning the representativeness of the national sample also apply here.

Table 6.2.5. Key characteristics of global and national frontier firms.

	Global	***National frontier firms***						
Description	***Frontier***	*AT*	*FR*	*DE*	*HU*	*IT*	*ES*	*UK*
Policy variables								
Firms benefiting from some public support	1.000	0.889	0.933	1.000	1.000	0.957	1.000	0.938
Firm benefiting from public support to investment	0.316	0.333	0.000	0.105	0.167	0.087	0.488	0.125
Firm benefiting from public support to R&D	0.228	0.667	0.133	0.000	0.083	0.174	0.293	0.125
Firm benefiting from public support to export	0.025	0.111	0.000	0.053	0.000	0.000	0.024	0.000
Firms undertaking R&D with public R&D centres/Univ.	0.987	0.778	0.867	1.000	1.000	0.913	1.000	0.875
Firms with shared held by public sector	0.025	0.111	0.000	0.000	0.000	0.000	0.024	0.063
Firm controls used in the main specifications								
Firm aged less than 6 years	0.051	0.000	0.067	0.053	0.083	0.130	0.000	0.000
Firm aged between 6 and 20	0.392	0.111	0.067	0.263	0.750	0.391	0.488	0.375
Firm aged 20 and over	0.557	0.889	0.867	0.684	0.167	0.478	0.512	0.625
Firm with less than 50 employees	0.481	0.000	0.800	0.211	0.500	0.739	0.561	0.438
Firm with between 50 and 250 employees	0.278	0.333	0.200	0.474	0.167	0.217	0.171	0.375
Firm with 250 employees and over	0.241	0.667	0.000	0.316	0.333	0.043	0.268	0.188
Firm belonging to a national group	0.304	0.444	0.267	0.211	0.167	0.304	0.244	0.250
Firm belonging to a foreign group	0.203	0.333	0.333	0.474	0.417	0.087	0.268	0.438
Family controlled firm	0.494	0.556	0.467	0.632	0.333	0.652	0.390	0.313
Firm experiencing a marked sales reduction	0.646	0.667	0.867	0.579	0.667	0.739	0.707	0.625
Graduated workers/Total employment	0.075	0.027	0.113	0.035	0.189	0.062	0.073	0.021
Firm undertaking R&D projects	0.544	0.889	0.533	0.421	0.417	0.565	0.488	0.625
Firm exporting abroad from the home country	0.684	0.889	0.400	0.789	0.917	0.522	0.732	0.688
Physical investment/Sales	0.093	0.152	0.042	0.103	0.117	0.085	0.108	0.041

Source: EFIGE and authors' calculations.

Frontier firms are on average older than laggards. If we restrict attention to global leaders, it can be observed that 40% of these firms are aged between 6 and 20 years, and 56% are more than 20 years old. Global leaders are small companies (48% have less than 50 employees), who have established their market position because of a very high level of production efficiency. A large proportion of global frontier firms are affiliated to the business group; more precisely, 30% belong to a national group, 20% to a domestic group. Consistent with this, most companies are family controlled (50%). The fall of the market and the resulting drop in sales was severe for over 64% of global frontier firms. Despite this, these companies did not dismiss R&D projects and continued to sell their products abroad (54% and 68% of the total, respectively). The intensity of investment in physical assets was around 9.3% of firm sales in the period under examination, whilst the proportion of graduate workers in the total workforce amounted to 7.5%.

At the national level, there are some important differences in the characteristics of frontier firms compared to the pattern drawn for the leading firms of the EU (global frontier). The proportion of old firms is much higher in Austria and France (89% and 87%) against 56% at the global level. Hungary stands out for a larger fraction of national leaders aged between 6 and 20 years. The relative younger profile of these companies reflects the relative recent transition of this country to the open market economy that occurred in the early 1990s. National leaders are predominantly small-sized companies in France and Italy (80% and 74% of the leading companies). Appreciably above the mean is the proportion of large-sized national leaders in Austria.[33] In France, Spain and Italy, the percentage share of frontier firms that experienced a marked drop in sales between 2008 and 2009 is above the mean. The rate of investment in physical assets is relatively low in the UK and France in which these expenses amount to 4% of company sales. In the UK, national frontier firms do not appear particularly human capital intensive (as only 2.1% of the total workforce has a degree), in contrast to France and Hungary (where this stood at 11.3% and 18.9% respectively). The proportion of exporting firms among frontier firms is relatively high in Austria, Germany, Spain and Hungary.

[33] This finding is in line with Eurostat Structural Business statistics as indicating that, for 2010, the share of large firms in the universe of Austrian companies is above the EU-27 average (0.33% against 0.20).

6.2.3. Regression results

The econometric analysis starts with a baseline set of regressions for eqs. 6.2.1 and 6.2.2, excluding controls and policy variables. These specifications are estimated with panel data methods by exploiting annual data on TFP, which are available from the latest (restricted) release of the EFIGE dataset (see Table 6.2.6). These estimations are based on annual data between 2008 and 2014; accordingly, frontier firms are identified on an annual basis and hence change over time. All estimates use sampling weights and robust standard errors. Panel estimates include individual fixed effects to capture the impact of time-invariant firm heterogeneity, as well as country and industry dummies to capture the effect of common shocks (business cycle, etc.).

Table 6.2.6. TFP growth and distance to frontier: panel estimates (annual data 2008-14).

	(1)	(2)	(3)	(4)
	Global frontier		Global and national frontier	
Δ ln $TFP_{G,F}$	0.043***	0.041***	0.037***	0.036***
	(0.003)	(0.003)	(0.003)	(0.003)
$GAP_{G,i}$	-0.807***	-0.796***		
	(0.015)	(0.016)		
Δ ln $TFP_{N,F}$			0.004	0.006**
			(0.003)	(0.003)
$GAP_{G,N}$			-0.655***	-0.644***
			(0.020)	(0.021)
$GAP_{N,i}$			-0.819***	-0.808***
			(0.015)	(0.016)
	Panel	Panel (restricted)	Panel	Panel (restricted)
Observations	38,450	33,413	36,850	32,052
R-squared	0.442	0.439	0.449	0.447
N. of firms	8,928	7,081	8,825	7,037

Notes: Fixed Effects estimation without controls and policy variables. Estimates based frequency weights. Robust standard errors in parentheses. All estimates include firm fixed effects, and country, industry and year dummies. Δ ln $TFP_{G,F}$= TFP growth of the global frontier. $GAP_{G,i}$= productivity gap to the global frontier. Δ ln $TFP_{N,F}$= TFP growth of the national frontier. $GAP_{G,N}$= productivity gap between national and global frontier. $GAP_{N,i}$= productivity gap to the national frontier.

Cols. (1) and (2) show estimates of Eq. 6.2.1 in which we assume that TFP growth depends on productivity growth of the global frontier and on the gap of laggards to productivity levels of the EU leading firm. Col. (1) considers all firms included in the latest release of the EFIGE's dataset (8,928 firms for a total of 38,450 year observations). Col. (2) restricts the regression to those firms that will be considered in the cross-sectional estimates (7,081 firms for a total of 33,413 year observations). Panel estimates show that, in Europe, firm productivity growth is significantly driven by global leaders which, by increasing their production efficiency, or moving the production possibility frontier outward, create room for productivity growth for firms falling behind. A one-percentage point increase in the rate of TFP growth of the frontier firm at the EU level induces a 0.043% increase in productivity growth of the laggards. However, in line with the evidence surveyed above that documents the increasing productivity dispersion in most OECD countries, we observe that productivity growth is lower for those firms with a larger distance to the global frontier (around -0.80). In cols. (3) and (4), we refine the analysis by decomposing the distance to the frontier term ($GAP_{G,i}$) into a term associated with the distance of the laggards to national leaders ($GAP_{N,i}$) and a term associated with the distance of national leaders to the global frontier ($GAP_{G,N}$); this specification also accounts for productivity growth of national frontier ($\Delta \ln TFP_{N,F}$). These estimates show that the major effect of productivity growth at the frontier is still induced by global leaders (0.036-0.037) and national leaders play only a minor role (0.006 in col. 4). Decomposing the gap term into between- and within-country effects, the latter appears moderately larger (-0.808 vs -0.644). In other words, laggards struggle more to reach the productivity levels of the national frontier than national leaders do in order to catch up to the global frontier.

Next, we present cross-sectional estimates of our empirical model. Our main purpose is twofold. First, we seek to understand whether (and which) policy instruments have *direct effects* on productivity growth and, second, whether these policy measures also enable technology transfers between frontier and lagging firms (*indirect effects*).[34] The former effect is identified by the coefficient of the variable denoted as *Public support* in the regression tables; the indirect (or mediated) effect is identified by the coefficient of the variable termed as *Public support*GAP*. A positive and statistically significant coefficient for the latter regressor would be indicative that public policies were more supportive to productivity growth far from the frontier (i.e. for firms with a larger productivity gap). Conversely, a negative and statistically significant coefficient for the interaction variable would signal that firms closer to the national (or the global frontier) grew faster compared to laggards because of the effect of public policies. Below, we show the estimates of TFP growth effects of public support to investment, export and R&D. The Appendix contains an assessment of the productivity effects of R&D collaboration with Universities and

[34] All cross-sectional estimates include country and industry dummies and uses robust standard errors.

research centres, and an assessment of TFP growth performance of the firms with (partial or total) public sector participation.

Table 6.2.7. Productivity growth, productivity gap and public support to investment (cross-section estimates, 2008-14).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ ln $TFP_{G,F}$	-0.004	-0.008	-0.008	-0.010	-0.013	-0.024	-0.014
	(0.006)	(0.033)	(0.006)	(0.035)	(0.035)	(0.035)	(0.035)
$GAP_{G,i}$	-0.039**	-0.033*					
	(0.016)	(0.018)					
Δ ln $TFP_{N,F}$			0.024**	0.024**	0.024**	0.024**	0.024**
			(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
$GAP_{G,N}$			-0.018	-0.012	-0.011	0.006	-0.002
			(0.024)	(0.025)	(0.025)	(0.027)	(0.023)
$GAP_{N,i}$			-0.039**	-0.034*	-0.034*	-0.031	-0.029*
			(0.016)	(0.018)	(0.018)	(0.019)	(0.017)
Public support		0.052**		0.049**	0.050**	0.051**	0.049*
		(0.024)		(0.025)	(0.025)	(0.025)	(0.025)
Public support * $GAP_{G,i}$		-0.037*					
		(0.021)					
Public support * $GAP_{G,N}$				-0.062**	-0.058**	-0.057**	-0.058**
				(0.025)	(0.025)	(0.025)	(0.025)
Public support * $GAP_{N,i}$				-0.032	-0.032	-0.033	-0.031
				(0.022)	(0.022)	(0.022)	(0.023)
Economic controls	No	No	No	No	Yes	Yes	Yes
Control for technology transfers							
R&D variable * gap terms						R&D intensity	Human capital
Observations	7,155	7,146	7,142	7,133	7,126	7,127	7,126
R-squared	0.024	0.026	0.026	0.028	0.032	0.035	0.033

Notes: OLS estimation with robust standard errors in parentheses. Dependent variable: average TFP growth between 2008 and 2014. All estimates include country and two-digit sector fixed effects. Estimates are weighted with absolute sampling weights. Δ ln $TFP_{G,F}$= TFP growth of the global frontier. $GAP_{G,i}$= productivity gap to the global frontier. Δ ln $TFP_{N,F}$= TFP growth of the national frontier. $GAP_{G,N}$= productivity gap between national and global frontier. $GAP_{N,i}$= productivity gap to the national frontier. Economic controls include: dummy variables for small and medium sized firms, dummy variables for young (less than 7 years from establishment) and mature firms (between 7 and 20 years from establishment), dummy variables for firms belonging to national and international business group, a dummy variable for family controlled firm, a dummy variable for firms experiencing a marked reduction in sales between 2008 and 2009, percentages of graduated workers; a dummy variable for exporting firms, a dummy variable for R&D doing firms, the share of investment over sales. Control for technology

transfers include: R&D expenses/sales * $GAP_{G,N}$ and R&D expenses/sales * $GAP_{N,I}$ (col. 6); Percentage of graduates * $GAP_{G,N}$ and Percentage of graduates* $GAP_{N,I}$ (col. 7).

Table 6.2.7 reports OLS estimates of Eqs. (6.2.1) and (6.2.2) looking at the effect of public support for investment. Col. (1) displays the baseline model in which TFP growth is assumed to depend on productivity improvements experienced by the EU leading firms and the distance to the global frontier. Col. (2) introduces the policy variable under assessment, either in the form of a direct or mediated effect. Col. (3) reports estimates for the equation that disentangles the gap into two terms and acknowledges the role of global and national frontiers advances in productivity growth of laggards (Eq. 2). Col. (4) adds policy variables to this empirical setting. Col. (5) includes the broad set of factors, described above, that have been found to influence TFP growth in the earlier extensive literature.[35] For brevity, parameters of control variables used in the regression analysis are not shown. The literature on technology imitation and technology transfers from the frontier suggests that laggards experience productivity growth through these channels in proportion to the intensity of their R&D engagement or the endowment of human capital (see Griffith et al. 2004, Madsen et al. 2010). For this reason, we also account for these effects using the ratio of R&D expenses to total sales (col. 6) and the company's share of graduated employees (col. 7). These variables are included singularly and interacted with productivity gap terms with the aim of ruling out the possibility that the interaction between policy variables and the gap terms reflects the effect of R&D engagement in enabling technology transfers or facilitating productivity catch-up.

In the cross-sectional analysis setting, there is indication that TFP growth of the EU frontier firms does not play any role in productivity improvement of the laggard companies. The gap term is statistically significant and with a negative coefficient indicating that firms far from the global frontier experienced a slower rate of TFP growth (-0.039). This is consistent with the pattern of increasing dispersion in productivity levels of the European firms found by earlier studies. Col. (2) reveals that public support for physical investment does have direct effects on productivity growth likely promoting substitution across vintages of capital goods and, by this channel, raising firm efficiency. This argument is corroborated by the insignificance of the investment share on sales that is used as a control variable in this and in all our specifications (not shown). The productivity-enhancing effect of public support for investment is in line with the evidence provided by Gemmel et al. (2016). According to the estimates reported in col. (2), the productivity effect of public support for investment does not differ systematically with the firm distance to the EU frontier. Results differ somewhat when using the extended specification. Col. (3) shows that TFP growth is driven by advances in productivity levels of national leaders (0.024). Moreover, public support for investment is found to increase productivity growth of

[35] These control factors have been selected from a very large array of variables on the basis of their statistical power in our regression framework.

national leaders the closer these firms are to the global frontier (-0.058). This finding is confirmed even when we include control variables (col. 4) and allow for the intensity of R&D engagement (col. 6) or the endowment of human capital in promoting technology transfers from the frontier (col. 7).

Table 6.2.8 presents the results of the analysis conducted on the effect of public support for export. This policy instrument does not appear to systematically increase productivity, neither directly nor indirectly by enabling transfers. There is some indication that national leaders that did benefit from this type of public support and were close to the global frontier experienced faster productivity growth (-0.090; see col. 5). In principle, this type of public support is beneficial only for national leaders, that perform comparably well as global frontier firms, helping the former to close this gap and to be particularly competitive on the international market. However, it should be observed that this effect is not robust across specifications. The insignificance of public support for export does not seem related to the fact that the empirical model already includes a binary variable for the exporting status of the firm, as the latter turns out to be insignificant itself (not shown). It is likely that the status of the exporter is correlated with productivity levels and this factor is accounted for by the gap terms (which consists of the log-difference in productivity levels between the frontier company and the firm *i*). Another possibility is that firms receiving public support for export did increase their intensive margins -and through this channel they improved their production efficiency- but this effect is not adequately captured by our empirical model as it considers only the exporting status of the firm on the basis of a binary indicator.

Table 6.2.8. Productivity growth, productivity gap and public support to export (cross-section estimates, 2008-14).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ ln $TFP_{G,F}$	-0.004	-0.010	-0.008	-0.009	-0.013	-0.023	-0.014
	(0.006)	(0.033)	(0.006)	(0.034)	(0.035)	(0.035)	(0.035)
$GAP_{G,i}$	-0.039**	-0.038**					
	(0.016)	(0.016)					
Δ ln $TFP_{N,F}$			0.024**	0.024**	0.024**	0.024**	0.024**
			(0.011)	(0.010)	(0.011)	(0.011)	(0.011)
$GAP_{G,N}$			-0.018	-0.017	-0.016	0.002	-0.006
			(0.024)	(0.024)	(0.024)	(0.026)	(0.023)
$GAP_{N,i}$			-0.039**	-0.039**	-0.039**	-0.036**	-0.033**
			(0.016)	(0.016)	(0.017)	(0.017)	(0.015)
Public support		0.077		0.070	0.066	0.063	0.063
		(0.077)		(0.076)	(0.075)	(0.075)	(0.076)
Public support * $GAP_{G,i}$		-0.035					
		(0.056)					
Public support * $GAP_{G,N}$				-0.073	-0.090*	-0.075	-0.085
				(0.056)	(0.053)	(0.054)	(0.054)
Public support * $GAP_{N,i}$				-0.027	-0.021	-0.019	-0.018
				(0.057)	(0.055)	(0.055)	(0.056)
Economic controls	No	No	No	No	Yes	Yes	Yes
Control for technology transfers							
R&D variable * gap terms						R&D intensity	Human capital
Observations	7,155	7,151	7,142	7,138	7,131	7,132	7,131
R-squared	0.024	0.025	0.026	0.027	0.031	0.034	0.032

Notes: OLS estimation with robust standard errors in parentheses. Dependent variable: average TFP growth between 2008 and 2014. All estimates include country and two-digit sector dummies. Estimates are weighted with absolute sampling weights. Δ ln $TFP_{G,F}$= TFP growth of the global frontier. $GAP_{G,i}$= productivity gap to the global frontier. Δ ln $TFP_{N,F}$= TFP growth of the national frontier. $GAP_{G,N}$= productivity gap between national and global frontier. $GAP_{N,i}$= productivity gap to the national frontier. Economic controls include: dummy variables for small and medium sized firms, dummy variables for young (less than 6 years from establishment) and mature firms (between 6 and 20 years from establishment), dummy variables for firms belonging to national and international business groups, a dummy variable for family controlled firms, a dummy variable for firms experiencing a marked reduction in sales between 2008 and 2009, the percentage of graduated workers; a dummy variable for exporting firms, a dummy variable for R&D doing firms, the share of investment over sales. Controls for technology transfers include; R&D expenses/sales * $GAP_{G,N}$ and R&D expenses/sales * $GAP_{N,I}$ (col. 6); Percentage of graduates * $GAP_{G,N}$ and Percentage of graduates* $GAP_{N,I}$ (col. 7)

Further valuable insights emerge from the analysis of the productivity effects of public support for R&D (Table 6.2.9). This is based on a very comprehensive measure of public incentives, which includes either direct funding (R&D subsidies) or fiscal incentives (R&D tax credit). Whilst it is well known that these policy instruments stimulate R&D-based innovation through different channels, i.e. by reducing R&D costs and enhancing returns to research activities respectively (see David et al. 2000, and Hall and Van Reenen 2000, respectively), less explored is the issue of whether (and how) these policy measures increase production efficiency and TFP growth. Estimates reported in Table 6.2.9 indicate that national leaders gained from these policy instruments, but were limited to those close to EU leaders (-0.058). In other words, firms leading national markets that did access public incentives for R&D were able to close the productivity divide with European leaders faster. This result differs from the evidence found above for public support for capital investment. Indeed, the productivity effects of R&D support seem to be economically and statistically weaker than incentives for investment. Another important difference is that public support for R&D materialises into TFP increases only enabling technology transfers between national and frontier (i.e. R&D support has no direct effects).[36] However, it should be observed that the latter effect is not fully distinguishable from technology transfers activated by R&D-based absorptive capacity (proxied by R&D expenses over sales) as firms accessing to R&D public support are likely to be particularly R&D intensive (see col. 6).

Finally, it should be observed that the results in Tables 6.2.5-6.2.9 are broadly confirmed when extending the set of control variables. Conversely, no productivity effects (either directly or via technology transfers) are found to be associated with firm engagement in technological collaborations with public R&D centres and Universities, nor for firms partly or completely owned by the public sector (see Appendix Tables A.13 and A.14, respectively).

[36] National leaders that did access public support for investment amount to 105 firms, while 71 firms accessed R&D public support . Only 36 of these companies benefitted from both public incentives and this excludes the possibility that estimates in Table 5.2.9 capture the effect of public support for capital investment. Indeed, when we replicate estimates in Table 5.2.9 excluding those firms taking incentives for investment, results are broadly confirmed.

Table 6.2.9. Productivity growth, productivity gap and public support to R&D (cross-section estimates, 2008-14).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ ln $TFP_{G,F}$	-0.004	-0.008	-0.008	-0.007	-0.010	-0.021	-0.012
	(0.006)	(0.033)	(0.006)	(0.034)	(0.035)	(0.035)	(0.035)
$GAP_{G,i}$	-0.039**	-0.034**					
	(0.016)	(0.017)					
Δ ln $TFP_{N,F}$			0.024**	0.024**	0.024**	0.024**	0.024**
			(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
$GAP_{G,N}$			-0.018	-0.008	-0.007	0.006	0.002
			(0.024)	(0.025)	(0.025)	(0.026)	(0.023)
$GAP_{N,i}$			-0.039**	-0.034**	-0.034**	-0.033*	-0.029**
			(0.016)	(0.017)	(0.017)	(0.017)	(0.015)
Public support		0.041		0.039	0.040	0.041	0.039
		(0.040)		(0.040)	(0.040)	(0.043)	(0.041)
Public support * $GAP_{G,i}$		-0.028					
		(0.035)					
Public support * $GAP_{G,N}$				-0.058**	-0.056*	-0.038	-0.054*
				(0.029)	(0.029)	(0.028)	(0.029)
Public support * $GAP_{N,i}$				-0.025	-0.025	-0.023	-0.024
				(0.037)	(0.036)	(0.039)	(0.037)
Economic controls	No	No	No	No	Yes	Yes	Yes
Control for technology transfers							
R&D variable * gap terms						R&D intensity	Human capital
Observations	7,155	7,151	7,142	7,138	7,131	7,132	7,131
R-squared	0.024	0.025	0.026	0.028	0.032	0.034	0.032

Notes: OLS estimation with robust standard errors in parentheses. Dependent variable: average TFP growth between 2008 and 2014. All estimates include country and two-digit sector dummies. Estimates are weighted with absolute sampling weights. Δ ln $TFP_{G,F}$= TFP growth of the global frontier. $GAP_{G,i}$= productivity gap to the global frontier. Δ ln $TFP_{N,F}$= TFP growth of the national frontier. $GAP_{G,N}$= productivity gap between national and global frontier. $GAP_{N,i}$= productivity gap to the national frontier. Economic controls include: dummy variables for small and medium sized firms, dummy variables for young (less than 6 years from establishment) and mature firms (between 6 and 20 years from establishment), dummy variables for firms belonging to national and international business groups, a dummy variable for family controlled firms, a dummy variable for firms experiencing a marked reduction in sales between 2008 and 2009, the percentage of graduated workers; a dummy variable for exporting firms, a dummy variable for R&D doing firms, the share of investment over sales. Controls for technology transfers include; R&D expenses/sales * $GAP_{G,N}$ and R&D expenses/sales * $GAP_{N,I}$ (col. 6); Percentage of graduates * $GAP_{G,N}$ and Percentage of graduates* $GAP_{N,I}$ (col. 7)

6.2.3. Summary of EFIGE results and policy implications

Our results can be compared with the evidence provided by Andrews et al. (2015) which is the most closely related work in this infant stream of the literature. First, cross-sectional estimates indicate that productivity growth does depend on technology advances of national frontier firms only. Hence, from this perspective, our results differ from Andrews et al. (2015), although some positive role for TFP growth of the global leaders does arise from our panel estimates. However, in contrast, our analysis unambiguously points to the lack of productivity catch-up among EU manufacturing firms, i.e. TFP growth of laggards was slower far from the frontier. This excludes, for the average firm, the presence of technology transfers. Our evidence indicates that some productivity advantages have been taken by national leaders accessing public support for investment and R&D, which were able to close (at least partially) the divide with the most productive firms of the EFIGE sample. In this respect, our findings are consistent with the evidence provided by Andrews et al (2015) as these authors find that R&D policies yield within-firm productivity improvements for national frontier firms.

Some valuable insights for policy-making can be drawn from the analysis based on EFIGE data. First of all, it emerges that public support for investment in physical and knowledge (R&D) capital yield a positive effect which goes above the channel of factor accumulation. This productivity effect probably materialises with an increase in production efficiency induced by the adoption of new machinery and equipment (embodied technology), or the development of new products that forces companies to re-organize their core activities. It may also be possible that, through public incentives, firms carry out additional activities that are complementary to investment in capital and knowledge assets, such as advertising, marketing, training, business organization, etc. Hence, this finding suggests that a wide range of expenses should be admitted for fiscal deduction or to access public funds when they are targeted to immaterial activities that enhance the value of capital investment or research to the firm.

Conversely to the results for R&D public incentives, public support for investment has a direct impact on productivity growth. This may depend on the number of firms accessing to this policy instrument. Public support for R&D is less diffused and accordingly is found to be positively related only to the TFP growth of national leaders which are close to the global frontier. Hence, the effect of the R&D policy instrument is not direct but only mediated. An indirect effect has also been found for public support for investment, which is comparable in size to the one identified for public support for R&D.

Typically, in the literature, public funds are found to promote firm investment in capital assets or R&D on the basis that they relax financial constraints faced by companies when planning such activities. However, this does not appear to be the driving force behind our results for two reasons. First, the intensity of investment or R&D turns out to be unrelated to TFP growth. Second, various proxies for the

financial conditions of the firm have been included into the specification as controls and have been always found to be insignificant.

It should be borne in mind, however, that although the mediated effects of public incentives for capital investment and R&D are limited to a small set of (leading) companies at the country level, these may produce important macroeconomic effects in the long run, as long as national frontier firms favour technology diffusion within countries. This argument is corroborated by the positive and significant effect found for productivity growth of national leaders (Δ ln $TFP_{N,F}$) on TFP growth of the laggard firms (see in this respect the discussion in OECD, 2015).

Finally, as a caveat of the analysis, it should be acknowledged that the productivity effects of public policies might be due to the endogenous selection of supported firms. In other words, these companies may present some unobservable characteristics that make them more likely to either access the policy support or grow faster in terms of productivity, in times of market uncertainty and turbulence. This requires caution in the interpretation of the results.

7. Public policies and Reallocation: A Literature Review.

7.1 Introduction

This chapter of the report provides an empirical review of the role of public policy in stimulating productivity growth through its effect on the efficiency of resource allocation. The main focus is on the extent to which the regulation or de-regulation of markets (for products, labour services, financial services and so on) influences allocative efficiency within a given economy.

Studies have long documented large and persistent differences in productivity between countries. The abiding consensus was that these patterns arose – and were maintained – because of differential rates of technological diffusion. However, a new consensus has emerged that a major part of the heterogeneity can also be explained by differences in the environment in which businesses operate. Recently, studies have documented a considerable degree of heterogeneity between firms, even in narrowly defined industries, and linked this to aggregate economic performance through a focus on the extent to which there is a misallocation of resources between firms at the micro-economic level. As a consequence, there is now a body of literature which focuses on the influence of misallocation on aggregate productivity, and which links this to public policy.

In the first part of the review we provide a broad overview of this growing literature which attempts to link productivity differences between countries or industries to the misallocation of resources across firms within each country or industry. We review

evidence on the scale of misallocation within EU Member States (and more broadly) and discuss the various possible channels through which misallocation can arise.

In the second part of the review, we go on to review the evidence of the role of public policies as an influence on the scale of misallocation. We first discuss empirical studies which aim to provide a broad overview of the influence of policies relating to product, labour and financial markets. We then go on to review empirical studies on specific types of policy under these broad headings, drawing where possible on evidence of successful reforms in EU and non-EU countries. While a negative relationship between policy-induced frictions and productivity is a recurrent finding, the exact mechanism and impact tend to depend on the precise policy under consideration. Finally, within this section, we also review possible sources of heterogeneity in terms of the impact of reallocation mechanisms (for instance, variations across sectors and across the business cycle).

In terms of approach, the review seeks to distil the key points on each of the issues to be covered, and focuses on the most informative studies in each area, rather than attempting an exhaustive review of the available literature. It covers both theoretical and empirical studies published in the English language within the field of economics. As implied above, we do not confine our attention to the EU. We focus on EU evidence where available, but also call upon evidence for other countries and regions, where that evidence seems appropriate to the (varied) stages of development of countries within the EU.

The review proceeds in two broad sections. Section 7.2 reviews the potential role of misallocation as a source of productivity differences and considers the broad influence of public policy. Section 7.3 then goes on to consider evidence on the impact of public policy in either raising or lowering the degree of misallocation. Section 7.4 then concludes.

7.2 Misallocation as a potential source of productivity differences

7.2.1 The potential role of misallocation

Studies have long documented the considerable differences in income per capita between rich and poor countries, and have further shown that these mainly reflect large and persistent differences in labour productivity, with rates of labour utilisation playing a relatively modest role (see Figure 1 in Andrews and Cingano, 2014, for recent evidence across the OECD).

In seeking to explain such heterogeneity in rates of output per worker, some considerable attention has historically been placed on rates of technology diffusion (see Grossman and Helpman, 1991; Howitt, 2000). In a recent paper, Comin and Hobijn (2010) suggest that the cross-country variation in the adoption of technologies accounts for at least 25 percent of per capita income differences. However, a range of studies (e.g. Klenow and Rodriguez-Clare, 1997; Hall and Jones, 1999; Caselli, 2005) show that it is impossible to explain cross-country variation in output per

worker solely through variation in physical and human capital, even after making adjustments for the quality of these inputs, and other possible sources of mismeasurement (e.g. with respect to the role of ICT capital). Cross-country differences in total factor productivity (TFP) have thus increasingly come to be considered an important factor.

O'Mahony and Timmer (2009) are among those who show evidence of considerable variation in relative levels of TFP within Europe, and between Europe and the US and Japan. In seeking to explain these differences (and those which are also apparent between the developed and the developing world), an increasing focus is being placed on factors which affect the allocation of resources across firms within an economy. An efficient allocation occurs when resources are allocated between firms in line with their productivity. By extension, in an economy characterised by allocative efficiency, the most productive firms should also be the largest. This optimal allocation may not arise, however, if firms face different levels of tax or subsidy, by which we mean policies or institutional features of the business environment which create heterogeneity in the prices faced by individual producers. Such heterogeneity may arise *inter alia* if one firm has access to cheaper credit than another, or is exempt from regulations which raise firing costs. The prices of these input factors then no longer reflect their marginal productivities. In the face of such differential taxes or subsidies, it is feasible for an unproductive establishment to become relatively large if the level of tax it faces is relatively low; similarly, a more productive establishment may remain small if the level of tax it faces is relatively high (see Restuccia, 2013, for a simple exposition). Under such scenarios, the allocation of resources in the economy is no longer efficient.

The ability to identify factors which may cause such price wedges and any associated misallocation does not necessarily imply that these factors are quantitatively important in explaining variations in economic performance. However, models have been developed which show that policies which create heterogeneity in the prices faced by individual producers can lead to sizeable decreases in output and measured total factor productivity (TFP) (see Restuccia and Rogerson, 2008; Bartelsman et al, 2013a; Da Rocha et al, 2016a for example).

A literature has thus developed, comprising both theoretical and empirical studies which seek to: (i) articulate the mechanisms through which resource misallocation influences TFP; (ii) identify the policy reforms which can be implemented to bring about productivity growth through these channels; and (iii) quantify the importance of these various effects. The literature holds considerable promise because, if one can identify the causes of misallocation and the means by which it may be reduced, this opens important avenues for productivity growth. However, whilst there has been some progress on this front, a detailed understanding of the causes and their associated remedies is still emerging.

7.2.2 Evidence on the scale of misallocation

Evidence to suggest that misallocation can depress productivity has been available for some time in the form of studies which show the role of factor reallocation in driving productivity growth. In a study of the US manufacturing sector in the 1970s and 1980s, Baily et al (1992) found that a substantial portion of the growth in productivity in the sector could be explained by the reallocation of factors across plants, away from less-productive plants to growing more-productive plants, and from failing exiting plants to entering new plants. Further evidence along the same lines has been provided by Foster et al (2001, 2006, 2008). Similarly, Disney et al (2003) examined the impact of restructuring on UK manufacturing productivity growth in the 1980s and early 1990s and found a sizeable contribution from net entry (see also Aghion et al, 2004).

More recently, however, metrics to gauge the scale of misallocation in an economy have been developed, aided by advances in the availability of plant or firm-level data. These metrics are advantageous as they allow for a comparison of the potential scale of misallocation across countries and sectors. Two which are particularly worthy of mention are: the dispersion in TFP within narrow industries; and the correlation between firm size and productivity.

In an influential paper, Hsieh and Klenow (2009) computed the dispersion in TFP across manufacturing plants within four-digit industries in the US, China and India.[37] The ratios of the 90th to the 10th percentiles of de-meaned TFP were computed as 5.0 in India, 4.9 in China and 3.3 in the US, consistent with a greater degree of misallocation in India and China, which was also found to be persistent over time. Similar metrics have also been computed for countries in East Asia (Hallward-Driemeier et al, 2002), Latin America (Busso et al, 2013) and Europe (Bartelsman et al, 2013a).[38]

The second metric, which measures the covariance between firm size and productivity, was proposed by Olley and Pakes (1996) in their study of productivity dynamics in the US telecommunications industry. The measure has been computed, among others, by Bartelsman et al (2013a), using a harmonized firm-level database covering manufacturing industries for the United States and seven European countries across the period 1993-2001. The measure should be higher in an economy with fewer distortions, and Bartelsman et al found it to be highest in US manufacturing (0.51), somewhat lower in the Western European countries of the UK, France, Germany and the Netherlands (0.15 to 0.3) and lowest of all in the Central and Eastern European countries of Hungary, Romania and Slovenia (-0.13 to 0.16). They found, however, that the covariance term increased substantially in this latter group of transition economies over time, while the increases were less marked in Western Europe and the United States, consistent with the view that the transition to

[37] In fact firms, rather than plants, in China.
[38] Such an approach arguably provides an upper-bound to the scale of misallocation, however, since even four-digit industry classifications may group together the producers of heterogeneous goods.

a market-based system allowed the counties of Central and Eastern Europe to improve their allocation of resources. Bartelsman et al (2013b) and Andrews and Cingano (2014) have gone on to compute the measure for larger sets of countries and across both manufacturing and service industries in the 2000s.[39] Although the pattern of results is not entirely consistent across these two studies, they generally indicate: (a) higher levels of allocative efficiency in Northern and Western European countries when compared with those in the South or East of Europe; (ii) higher levels of efficiency in manufacturing industries than in services (particularly non-ICT services); but (iii) some degree of convergence across countries over time, with those having the lowest levels of allocative efficiency registering some of the largest increases over the sample period.

7.2.3. Mechanisms and the role of public policy

A consensus has thus emerged in the literature that an important part of industry productivity gains can arise from factor reallocation from low to high productivity units and, moreover, that there is considerable scope to improve the allocative efficiency of most economies. Attention has then naturally focused on why there may be an imperfect allocation of resources and this, in turn, has prompted a focus on the influence of different forms of public policy.

There are two potential channels through which public policy may affect the degree of misallocation in the economy. The first is by influencing the allocation of resources among those who are currently operating in the marketplace, and the second is by influencing entry and exit. Most economic models of resource misallocation (Restuccia and Rogerson 2008; Hsieh and Klenow, 2009; Midrigan and Xu, 2014) have focused on the first of these aspects of misallocation. However, some have recently begun also to include the role of selection (e.g. Bartelsman et al, 2013a), showing this channel to have quantitatively important implications for aggregate TFP.

The literature has also focused most commonly on the static effects of distortions, but is increasingly incorporating possible dynamic effects, arising from mechanisms which amplify the effects of such distortions over space or time. For example, Jones (2013) and Cette et al (2013) emphasise that, alongside the direct effect of distortions in raising prices for producers of goods or services, there is also an indirect effect in raising prices for the downstream producers that they supply. Dynamic effects may also arise across time if distortions create a disincentive for high productivity plants to invest in productivity enhancements, in other words if the distribution of productivity across plants is endogenous with respect to the distortions (see Da Rocha et al, 2016a, for example). In this case, there may be effects on the *growth* of firm productivity, on top of the static misallocation.

How specifically might public policy play a role in these processes? One way is through excessive intervention, which might include protecting incumbent firms by

[39] Bartelsman et al (2013b) cover the period 2001-2009; Andrews and Cingano (2014) consider 2005 only.

discouraging entry or innovation, or protecting incumbent workers through the imposition of excessively high firing taxes. Another way is through lack of action, which might include insufficient supervision of banks and other elements of the economic infrastructure, which then inhibits investment.

Hsieh (2015) reviews a series of micro-economic determinants of aggregate productivity growth which may be amenable to public policy. He emphasises: the role of regulation in determining the costs of adjusting labour and capital inputs; the influence of the state in restricting entry to product markets; size-dependent regulations which create disincentives for firm growth; policies which distort the allocation of talent or skill across the economy; trade barriers; and inefficiencies in housing markets. Hsieh argues that the implementation of a single policy in isolation is not likely to be effective, and a combination of policies will be usually required to yield large productivity effects. The effectiveness of different policies is also likely to respond to country specific factors and related to the level of economic development. With these caveats in mind, we nonetheless go on in the following sections to review the empirical evidence on the scale of misallocation and on the degree of influence that specific types of public policy may have in reducing it.

7.3 Evidence on the impact of public policy

7.3.1. Introduction

Evidence of the impact of policy distortions on productivity takes two broad forms: (i) 'direct' evidence arising from studies which seek to quantify the impact of *specific policies*; and (ii) 'indirect' evidence from studies seeking to quantify the net effect of *all possible sources* of misallocation.

Studies taking the indirect approach seek to compute metrics on the scale of misallocation, as summarised in Section 6.2, and then run simulations to evaluate the quantitative impact on productivity of reducing those distortions. In an abstract case, Restuccia and Rogerson (2008) estimate TFP reductions of between 0 and 50 per cent, depending on the scale and prevalence of the tax wedges. In the paper mentioned earlier, Hsieh and Klenow (2009) use the measured dispersion in TFP across plants to evaluate how much aggregate manufacturing output in China and India could increase if the efficiency of the production processes was comparable to that prevailing in the US. Their approach indicated that, if capital and labour were reallocated to match US levels of allocative efficiency, TFP would increase by 30%–50% in China and 40%–60% in India. In a similar paper, Busso et al (2013) estimated that reallocating capital and labour to equalize marginal products in manufacturing in Latin America would raise aggregate TFP by up to 50% relative to the gain that could be obtained in the US, depending on the countries and years considered.

These indirect studies thus point to large effects and are thus helpful in demonstrating the *potential* of policy reform. However, whilst they can indicate the relative importance of different channels (e.g. entry and exist vs reallocation) in generating the aggregate outcomes, they are unable to pinpoint the policies which may be most effective. This requires a direct approach.

The limitations of the direct approach are that: (i) some policy-related distortions (e.g. preferential treatment of certain companies) may be difficult to measure and thus evaluate; and (ii) potential complementarities between different policies may be difficult to identify. Perhaps as a consequence, the effects that are identified tend to be relatively small in comparison to those suggested by the indirect approach. However, being able to demonstrate a robust causal effect of specific policy reforms in a real-life setting is critical to effective policy formation. As Hsieh and Klenow (2009) have shown in the case of India, being able to identify policies which could *potentially* inhibit allocative efficiency does not necessarily imply that reform of those policies will bring about improvements; such improvements may have been driven by other factors.[40] This serves to illustrate the value of the direct approach.

We discuss the evidence on the direct effect of specific policies under a variety of headings below. The discussion covers studies which examine specific reform episodes as well as those which utilise sectoral and international variance in tax wedges to estimate the likely effects of policy changes. It will be apparent from the discussion that policies governing labour markets, product markets and financial markets all have a potential role to play in promoting allocative efficiency. Yet whilst an array of direct evidence is emerging under each of these headings to indicate the nature and scale of the effects, there is still progress to be made in terms of identifying the most influential policies with precision.

7.3.2 Labour market regulations

Labour market regulations may have a variety of implications for productivity (see Bassanini et al, 2009, for one review) but, for the purposes of the present discussion, the main concern is that regulations which impose implicit or explicit costs on a firm's ability to adjust the quantity or price of labour may impair allocative efficiency by slowing down the speed of adjustment towards equilibrium (see Mortensen and Pissarides, 1999). The main focus of the literature has been on dismissal restrictions and firing taxes. Since these increase the cost of firing workers, they reduce the productivity threshold at which firms are willing to lay off workers; firms will thus retain workers whose wage exceeds their marginal product. In addition, firms will be reluctant to hire new workers in the face of uncertainty about future demand.

It is apparent from indices of employment protection legislation (EPL) that the variation across countries in the scale of these labour adjustment costs can be substantial (OECD, 2013; Gwartney et al, 2015) and empirical studies show that job flows are indeed lower in countries where labour regulations are more rigid.

[40] For a more general review of the determinants of productivity, see Syverson (2011).

Haltiwanger et al (2008), for example, study job flows in the 1990s within a sample of 16 developed and emerging economies and find that more stringent hiring and firing regulations reduce job turnover – in particular by compressing the differentials between high and low turnover industry or size classes. Similar results are obtained by Micco and Pages (2006).

This kind of evidence does not, in itself, prove that EPL has material consequences for productivity. However, Hopenhayn and Rogerson (1993) build a general equilibrium model of the process of job reallocation, and calibrate it to the US manufacturing sector. They show that a tax on dismissals causes firms to be more cautious about job creation, which in turn reduces the rate of job destruction. As a result, firms end up making fewer adjustments to their labour force. Their model further predicts that productivity will deteriorate as a consequence, with a firing tax equal to one year's wages reducing average labour productivity by around 2 per cent. Moscoso Boedo and Mukoyama (2012) then adopt Hopenhayn and Rogerson's model and use it to consider the role of both firing costs and entry regulations in explaining cross-country productivity differences.[41] Their results suggest that raising the level of firing costs from that applying in the US (zero) to that applying in low-income countries will reduce TFP by around 7%.[42]

Da Rocha et al (2016b) also build on the model of Hopenhayn and Rogerson (1993) but allow firing costs to affect the distribution of productivity, thus incorporating one of the dynamic amplification effects referred to in Section 6.2.3. When they calibrate their model, they find that a firing tax equal to one year's wages reduces TFP by around 4 per cent (twice the size of the effect on average labour productivity predicted by Hopenhayn and Rogerson (1993)). Notably, the bulk of the effect in Da Rocha et al's simulation is shown to come via the dynamic effect of firing costs in changing the distribution of establishment productivity, rather than through the static misallocation effect. In terms of mechanisms, one possibility is that such labour adjustment costs lower firms' propensity to adopt productivity-enhancing technology. Indeed, Bartelsman et al. (2010) use a two-sector labour search model and calibrate it to show that firing costs can lower the adoption rates of ICT and reduce the share of resources allocated to high growth sectors.

Moving beyond these simulations, empirical studies of the impact of EPL have taken two forms. One approach is to use a difference-in-difference strategy with sector-level panels covering multiple countries, following Rajan and Zingales (1998). The other is to study specific episodes of policy reform.

Bassanini et al (2009) use the Rajan-Zingales (RZ) approach to examine the impact of employment protection legislation on productivity performance using the OECD's

[41] Entry regulations are discussed in more detail in Section 6.3.4 below.
[42] Low income countries are defined by Moscoso Boedo and Mukoyama (2012) as those with gross national income below 2% of the US level. Firing costs in such countries average around three years' wages – see their Figure 2.

EPL indexes. They find that dismissal regulations have a negative impact on TFP growth in those industries that rely more on lay-offs than on voluntary quits to adjust their workforce in response to industry-idiosyncratic technological and market driven factors. Restrictions on temporary employment, if anything, have a positive impact on TFP growth. They thus advocate the relaxation of overly strict dismissal regulations. In a similar vein, Cingano et al (2010) find that EPL reduces labour productivity (measured as value added per worker) more in high reallocation sectors relative to low reallocation sectors. They also find that stricter EPL reduces value-added per worker relatively more in financially constrained firms, indicating a potential interaction between the effects of different forms of public policy.

Andrews and Cingano (2014) also use the RZ approach – again in conjunction with the OECD's EPL index - but go on to estimate the gains in allocative efficiency from lowering restrictions on individual dismissals. They estimate that reducing employment protections around individual dismissals across the EU to the level seen in the UK would bring allocative efficiency in the EU up to the level of US (rising 14 log points to 36 log points, compared with 39 for the US). The benefits would – as expected – be above-average in highly regulated countries such as Germany, Sweden and the Netherlands. This is also the case in Cette et al's (2014) simulations based on data for 11 EU countries, the US, Canada and Japan. In this sample of countries, their estimations suggest that a one-off shift to the lightest level of EPL regulation (similar to that found in the UK) would bring about a long-term gain in TFP of around 2 per cent. These are, of course, extreme scenarios, but they are helpful in putting some kind of scale on the potential gains.

Other studies have sought to evaluate the impact of actual policies or reforms. Petrin and Sivadasan (2013), for example, focus on two legislative changes which raised firing costs in Chile from around 0.75 months of wages pre-1984 to around 3 months' wages post-1991. They propose a model in which they show that the impact of frictions on allocative efficiency can be measured by examining the gap between an input's marginal product and its marginal cost. They then show that the changes in firing costs were associated with increases in the mean gap between manufacturing plants' marginal products of labour (derived from industry-level production functions) and the plants' average wages, implying that the increased firing costs reduced allocative efficiency over the period in question.

In a rather different study, Autor *et al.* (2007) examine the impact of the adoption of unfair dismissal protections in the US over the period 1970-99, during which the ability of employers to terminate employment relationships ' at will' was substantially eroded. Using cross-state differences in the timing of adoption in conjunction with firm-level microdata, they find that the adoption of unfair dismissal protections led to reductions in annual net job flows and increased capital deepening. It also brought about a reduction of TFP in the order of 1-2%. More recently, Cingano et al (2015) have used Italian data to examine the effects of a 1990 reform which raised dismissal costs for firms with fewer than 15 employees only. They find effects similar

in magnitude to Autor et al, estimating a reduction in TFP of around 3%. Taking a different approach, Braguinksy et al (2011) use simulations to estimate the effects of reducing the strong protections for regular workers in Portugal, which make it difficult for all but the smallest firms to lay off workers. They estimate that removing these restrictions could raise net output by at least 9 per cent.

It is not only employment protection regulations which can affect the level of efficient allocation in the economy. Adalet McGowan and Andrews (2015a, 2015b) discuss policies which affect the degree of 'skill mismatch' in the economy. They show that higher levels of mismatch between workers' skills and the requirements of their jobs are associated with lower labour productivity through a less efficient allocation of resources, suggesting that this may arise because, when the share of over-skilled workers is higher, more productive firms find it more difficult to attract skilled labour and gain market shares at the expense of less productive firms. They estimate that reducing skill mismatches to 'best practice' levels in each industry could raise allocative efficiency by around 10% in countries such as Italy and Spain (thereby eradicating roughly one fifth of the gap in allocative efficiency between these countries and the US). Policies which are found to be related to the degree of skills mismatch include the firing taxes discussed earlier (and the product market regulations discussed in Section 6.3.4 below), but also policies affecting the flexibility of wage setting, the degree of segmentation in the labour market and the efficiency of the housing market.

Empirical evidence in these various domains is available from other sources. Propper and Van Reenen (2010), for example, study the impact of centralised bargaining on the allocation of skilled workers and service quality in the UK health service. They find that this form of wage inflexibility lowers the quality of nurses in hospitals located in areas of high ambient wages (since the hospital wage is less competitive than in areas of low ambient wages). This lack of wage competitiveness is, in turn, associated with a higher level of hospital deaths from emergency heart attacks, with the attendant net social costs estimated to be in the region of £200m.

In terms of labour market segmentation, Hsieh et al (2013) study the convergence in the occupational distribution between white men, women and ethnic minorities in the US since the 1960s. They model labour market frictions, such as barriers to education and discriminative hiring practices, as 'taxes' on earnings which affect the occupational distribution between different groups in the labour market. Their model suggests that a narrowing of occupational differentials can explain 15 percent of the growth in aggregate TFP in the US from 1960 to 2008.

Finally, turning to policies which affect skill mismatches through the housing market, Hsieh and Moretti (2015) argue that the rigid housing markets in some large US cities have a sizable effect on mobility and thus labour allocation between areas with different levels of productivity, which ultimately affects aggregate productivity growth. Housing policies which may restrict mobility include those which: restrict land use;

limit access to credit; increase rent controls; or raise property transaction costs. Andrews et al (2011) provide related evidence on the scale of such policies and their implications on residential mobility using data from OECD countries. Hsieh and Moretti (2015) estimate that lowering land use regulations in New York, San Francisco and San Jose to the level of the median city would increase U.S. output by 9.7%, by allowing more workers to access the high productivity of these high TFP cities.

7.3.3 Size-dependent policies

An expanding tranche of the literature has focused on size-dependent policies – these being some of the most obvious ways in which policy makers can introduce variations in tax wedges between firms. Such policies can take different forms. They include labour regulations which only apply to larger firms (e.g. requirements to establish formal systems of employee representation), tax breaks and subsidies for SMEs, and planning regulations which place additional conditions on the establishment of larger plants (as in the retail sector in some countries). Such policies can reduce the incentives for high productivity firms to grow and, conversely, encourage low productivity ones to grow larger than is efficient.

Guner et al (2008) provide a range of examples of policies which impose restrictions on firms above a certain size threshold, and then go on to develop a framework under which they assess the productivity consequences of implementing such policies. In common with most parts of this subset of the literature, they focus primarily on the implications for overall output or average labour productivity, rather than TFP. However, they estimate that policies which reduce the average size of establishments by 20% can lead to reductions in output and output per establishment of up to 8% and 26% respectively. It is notable, nevertheless, that these figures apply in the case of restrictions based on capital use – restrictions based on firms' employment size (arguably the more common of the two) are found to have lesser effects overall.[43]

Specific instances of size-dependent policies are the subject of the studies by Braguinsky et al (2011) and Cingano et al (2015) mentioned in Section 6.3.2. These studies consider the direct effects of size-dependent labour regulations in Portugal and Italy respectively and, as previously discussed, both identify costs arising from these policies, either in terms of aggregate output or TFP. The Italian case, in which a number of labour regulations apply only to firms with 15 or more employees, is also the subject of simulations by Guner at al (2008) and, whilst their model does not generate the observed establishment size distribution in Italy, it nonetheless predicts that the presence of implicit taxes related to establishment size leads to substantive drops in output per worker.

[43] Guner et al (2008) do estimate the impact of capital use restrictions on TFP, with a 20% reduction in average size leading to a TFP reduction of between 1 and 3%. However they do not report the TFP implications of labour use restrictions.

Two further studies of note have focused on the case of France, highlighting in particular the impact of certain labour market regulations which apply for firms with 50+ employees. These regulations include the requirement to establish certain forms of employee representation, and the requirement to pay a higher rate of training tax. Gourio and Roys (2014) and Garicano et al (2013) both show that the size distribution of firms in France is visibly distorted, with a mass of firms sitting just below the 50-employee threshold. Gourio and Roys (2014) indicate that the regulation is perceived by firms as equivalent to the sunk cost of just over 1 year of a workers' wage and, through simulations, estimate that removing the size threshold would raise output in France by 0.3%. Garicano et al (2013) estimate larger gains of up to 5% of GDP, but the differences are judged by Gourio and Roys (2014: 406-8) to arise largely because of differing assumptions about wage flexibility: Garicano et al assume rigid wages, whereas the model of Gourio and Roys allows wages to adjust over time.

In the aforementioned studies, the effects of changes in size-dependent policies are estimated through simulations. Very few studies have looked at specific policy reforms, but one such example is Haskel and Sadun (2011), who study the effects of a regulatory change in the UK in the mid-1990s which increased the costs of opening large retail stores. These new regulations – which aimed to limit the numbers of large, out-of-town stores and promote inner-town development – prohibited firms from taking full advantage of economies of scale and brought about a substantial reduction in the average size of retail stores in the UK.[44] Haskel and Sadun estimate that the downward shift in average store size brought about a 0.4% per annum reduction in the TFP of retail chains in the UK. This equates to around 40% of the slowdown in retail TFP growth in the UK between 1995 and 2000, and around 13% of the entire market sector slowdown over the same period.

7.3.4 Product market regulations

The third class of policies to be considered concerns regulations over product markets. Such regulations typically establish barriers to domestic competition or barriers to foreign trade and investment, or impose cumbersome or expensive administrative requirements. These raise entry costs and so can distort the industry structure by allowing low productivity firms to operate and grow larger than they would otherwise do in an undistorted economy (Bartelsman et al, 2013a). High entry costs can also reduce firms' incentives to invest in new technology (Poschke, 2010). However, as Nicoletti and Scarpetta (2003) emphasise, liberalising markets can also reduce firms' incentives to invest, because of uncertainty over their longevity. The overall effect on TFP of reducing product market regulations is thus somewhat ambiguous a priori.

Broad evaluations of the impact of product market regulations are provided by Nicoletti and Scarpetta (2003) and Cette et al (2014), with the latter study already

[44] The employment size of the median supermarket fell by 25 per cent in four years.

having been mentioned in Section 6.3.2. Both of these studies are based on multi-country panel data, with the extent of product market regulation measured through OECD indices.

Nicoletti and Scarpetta (2003) studied the relationship between product market regulations and productivity across 24 OECD countries using indicators of barriers to entry, barriers to trade and administrative burden. In their study, these various measures of product market regulation significantly curbed productivity performance at the industry level, with the long-run costs being higher in countries that were further away from the technological frontier. Their results suggested that aligning product market regulations with those of the most liberal OECD country (the UK) would raise the annual rate of TFP growth in continental EU countries by between 0.4% and 1.1% over a period of ten years. The gain would be highest in Greece, but also substantial (around 0.7%) in Germany, Italy and Portugal. Cette et al (2014), for their part, produce simulations based on data for 14 OECD countries which suggest that a one-off shift to the lightest level of product regulation (similar to that found in the UK or USA) would bring about a long-term gain in TFP of around 2.5 per cent.[45]

Other studies of product market regulation take a narrower focus than the aforementioned studies, emphasising the impact of specific types of product market 'tax'. Barseghayan and DiCecio (2011) focus on TFP differences arising from cross-country variation in entry costs (with a specific focus on the legal fees associated with registering firms). Their model is estimated on a large sample of 128 countries using fee data from the World Bank, and suggests that moving from the highest to the lowest decile of entry costs raises TFP by a factor of 1.5. The degree of cross-country variation in this aspect of the regulatory environment is somewhat smaller in the EU than in the larger sample considered by Barseghayan and DiCecio. Studies have shown, nonetheless, that it can have substantive implications. Andrews and Cingano (2014) take a similar approach to Nicoletti and Scarpetta and Cette et al to estimate the gains in allocative efficiency that could arise from lowering the administrative burdens on start-ups within the EU. They estimate that reducing these burdens to the level seen in Denmark (the lowest in the EU) would increase the contribution of allocative efficiency to productivity in the EU by 100%. The benefits would be greatest in Poland and Greece, but also above-average in countries such as Portugal and Spain.

[45] The study by Cette et al, (2014) is notable as the major part of the TFP gain associated with the reform of product market regulation was estimated to have come through reductions in the regulation of services (such as transport, communication and retail). Bourles et al (2013) and Barone and Cingano (2012) both show that distortions in service industries in OECD countries can have important negative effects on firms that use these inputs 'downstream' (see also Cette et al, 2013). See the discussion of amplification mechanisms in Section 6.2.3

Another focus of empirical work has been the role of the state in creating barriers to entry through limiting domestic or foreign investment in specific industries (e.g. through state ownership). In their seminal study, Hsieh and Klenow (2009) show that, in the late 1990s, the TFP of state-owned firms in China was around 40% lower than that of privately-owned domestic firms; however, the gap narrowed in the early 2000s with the closure and privatization of many state-owned firms, thereby improving the degree of allocative efficiency through reform. Other evidence of the productivity gains arising from privatisation is provided by La Porta and Lopez de Silanes (1999), who studied around 200 privatisations in Mexico in the late 1980s, and by Brown et al (2006) who focus on privatisations in Central and Eastern Europe. Brown et al (2006) examine the privatisation of state-owned manufacturing firms in Hungary, Romania, Ukraine and Russia, and find a positive effect on TFP, on average, but also substantial variation by country. TFP increases by around 15% in Romania, 8% in Hungary, and 2% in Ukraine, but falls by 3% in Russia. Brown et al are unable to explain these differences in full, but suggest that they may be at least partly explained by the higher concentration of ownership post-privatisation in Hungary and Romania. Their results also indicate that the introduction of foreign capital brings about larger gains than a transition to predominantly domestic private ownership. Estrin et al (2007) offer similar conclusions in their broad review of the literature on privatisations in transition economies.

Nevertheless, even after privatization there may be firms who can use their political connections to gain preferential treatment in the market place. Hsieh and Song (2015) show that this is what happened to the privatized state owned firms in China. Policies which limit the use of political connections are therefore likely to be valuable, but identifying political connections is difficult empirically if one is to try to test the impact of reforms in this area.

Governments can also impair allocative efficiency by allowing private monopolies, with some industry-specific studies providing evidence that deregulation can result in an improved resource allocation in specific sectors. Olley and Pakes (1996) studied the deregulation of the telecommunications industry in the US and Canada, where an anti-trust case led, in the mid-1980s, to the break-up of the previously state-sanctioned monopoly over local telephone services. They found that deregulation was followed by a reallocation of capital to more productive plants, facilitated in part through the closure of unproductive plants and their replacement with new, more productive units. In essence, the liberalisation of the regulatory environment created new opportunities for firms to enter the market and affect the position of incumbents, thereby altering the market structure.

Moving away from regulations affecting firm entry or ownership, one can also identify sources of misallocation arising from the use of trade barriers. These have the potential to depress allocative efficiency by favouring inefficient domestic producers at the expense of more-efficient producers based abroad, and can create distortions

across two dimensions: first in the market for intermediate inputs; and second in the market for consumption goods.

Bond et al (2013) study the distortions arising from a particularly large increase in trade tariffs which took place in US in the 1930s, when the Smoot-Hawley Act raised the mean industry tariff on imported inputs from 32% to 46%. Bond et al find that this increase in tariff protection for domestic producers reduced TFP by around 0.5% (considerably increasing the productivity cost of tariff barriers when compared with the period prior to the Act). Others have studied the gains obtained from tariff *reductions*. In particular, Lileeva and Trefler (2012) studied a sample of Canadian manufacturing plants that had never exported prior to the implementation of the Canada-US Free Trade Agreement (FTA). Using an instrumental variables approach they are able to show that the associated cuts in US tariffs had a positive causal impact on the propensity of Canadian plants to export, whilst the cuts in Canadian tariffs put pressure on other Canadian plants to contract or exit. This in turn increased the market share of high-productivity plants in Canadian manufacturing, raising aggregate productivity in the sector (in their case by around 8%). In a similar vein, Eslava et al (2013) study tariff reductions in Colombia in the 1990s and find that these improved the degree of resource allocation, whilst Pavcnik (2002) identifies increases in allocative efficiency arising from trade liberalisation in Chile in the late 1970s and early 1980s.

Non-tariff barriers can include the harmonisation of standards, reduction in border controls and the development of a common competition policy, and these are the focus of Griffith's (2001) study of the impact of the EU Single Market Programme on competition and productivity in UK manufacturing in the 1980s and 1990s. She finds that the introduction of the SMP raised the degree of product market competition in UK manufacturing, and that this brought about increases in both the level and the growth rate of TFP (each rising by around 1 per cent more in industries affected by the SMP than in less-affected sectors).[46]

How do the potential gains from the reform of product market regulations compare with the potential gains from labour market reform? Some of the broad studies mentioned earlier in this section include measures of labour market regulation and product market regulation alongside one another, and so are able to provide some indications of the potential gains in relative terms. In each case, they tend to be broadly similar. Cette et al's (2014) estimate that a one-off shift to the lightest level of product market regulation would bring about a long-term gain in TFP of around 2.5 per cent, compared with a 2 per cent gain from a levelling down of employment protection; Andrews and Cingano (2014) find that the potential 100% increase in allocative efficiency arising from a levelling down of market entry costs across the

[46] See Melitz and Trefler (2012) for further discussion of this broad literature on the potential gains from changes to trade policy.

EU compares with a 150% increase arising from a levelling-down of firing costs. Notable gains can therefore be obtained in both domains.

7.3.5 Financial markets

The final set of policies to be considered concerns those relating to financial markets. Under this heading, the focus is on credit market imperfections and banking regulation, that is regulations affecting investment in, and the divestment of, capital goods, and regulations affecting the flow of capital. Financial frictions reduce TFP through two channels: first, they introduce barriers to the transfer of capital between incumbent firms, which gives rise to the misallocation of resources among these firms; second, they distort decisions around entry and the adoption of new technology. As we emerge from the financial crisis, an important policy issue is how credit constraints may affect the allocation of resources and productivity growth.

Midrigan and Xu (2010) use a calibrated model of heterogeneous firms to estimate the productivity losses arising from poorly-functioning financial markets which place constraints on the amount of debt and equity that producers can issue. Their estimates predict fairly modest TFP losses from misallocation (in the order of 5-10%), but potentially large losses (in the order of 40%) from inefficiently low levels of entry and technology adoption. Others also show how credit market imperfections can affect resource allocation and entry decisions to generate large TFP losses (see Buera et al 2011; Greenwood et al, 2013).

Adopting a trade theory perspective, Kukenova (2011) also finds evidence that financial liberalization promotes more efficient allocation of the resources in the economy, arguing that differences in credit constraints across industries shape the sectoral composition of a country's exports, causing this distribution to deviate from the efficient one. A well-developed banking system can thus push exporters towards the optimal use of the country's factor endowments, making the most of the country's comparative advantage. Evaluating the impact of the liberalization of capital accounts and stock markets across 91 countries over the period 1975-2003, Kukenova finds that, after liberalisation, products that are incompatible with a country's factor endowments become less important in a country's export portfolio. Financial liberalization is thus found to be associated with an improvement in allocative efficiency.

The type of financial distortions that can affect the allocation of factors across firms are particularly prevalent in developing countries. Kalemli-Ozcan and Sorensen (2012) study capital misallocation within and across 10 African countries in the mid-2000s using information on manufacturing establishments from the World Bank Productivity and Investment Climate Survey. They show that moving from a firm where access to finance is 'no obstacle' to a firm where access to finance is a 'very severe' obstacle increases firms' marginal product of capital by 45 per cent.

Nevertheless, developed countries are not immune to financial distortions. In Spain and Italy, processes of "unfavourable" reallocation or "misallocation", which unfolded in response to capital inflows following the introduction of the Euro, has been shown to have reduced average levels of productive efficiency. Using firm-level Spanish manufacturing data, Gopinath et al. (2015) argue that the decline in the real interest rate, often attributed to the euro convergence process, led to a decline in sectoral total factor productivity as capital inflows were misallocated toward firms which had a higher net worth, but which were not necessarily more productive. This scenario was also observed in other economies in Southern Europe, such as Portugal.

In a further study focusing on advanced countries, Fatica (2013) looks at taxes on different types of asset. She finds that corporate taxes affect the composition of new investment, and hence the capital stock. Using EUKLEMS data on 10 EU countries and the US over the period 1991-2007, she finds that non-uniform taxes have led to an under-investment in ICT and transportation equipment and an over-investment in other machinery and equipment, with the 'misallocated' capital being in the order of 4% of the existing aggregate capital stock.

Further studies of developed nations have examined the impact of financial frictions which encourage business owners to pass ownership of their firm to their children (especially the eldest son: so-called primogeniture). Keeping ownership in the family may be influenced by tax subsidies for family-owned firms, but can also be encouraged by tax exemptions for inherited business assets, as applies in the UK.[47] To the extent that such exemptions encourage inter-generational persistence in family ownership, they can promote the misallocation of managerial talent and thus impair allocative efficiency.[48] Bloom and Van Reenen (2010) use firm-level survey data from multiple countries to show that family-owned firms with a family member as CEO score particularly badly on an index of productivity-enhancing management practices.

7.3.6 Sources of heterogeneity

Having reviewed the evidence on the potential influence on misallocation of policy distortions relating to labour, product and financial markets, we now turn, in our final substantive section, to consider possible sources of heterogeneity. We focus in particular on variations across the business cycle and on heterogeneity across sectors.

Several papers have assessed the role played by the reallocation mechanisms in different phases of the business cycle. In the light of the recent financial crisis and global economic downturn, evidence has shown that the allocative efficiency of

[47] In less developed countries, it may also be encouraged by legal deficiencies which lead business owners to feel poorly protected from theft by external managers.

[48] See the earlier discussion of skills mismatches. Primogeniture also potentially impairs productivity by reducing the incentives for the entrepreneur's children – and other managers in the firm – to acquire human capital and expend effort.

resources among firms worsens during a recession as a result of the disruptions in the financial markets which increase the cost of external finance and hinder the growth of small, highly-productive firms. Di Nola (2015) evaluates the contribution of financial frictions in explaining the drop in aggregate TFP in the US through the increased misallocation around the time of the Great Recession. The results suggest that financial frictions account for a significant part of the drop in aggregate TFP. For the UK, Barnett et al (2014) find that reallocation mechanisms between firms (in terms of both the movement of labour and firm entry and exit) contributed significantly to aggregate productivity growth before the crisis; since then its contribution has fallen substantially. They conclude that around one third of the productivity slowdown after 2007 can be attributed to slower reallocation of resources. Oulton and Sebastiá-Barriel (2013) further argue that a financial crisis temporarily reduces productivity growth by approximately one percentage point, and that has a long-lasting effect on the level of productivity, as reallocation of capital from less productive to more productive uses is hampered.

This is all in contrast to Schumpeter's notion of creative destruction, which highlights the `cleansing effect' potential of economic recessions (see Aghion and Howitt, 1992). This cleansing potential is emphasised in theoretical papers which consider the reallocation effects of recessions (e.g. see Caballero and Hammour, 1994). Coricelli et al. (2016) do find evidence that financial crises improve the allocation of resources across industries, but only in developing economies. In their analysis of manufacturing sectors across a large number of recessions, the sectoral-level misallocation of resources does not significantly change in developed economies in times of recession.

Turning to variations across sectors, research has found that stringent regulations are more disruptive to resource allocation in more innovative sectors. Andrews, Criscuolo and Menon (2014) investigate differences across the OECD countries in the ability of innovative firms to attract resources that help them to grow. The authors estimate that a levelling-down of employment protection legislation and product market regulation from the highest observed levels (Portugal and Poland, respectively) to the average levels (Norway and Belgium) would double the amount of labour reallocated to innovative (patenting) firms. Gains associated with similar reductions in the extents of barriers to trade, judicial systems, bankruptcy legislation and financial market regulation would bring smaller but nonetheless important flows of input movements to patenting firms away from less innovative companies (in the range between 30 and 70%). These effects are comparable in size to those estimated by Balasubramanian and Sivadasan (2011) for the US.

7.4 Summing up

Empirical work has, for some time, provided evidence of large and persistent differences in productivity between countries. Whilst a considerable part of these differences has traditionally been attributed to differential rates of technological diffusion, a new consensus has emerged that a major part of the heterogeneity can

also be explained by differences in the environment in which businesses operate. Studies have documented considerable heterogeneity between firms in narrowly-defined industries and linked this to aggregate economic performance through a focus on the extent to which resources are misallocated at the micro level (Hsieh and Klenow, 2009, being one particularly influential example). As a consequence, a body of literature has emerged which focuses on the influence of misallocation on aggregate productivity, and which links this to public policy.

A major focus of this literature is the extent to which the regulation or de-regulation of markets has the potential to raise allocative efficiency within a given economy by reducing the degree of heterogeneity in input prices across individual producers. We have reviewed the evidence on the effect of specific policies under three headings – labour markets, product markets and financial markets – covering studies which examine specific reform episodes as well as those which utilise sectoral and international variance in tax wedges to estimate the likely effects of policy changes.

It is apparent from the foregoing discussion that policies in all three of these areas have a potential role to play in promoting allocative efficiency. The specific contribution of possible reforms clearly depends upon the individual circumstances, yet the available evidence suggests that the possible gains can be substantial. This is perhaps most evident in the case of labour market regulations governing firing taxes, and in the case of product market regulations governing market entry. Here, a range of studies have shown that countries can obtain sizeable gains in TFP by lowering these barriers to market adjustment.[49] Reform of financial markets can also bring gains in specific circumstances – notably in relation to trade tariffs and taxes on capital investment – but the opportunities for sizeable gains in this domain appear more limited, at least among the developed countries of the EU.

Yet whilst an array of direct evidence is emerging under these various headings to indicate the nature and scale of the effects, there is still progress to be made. For instance, studies are emerging which consider entry and exit dynamics alongside misallocation among incumbent firms, and these tend to suggest that the former can have important implications for TFP. Progress can also be made in the area of measurement. In the area of labour regulations, for example, most existing work focuses on firing taxes, and so additional work on a wider range of price wedges (e.g. training taxes and employment subsidies) would be welcome. One other additional area for future development is to better understand the interactions between policies and their dynamic effects. These issues will undoubtedly form the focus of future work and, as they are tackled, we will further develop our understanding of the role of misallocation as a drag on productivity, and find ourselves better placed to design policies to reduce it.

[49] Note that we are focusing here on TFP gains. We do not comment on the other potential effects of such regulatory reforms, e.g. for individual workers or entrepreneurs.

8. The productivity puzzle in the UK.[50]

Since the financial crisis of 2007-8 productivity growth has stagnated, more or less, across the advanced economies. The experience of the UK has been particularly stark. While aggregate GDP growth has been more robust in the UK than in many other European countries, UK labour productivity growth has ground to a halt. Indeed, in the initial years that followed the global financial crisis productivity weakness was viewed largely as a UK specific issue. More recently it has become apparent that productivity growth has also weakened substantially elsewhere, albeit perhaps less so than in the UK.

The situation is illustrated in Table 8.1, where we show annualised growth in labour productivity in the UK and a number of other European economies, the US, Canada and Japan before and after the financial crisis of 2008. In all countries shown, with the exception of Spain, annualised labour productivity growth was weaker 2008-2014 than 1998-2007. This is the case in most countries even when we ignore the recession years of 2008 and 2009; the exceptions are Spain and the Netherlands.

The UK stands out in Table 8.1. In the 10 years before the crisis UK labour productivity growth was relatively strong, at an annualised rate of 2.2 per cent, surpassed only by Ireland amongst the list of countries shown. During this decade the productivity gap was narrowing between the UK and the US and between the UK and many other European economies. With the global financial crisis this period of catch-up came to an end. On average over the years 2008-2014 UK labour productivity growth has been absent, such that the level of UK labour productivity in 2014 was no different to that in 2007.

The contrast in labour productivity growth before and after the crisis is larger in the UK than elsewhere, partly because of the UK's strong performance in the decade prior to 2008, but also because of the complete stagnation in productivity growth since then. This is illustrated in Table 8.1 where we show labour productivity levels in 2014 compared to what would have been had labour productivity growth continued at the pace of 1998-2007. In 2014 UK labour productivity was 16% below an extrapolation of its pre-crisis trend. This gap is twice as large as that observed in other countries in Table 8.1, leaving UK productivity levels 2014 at the bottom of the table, worse only in Japan (see final column).

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[50] *Disclaimer: This work contains statistical data which is Crown Copyright; it has been made available by the Office for National Statistics (ONS) through the Secure Data Service (SDS) and has been used by permission. Neither the ONS or SDS bear any responsibility for the analysis or interpretation of the data reported here. This work uses research datasets which may not exactly reproduce National Statistics aggregates.*

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Table 8.1 International comparisons of labour productivity

	Annualised growth in constant price GDP per hour worked					Productivity gap	Productivity levels
	1998-2007	2008-2009	2010-2014	2008-2014	Change after 2007	2014 level relative to trend	Current price GDP per hour worked UK=100
Belgium	0.9	-0.5	0.4	0.1	-0.7	-5	134
Canada	1.4	0.3	1.2	1.0	-0.4	-3	104
France	1.8	-0.7	0.9	0.5	-1.3	-10	131
Germany	1.6	-1.2	1.3	0.6	-1.0	-8	136
Ireland	3.1	1.4	2.6	2.3	-0.9	-7	130
Italy	0.6	-1.7	0.3	-0.3	-0.9	-6	110
Japan	1.6	-0.4	1.2	0.7	-0.9	-7	84
Netherlands	1.5	-1.6	2.6	1.4	-0.1	-1	145
Spain	-0.1	2.0	1.5	1.7	1.8	13	105
UK	**2.2**	**-1.2**	**0.5**	**0.0**	**-2.1**	**-16**	**100**
US	2.1	1.4	0.9	1.0	-1.0	-8	130

Source: *International Comparisons of Productivity - Final Estimates: 2014* , Office for National Statistics, February 2016

The weakness of UK productivity growth since the Great Recession, known as the UK's "productivity puzzle", has spurred a substantial amount of research into understanding its causes. While a number of explanations have been put forward, much is still not well understood. Bryson and Forth (2015) and Barnett et al. (2014) provide an overview of the evidence.

Some have suggested that the combination of increased downward flexibility in real wages (Gregg et al., 2014) combined with a credit supply shock has led firms to move towards less capital intensive forms of production (Pessoa and Van Reenen, 2014). However, others have provided evidence that a lack of investment and capital shallowing is unlikely to explain much of recent labour productivity weakness in the UK (Oulton, 2013; Goodridge, Haskel & Wallis, 2015). Rather, it would appear that the weakness of UK labour productivity growth in the 6 years after the crisis is mainly explained by a sharp reduction in the rate of TFP growth.

Part of the weakness in labour productivity and TFP growth is explained by developments in particularly exposed industries such as financial services. For example, Goodridge, Haskel & Wallis (2015) find that developments in the oil and gas sectors and financial services together can account for a third of the gap between actual and trend TFP that opened up between 2007 and 2011. Nonetheless, it is also evident that many other sectors have experienced a slowdown in labour productivity growth since the financial crisis (Riley & Rosazza Bondibene, 2016).

Measurement error has been suggested as another factor that may have contributed to the UK productivity puzzle. A number of limitations in measuring the modern economy are highlighted in a recent review of UK economic statistics (Bean, 2016). In particular, the Bean review suggests that the failure to take into account new

features of the 'digital' economy[51] mean that official data may underestimate economic activity. On a similar topic, Cette et al. (2015) suggest that mismeasurement of quality of ICT may have led to labour productivity growth being underestimated (although by the same argument TFP may be overestimated). Others have conjectured that mismeasurement of import prices may have exacerbated mismeasurement of labour productivity in the UK relative to the US. This is related to the issue of single versus double deflation. Current practice by the UK central statistical office is to estimate real value added using a single deflation method. As pointed out in Bean (2016), this may give rise to potential distortions in estimating both aggregate real GDP and the relative contribution of each industry to aggregate real GDP. While these measurement issues may help explain the softening of productivity growth between the early 2000s and more recent years, it is difficult to see that this could explain the marked shift in productivity growth after 2007.

Another popular hypothesis has been that the financial crisis led to inefficient resource reallocation across companies. For example, Barnett *et al.* (2014) suggest inefficient resource reallocation may explain a substantial part of recent productivity weakness in the UK. Analyses of firm-level data suggest there is some evidence that impaired resource allocation, for example due to credit constraints or uncertainty, may have reduced labour productivity growth somewhat (Riley *et al.*, 2015). However, such factors do not obviously explain a lot of the UK productivity puzzle. Indeed, Riley *et al.* (2015) find that widespread productivity weakness within firms, rather than a shift in the structure of the business population within industries, accounts for most of the productivity puzzle and suggest this points to a common factor driving recent trends. Franklin, Rostom & Thwaites (2015) suggest financial constraints during the recession led to sharp reductions in productivity within firms, but perhaps unintuitively this effect partly comes about via increases in employment.

In this section we shed further light on the underlying causes of the UK productivity puzzle, focusing in particular on the misallocation hypothesis and the extent to which lack-lustre investment and capital-shallowing (versus a reduction in TFP growth) can explain labour productivity weakness. In moving beyond labour productivity we consider the contributions of a lack of investment and capital shallowing to the recent demise in UK labour productivity alongside TFP. While recent work points to TFP as the main "cause" of UK labour productivity weakness at the aggregate level, the derivation of firm level measures of capital and TFP lets us explore these issues further. In particular, we examine trends in allocative efficiency and reallocation in the UK much as in previous sections for European countries more widely. We examine the Olley-Pakes covariance measure between firm size and productivity as well as other measures of productivity dispersion. We also examine the dynamic

[51] For example: the movement of market activities such as travel agents into home-production, the increased sharing of skills and assets facilitated by the use of digital technologies, and the increased importance of investment in intangible knowledge-based assets.

Diewert-Fox decompositions for the UK. The data available for the UK is more suited to this than the company accounts data that is used in other sections.

Relative to previous UK work we provide new evidence by examining trends in misallocation and TFP; most work on misallocation in the UK considers labour productivity rather than TFP. The analysis in this section complements the analysis in previous sections, providing a comparison (for the UK only) of trends using an alternate firm level data source (one which is more easily weighted to be representative of the UK business population) and by considering dynamic decompositions rather than static decompositions alone.

8.1. Methodology

There are a number of empirical approaches to the decomposition of productivity levels and growth rates available in the literature. These enable us to explore the extent to which specific groups of firms contribute to productivity performance over time. Firms are usually identified as those that enter, those that exit and continuing firms in the market.

As in previous sections we first explore developments in the efficiency of resource allocation or "allocative efficiency" as measured by the Olley-Pakes (OP) covariance term between firm size and productivity within sectors (Olley & Pakes, 1996). This is calculated as the difference between the market share-weighted sum of firms' (log) productivity within the sector and the simple average of (log) productivity across firms within the sector.

Next we turn to the decomposition of productivity *growth*. Riley *et al.* (2015) suggest the commonly used growth decompositions of Foster, Haltiwanger & Krizan (2001) and Griliches & Regev (1995) may be particularly misleading when productivity growth moves between growth and stagnation phases and will tend to exaggerate changes in the productivity growth contribution of resource reallocation between such phases. The productivity growth decomposition of Melitz & Polanec (2015) provides a dynamic counterpart to the static OP decomposition, but is less robust in small samples. Therefore they use a decomposition method first proposed by Diewert & Fox (2010) (hereafter DF), which is essentially a hybrid of the extended Griliches & Regev (1995) decomposition reported in Baily, Bartelman & Haltiwanger (2001) and the MP decomposition.

We write aggregate productivity at time *t* (Π_t) as a weighted average of the level of productivity of individual firms (π_{it}):

(8.1) $$\Pi_t = \sum_i s_{it}\pi_{it}$$

where weights s_{it} measure firm *i*'s market share at time *t*, $s_{it} \geq 0$ and $\sum_i s_{it} = 1$. Continuing firm *i*'s share of the market of continuing firms is written as $s_{Cit} = \frac{s_{it}}{\sum_{i \in C} s_{it}}$, where $\sum_{i \in C} s_{Cit} = 1$. We then decompose the change in aggregate productivity between time *t-k* and time *t* as:

(8.2)
$$\Delta\Pi_t = \sum_{i\in C} \overline{s}_{Ci}\Delta\pi_{it} + \sum_{i\in C} \Delta s_{Cit}(\overline{\pi}_i - \overline{\Pi}_C) + \sum_{i\in N} s_{it}(\pi_{it} - \Pi_{Ct}) - \sum_{i\in X} s_{i,t-k}(\pi_{i,t-k} - \Pi_{C,t-k})$$

where a bar above a variable denotes an average across time *t* and time *t-k*, and where $\Pi_{Ct} = \sum_{i\in C} s_{Cit}\pi_{it}$ is the share weighted average of productivity for continuing firms only, equivalent to aggregate productivity for this subset of firms. In (8.2) the first sum is the within component and the second sum the between component, which is positive if firms that are on average more (less) productive over the two periods (time *t* and time *t-k*) gain (lose) market share. The last two sums in (8.2) measure the productivity contributions from entry and exit respectively. The contribution to aggregate productivity growth of entrants (exitors) is positive if their productivity exceeds (is less than) the average productivity at time *t* of incumbents (at time *t-k* of survivors). (Note, we weight these formulas with appropriate sampling weights.)

8.2 Data

The main data source we use for the decomposition analysis is the Annual Respondents Database (ARD), which pulls together information from the Inter-Departmental Business Register (IDBR), Annual Business Inquiry, Annual Business Survey and the Business Register Employment Survey (BRES). The ARD holds information on the nature of production in British establishments and is essentially a census of larger establishments and a stratified random sample of establishments with less than 250 employees. Details of the ARD data can be found in Bovill (2012), and additional discussion is available in Riley & Rosazza Bondibene (2016). The ARD is the prime source of data used to study firm-level productivity patterns in the UK. One benefit of these data is that they can be weighted to be nationally representative.

The sampling frame for the ARD is the IDBR, a list of all incorporated businesses and other businesses registered for tax purposes. The ARD includes basic information (e.g. industry, ownership structure, and indicative employment) for all establishments in the sampling frame. These population data allow us to determine entry and exit, which cannot be calculated from the surveyed sample alone (Disney *et al.*, 2003), and allow us to calculate grossing weights.[52]

We undertake our analysis at the level of the reporting unit, which is the sampling unit. This is similar to the unit of analysis used in many other studies. Note that

[52] It is important to proxy with the micro-data the aggregate trends we ultimately wish to examine. Note that limitations of the data require us to use different sampling weights for the longitudinal and cross-sectional elements of the data. We avoid extreme weights by aggregating up sampling cells. Even so, it is often not possible to proxy trends in more detailed sectors.

reporting unit identifiers may change with ownership changes so that entry and exit of reporting units might reflect genuine market entry or exit, but might also reflect mergers and acquisitions that appear as changes within and between continuing plants or holding companies.

We focus on reporting units with 10 or more employees, in part because available information on employment is less adequate for very small firms[53] and because longitudinal sampling probabilities are very small for this group.

The ARD covers businesses in the non-financial non-agricultural market sectors. The ARD includes partial coverage of the agricultural sector (we exclude these businesses) as well as businesses in "non-market" service sectors such as education, health and social work. As in similar analysis for the UK we exclude businesses in these latter sectors where inputs and outputs are thought not to be directly comparable, making productivity analysis difficult to undertake. We also exclude businesses in the mining and quarrying, and utilities sectors (typically very large businesses with erratic patterns of output) and in the real estate sector, where output mostly reflects imputed housing rents.[54] Data are available for these market sectors 1997-2013.[55]

The survey contains financial information in current values. In order to construct estimates of real productivity we use GVA deflators available at the 2- and 3-digit sector level.

Unlike the Company Accounts data, the business survey does not include measures of firms' capital stocks. It does however have detailed information on investment. In order to construct measures of TFP we therefore need first to construct measures of firms' capital stocks using available information on firms' capital investments. We do this using a standard PIM model. We then derive estimates of firms' capital services in order to derive firm-level TFP.

The survey contains information on capital acquisitions and disposals of several assets: buildings & land; software; plant, machinery & equipment. This asset detail is imputed for some smaller (less than 250 employees) firms. In using the PIM to calculate firm-level capital stocks for each of these asset classes we derive starting stocks based on sector level capital intensity. We interpolate missing net investment values (recall that firms appear in the survey with gaps) using a simple straightline interpolation of real investment. Investment deflators by asset type and sector are derived from published data on constant and current price gross-fixed capital formation. Depreciation rates are informed by EUKLEMS and Oulton & Wallis, 2015. Where negative capital stocks result from these calculations we re-calibrate the PIM.

[53] In particular, the employment information for these firms may be several years out of date, affecting measured productivity and market shares.
[54] The data available are coded to SIC03 before 2008 and to SIC07 from 2008 onwards. This leads to some discontinuity in the data series we are able to derive.
[55] A preliminary version of the data for 2014 is also available, but we do not use this as differences in results derived from preliminary and final versions of the data are in some cases non-negligible.

In deriving TFP we need to construct an index of capital services, which we do by weighting together for each firm the firm-level stock of each asset (buildings; software; plant, machinery & equipment). Weights used in this calculation are derived at the industry-level and measure the share of services from a particular asset in the total asset flow. These are derived using published information on industry level capital stocks and an estimate of the user cost of capital.[56]

We then measure total factor productivity (TFP) as in previous sections using a Solow approach. Note that estimates of firms' capital stocks are particularly sensitive for young (i.e., entering) firms. This is because for these firms capital stock estimates are particularly sensitive to the estimate of starting stocks. Hence, TFP estimates are similarly sensitive for these firms. Note also that derived measures of TFP at the level of the firm cannot take into account the effect on labour productivity growth of changes in labour composition (these are not thought to explain recent UK productivity weakness; Rincon-Aznar et al. 2015) and average hours.

8.3 Results

Table 8.2 illustrates the aggregate trends that can be derived from the micro-data that we use. We show these for the market sector as a whole and separately for manufacturing, market services and the construction sector. We show annualised growth over three year periods (2001-2004, 2004-2007, 2007-2010, 2010-2013) in capital services per worker, GVA per worker and TFP.

Capital services per worker rose by on average 2.8% per annum in the market sector in the 6 years before the financial crisis (2.4% 2002-2004 and 3.2% 2005-2007), and less thereafter. This pattern was particularly evident in the manufacturing and the construction sectors, where building and plant, machinery and equipment assets are more dominant than in services. In terms of labour productivity profiles, the data suggests relatively strong growth during the years before 2008. Labour productivity growth rates in Table 8.2 are higher than for the whole economy in Table 8.1, partly reflecting different sector coverage and different data sources. But, the patterns in the micro-data show the familiar stall in productivity after 2007. These data show a reduction in average annual labour productivity growth of around 3%-points after 2008. This shift is larger in magnitude in the manufacturing and construction sectors than in market services. The bottom panel in Table 8.2 shows the patterns of TFP growth in our data. The data exhibit a sharp drop in annual TFP growth on average 2008-2013 compared to 2002-2007. We also show the share of the change in labour productivity growth post 2007 associated with the change in TFP growth. The data suggest that 4/5 of the change in labour productivity growth in the market sector was

[56] In deriving the user cost of capital we use an external rate of return as given by 10-year bond yields. Asset deflators by asset type and sector are derived from ONS published data on the current and constant price value of capital assets. We use tax adjustment factors published in Oulton & Wallis (2015).

accounted for by a reduction in TFP growth. The drop in TFP growth accounts for less of the drop in labour productivity growth in the manufacturing and construction sectors than in market services. In these sectors the reduction in investment and slowdown in the growth of capital services per employee accounted for more of the labour productivity slowdown. It is possible that these sectoral differences partly reflect sectoral differences in the importance of unmeasured intangible assets.

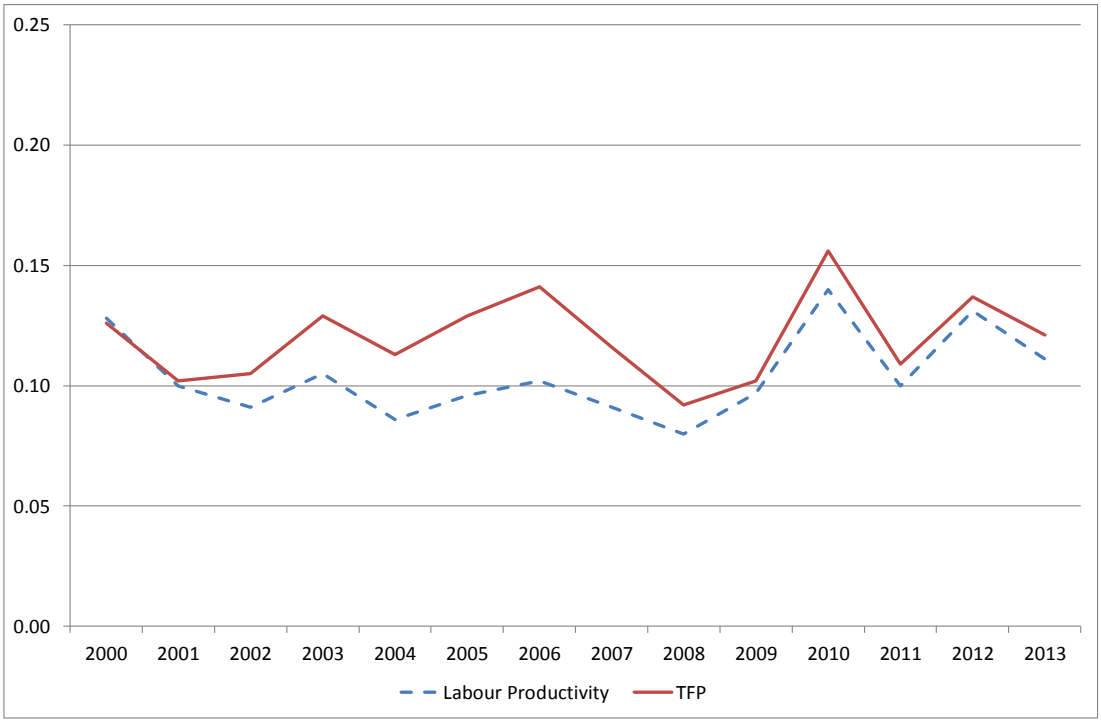
Table 8.2 Aggregate trends in productivity derived from business microdata

	Market sector	Manufacturing	Market services	Construction
Capital Services per worker				
2002-2004	0.024	0.048	0.019	0.028
2005-2007	0.032	0.058	0.022	0.079
2008-2010	0.014	0.027	0.020	-0.042
2011-2013	0.007	-0.016	0.017	0.008
Change after 2007	-0.017	-0.048	-0.002	-0.070
GVA per worker				
2002-2004	0.024	0.073	0.011	0.017
2005-2007	0.052	0.055	0.059	0.039
2008-2010	-0.002	0.028	-0.007	-0.026
2011-2013	0.013	-0.013	0.024	0.002
Change after 2007	-0.033	-0.057	-0.027	-0.040
TFP				
2002-2004	0.016	0.056	0.005	0.007
2005-2007	0.041	0.035	0.051	0.011
2008-2010	-0.007	0.019	-0.014	-0.011
2011-2013	0.010	-0.008	0.018	-0.001
Change after 2007	-0.027	-0.040	-0.026	-0.015
Share of LP change associated with TFP	0.82	0.71	0.98	0.38

Source: Annual Respondents Database and author's calculations. Market sector includes market services, manufacturing and construction. Financial services and real estate excluded from market services.

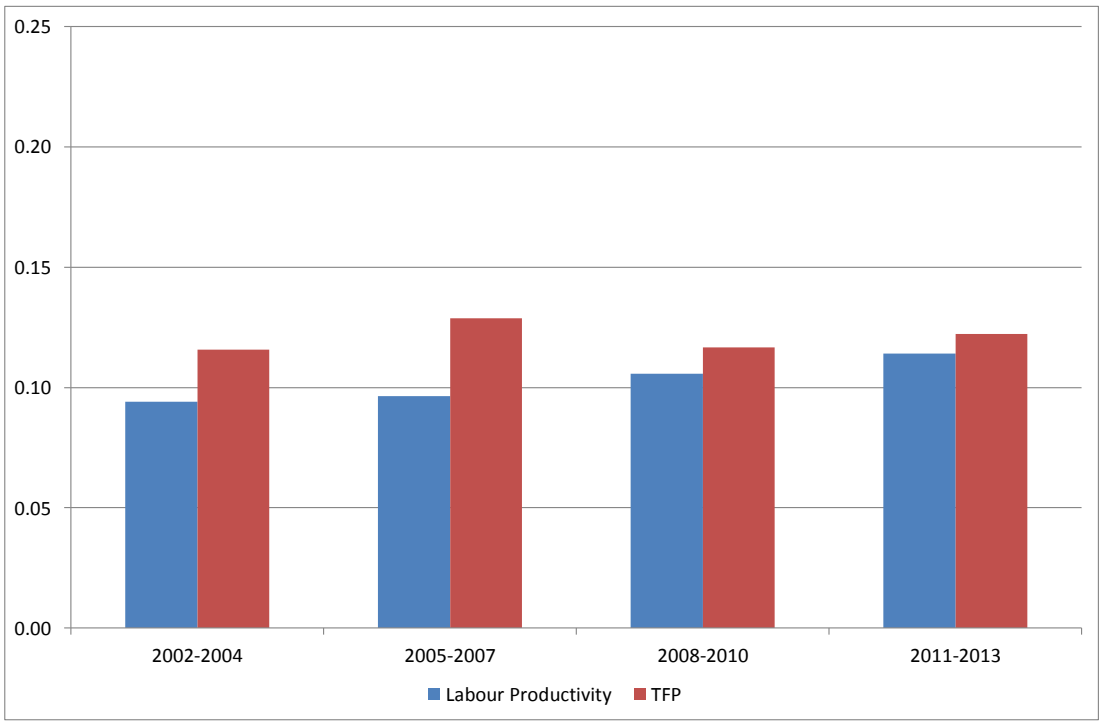
Figure 8.1 illustrates the Olley-Pakes covariance term between firms' market share and productivity levels in the UK market sector. We show this covariance for both a labour productivity and a TFP index. Market shares are measured using employment shares. The Olley-Pakes covariance term suggests there is a positive covariance between labour productivity levels and market share or firm size. The covariance between market share and TFP levels is slightly higher than between market share and labour productivity levels. On average there is little difference in allocative efficiency, as measured here, before and after 2007/8. In Figure 8.2 we present the data as 3-year averages, which are less erratic. The OP covariance term for labour productivity rises a little over time, whereas the OP covariance term for TFP does not follow any trend. There is no evidence of a significant drop in allocative efficiency since 2007 on either productivity measure. This is consistent with the evidence in

Figure 8.1 Olley-Pakes covariance term between market share and productivity (Market sector)



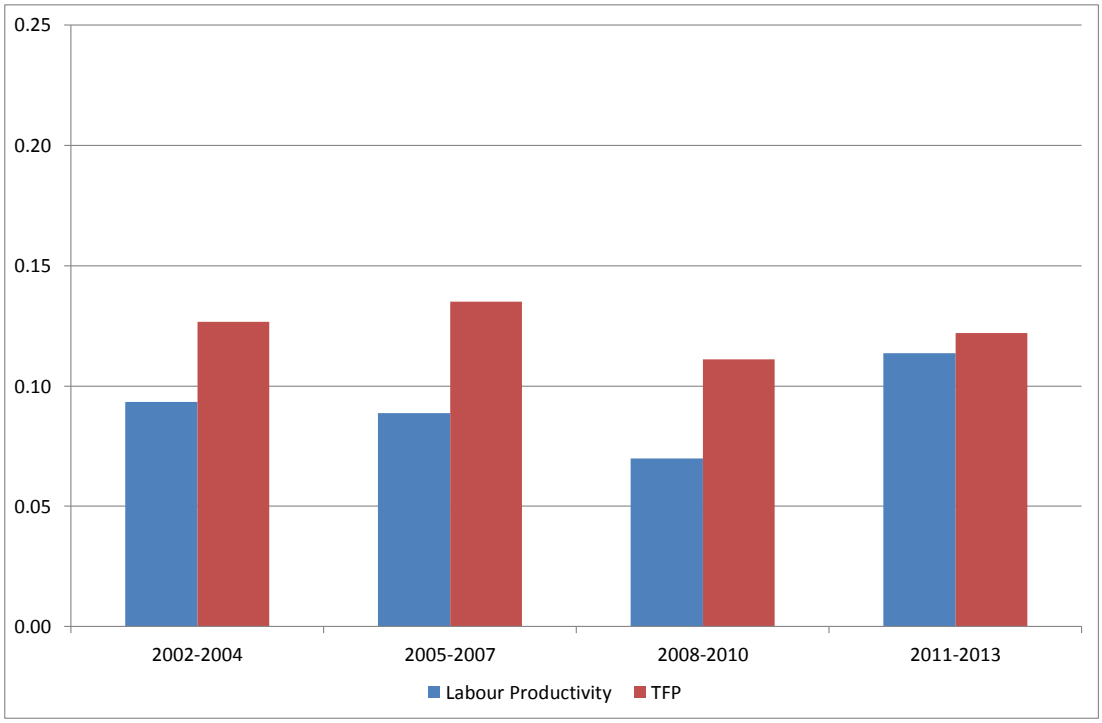
Source: Annual Respondents Database and author's calculations. Market sector includes market services, manufacturing and construction. Financial services and real estate excluded from market services.

Figure 8.2 Olley-Pakes covariance term between market share and productivity (Market sector, 3 year averages)



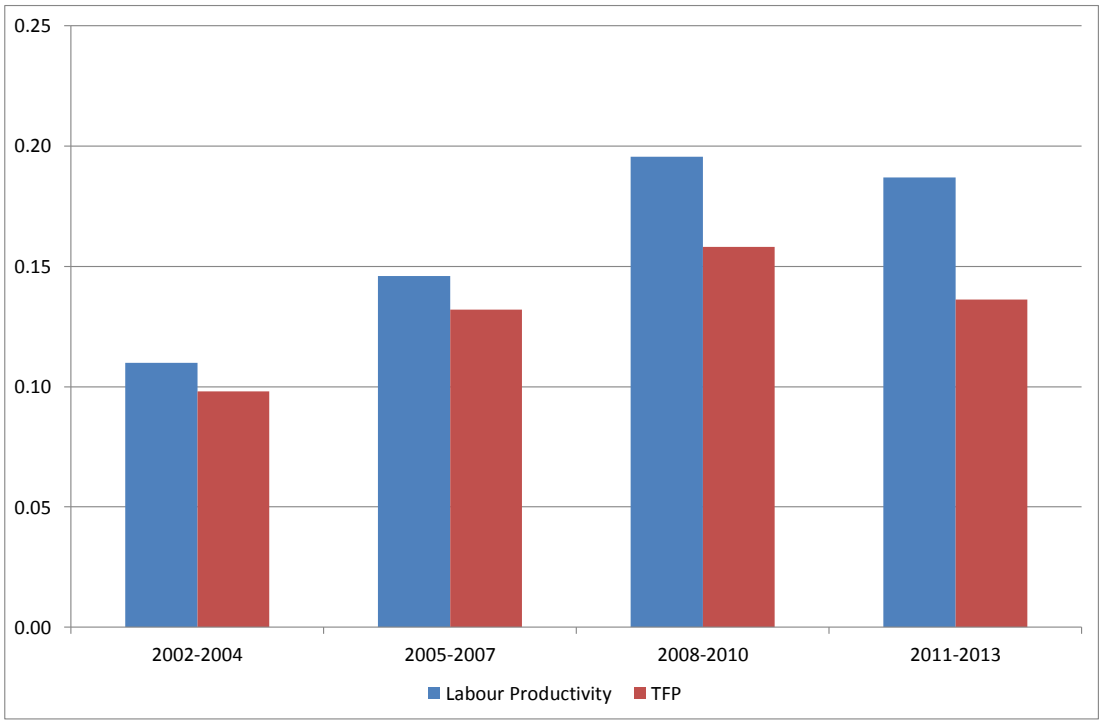
Source: Annual Respondents Database and author's calculations. Market sector includes market services, manufacturing and construction. Financial services and real estate excluded from market services.

Figure 8.3 Olley-Pakes covariance term between market share and productivity (Market services, 3 year averages)



Source: Annual Respondents Database and author's calculations. Financial services and real estate excluded.

Figure 8.4 Olley-Pakes covariance term between market share and productivity (Manufacturing, 3 year averages)



Source: Annual Respondents Database and author's calculations.

0Riley and Rosazza Bondibene (2016) for labour productivity and in previous sections of this report for TFP.

In Figure 8.3 we illustrate the labour productivity and TFP Olley-Pakes terms for market services. On average, the Olley-Pakes covariance term between size and TFP is slightly lower after 2007 than before, although these differences are small. The Olley-Pakes covariance term between size and labour productivity is little different on average 2002-2007 and 2008-2013, but shows a slight dip in 2008-2010, before rebounding 2010-2013.[57]

In Figure 8.4 we illustrate these measures of allocative efficiency for the manufacturing sector. Here, in contrast to market services, the covariance between size and productivity is greater for labour productivity than TFP. This may partly reflect a positive covariance between tangible capital intensity and firm size. Again there is no evidence that allocative efficiency should have deteriorated since the financial crisis.

In Tables 8.3 and 8.4 we show the Diewert-Fox decomposition of productivity growth as measured by a labour productivity and TFP index, respectively. The sample of firms that we can use for this dynamic decomposition is different (and smaller) than the sample we use to illustrate aggregate trends in the data and that underlie the Olley-Pakes covariance terms illustrated above. Therefore, the trends in the data shown in Tables 8.3 and 8.4 are slightly different than shown in Table 8.2.

Table 8.3 Diewert-Fox decomposition of labour productivity growth

	Total	Within	Between	Entry	Exit	Continuing firms	Net entry	Reallocation
Market sector								
2001-2007	0.204	0.128	0.040	0.006	0.031	0.168	0.036	0.076
2007-2013	-0.004	-0.057	0.045	-0.021	0.030	-0.012	0.009	0.053
2007-2013 less 2001-2007	-0.208	-0.185	0.005	-0.027	-0.001	-0.180	-0.028	-0.023
Market services								
2001-2007	0.172	0.103	0.044	0.005	0.021	0.147	0.026	0.069
2007-2013	0.005	-0.051	0.047	-0.024	0.032	-0.004	0.008	0.055
2007-2013 less 2001-2007	-0.168	-0.153	0.003	-0.028	0.011	-0.150	-0.017	-0.014
Manufacturing								
2001-2007	0.324	0.241	0.024	0.015	0.044	0.265	0.059	0.083
2007-2013	-0.045	-0.094	0.034	-0.007	0.023	-0.061	0.016	0.049
2007-2013 less 2001-2007	-0.369	-0.335	0.010	-0.022	-0.022	-0.325	-0.044	-0.034

Source: Annual Respondents Database and author's calculations. Market sector includes market services, manufacturing and construction. Financial services and real estate excluded from market services.

[57] This pattern over time in the OP term for labour productivity in market services is slightly different to that in Riley and Rosazza-Bondibene (2016). Differences arise because of differences in the deflators used and in the cross-walk used between SIC03 and SIC07.

Table 8.4 Diewert-Fox decomposition of TFP growth

	Total	Within	Between	Entry	Exit	Continuing firms	Net entry	Reallocation
Market sector								
2001-2007	0.247	0.179	0.062	-0.023	0.030	0.241	0.006	0.068
2007-2013	0.022	-0.018	0.059	-0.031	0.012	0.041	-0.019	0.040
2007-2013 less 2001-2007	-0.226	-0.197	-0.003	-0.007	-0.018	-0.201	-0.025	-0.028
Market services								
2001-2007	0.244	0.188	0.068	-0.030	0.018	0.256	-0.011	0.057
2007-2013	0.027	-0.009	0.061	-0.034	0.009	0.052	-0.025	0.036
2007-2013 less 2001-2007	-0.218	-0.197	-0.007	-0.004	-0.010	-0.204	-0.014	-0.021
Manufacturing								
2001-2007	0.306	0.223	0.042	-0.002	0.043	0.266	0.041	0.083
2007-2013	-0.026	-0.074	0.038	-0.012	0.023	-0.037	0.011	0.049
2007-2013 less 2001-2007	-0.332	-0.298	-0.005	-0.009	-0.021	-0.302	-0.030	-0.034

Source: Annual Respondents Database and author's calculations. Market sector includes market services, manufacturing and construction. Financial services and real estate excluded from market services.

In Table 8.3 we see that labour productivity in our (weighted) sample rose by around 20% between 2001 and 2007 in the UK market sector. This increase is then decomposed into the contribution of productivity growth within surviving or continuing firms, reallocation between continuing firms, entry and exit. The latter three terms sum to the contribution of resource reallocation to total productivity growth. Between 2001 and 2007 around two fifths of the change in labour productivity (7.6%-points) came about via the reallocation of resources across the business population. The rest of aggregate labour productivity change arising through the improvement of labour productivity within surviving businesses.

We also see in Table 8.3 that between 2007 and 2013 there was no change in labour productivity in the market sector in our weighted sample, consistent with other evidence. The contribution of resource reallocation to aggregate productivity growth was positive over this period, albeit slightly less than over the period 2001-2007 at 5.3%-points because of a fall in the contribution of firm entry. The stagnation in aggregate productivity growth was very much accounted for by the lack of productivity growth within existing firms; indeed in this sample we find that productivity within surviving businesses actually dropped. This pattern in evident in both manufacturing and market services and has been highlighted elsewhere (see e.g. Riley & Rosazza Bondibene, 2016).

In Table 8.4 we consider the decomposition of TFP in this same weighted sample. Here we see a similar pattern when attempting to account for the fall in productivity growth before and after 2007. The decline in TFP growth is of a similar magnitude to the decline in labour productivity growth and most of this change is driven by the lack of TFP growth within surviving businesses 2007-2013. This pattern is replicated in manufacturing and market services. When we look at TFP we do see that the decline in the contribution of net entry to aggregate productivity growth appears to be more

associated with a decline in the contribution of firm exit than a decline in the contribution of firm entry. We note, however, the additional difficulties in accurately capturing TFP for entrants, where assumptions about starting stocks are important.

8.4 Discussion

The analysis in this section complements the analysis of allocative efficiency in previous sections by providing evidence based on another data source; importantly one that is nationally representative of the UK business population. It extends existing UK research, by providing evidence on allocative efficiency before and after the financial crisis in relation to TFP.

The findings here clearly suggest that the correlation between firm size and TFP levels is positive; the allocation of more resources to more productive firms boosts aggregate productivity levels. The dynamic analysis also suggests that around a third of TFP growth over the six years before the global financial crisis was accounted for by changes in the distribution of resources across the business population; the reallocation of resources towards more productive surviving businesses and the reallocation of resources from exiting towards new businesses. This positive contribution of business demographics towards aggregate productivity is in keeping with international evidence and points towards the potential importance of policy in ensuring that these demographic forces are allowed to operate.

Perhaps more interesting is the lack of any strong evidence in the analysis here that the efficiency of resource allocation or reallocation should have substantially contributed to the demise of aggregate TFP growth in recent years. This is consistent with the evidence presented using alternative datasets for the UK in earlier sections and with the evidence there presented for other European countries. It is also consistent with existing evidence from aggregate data, which suggests that a lack of TFP growth accounts for most of the stagnation in UK labour productivity growth, and with existing evidence from micro-data, which suggests that most of the decline in labour productivity growth stems from a lack of growth within existing firms.

This is not to say that there has been loss at all in terms of the efficiency of resource reallocation arising with the credit constraints and uncertainty presented by the global financial crisis. Clearly, for some smaller firms factors such as credit constraints are likely to have hampered growth opportunities in the wake of the crisis. Indeed, the analysis here suggests that after 2007 entering firms have been relatively less productive compared to surviving firms than before, therefore reducing more or adding less to aggregate productivity growth. This picture is more evident when we look at labour productivity than when we consider TFP, which would be consistent with a story where access to capital became more difficult for entering firms after the crisis; again we stress the added difficulty of measuring TFP for new

firms. Such evidence may point to a role for policy in ensuring market entry can take place unimpeded. However, the evidence here suggests such policies would not address the key factors underlying the UK productivity puzzle.

The analysis in this section also suggests there may be sectoral differences in the extent to which capital shallowing can account for the weakness of UK labour productivity growth since 2007; although we would point out that some of the observed sectoral differences may arise due to difficulties in the measurement of intangible capital services. We find that capital shallowing has played a more important role in labour productivity weakness in the production industries compared to service sector industries. In market services TFP weakness appears to account for most of the change in labour productivity growth. In manufacturing and construction the slowdown in investment per worker has gradually led to a more pronounced reduction in the contribution of capital deepening towards labour productivity growth.

9. Summary of findings

The main findings of this research can be summarised as follows:

- All the EU countries analysed in this study exhibit positive levels of allocative efficiency during the period 2003-2014, consistent with previous evidence. This suggests that reallocation of resources can play an important part in explaining cross-country differences in levels of productivity. However, caution is needed in drawing conclusions as our data present some important limitations in terms of national representativeness, coverage and comparability.

- The degree of productivity-enhancing resource allocation appears larger on average at the beginning of the 2000s than in the latter part of the period. Overall we find that on average allocative efficiency has not changed to a great extent in the EU as a whole since the start of the recession, although results suggest that it has seen a small decrease over the last few years. This is not universal however, and there are significant differences across countries. Some of the economies presenting higher levels of allocative efficiency include Hungary, Poland, Bulgaria, Belgium and Spain.

- We also find some key differences across industries. When considering broad industry groups, on average we find that manufacturing industries experience lower levels of allocative efficiency than (market) services industries. Only in the other production industries (utilities, construction) of some countries do we obtain negative estimates of allocative efficiency.

- Our analysis of TFP inequality reveals that the level of inequality among EU firms has increased significantly since 2007. We also find that despite the existing differences in TFP across countries, these appear lower than those existing within countries or size groups. The industry dimension also appears fairly important, and the levels of dispersion of productivity appear higher in services than in manufacturing sectors.

- In terms of the characterisation of the technology frontier, we find that firms at the EU productivity frontier are typically older, although this applies mainly in the manufacturing sector. They are also larger in some industries, but not in all . Overall we observe that the average size of frontier and non-frontier firms has decreased since the crisis in many industries, but it appears that EU frontier firms in manufacturing have been more resilient.

- When considering the national frontier, instead we find that firms at the national productivity frontier are relatively younger, both in manufacturing and services. In terms of size, we find that the average firm size of national frontier firms has decreased since the crisis, and our results suggest that national frontier firms have been less resilient to the crisis than the EU counterparts. In general frontier firms are more profitable than non-frontier firms, and those in manufacturing have performed particularly well after the crisis.

- We find that there is a considerably degree of persistence both in the status of frontier and non-frontier firms, in particular in relation to the EU space. The average exit rates from frontier to non-frontier status substantially exceeded the entry rates from non-frontier to frontier, and the transition rates from frontier to non-frontier status have been reduced in the post-crisis period.

- We investigate the main factors that determine a firm's relative position to the frontier. We find that size and workforce skills help decrease the distance to the frontier. Firm age seems to increase the distance to the frontier, but this is less so since the crisis, although this is not the case in manufacturing.

- At the firm level we still find that firms that are far from the frontier experience slower TFP growth. We also find that R&D policies yield within firm productivity improvements for the national frontier firms, and that this may lead to productivity effects for the overall economy.

- While we find that TFP levels tend to diverge across EU economies, there is also evidence of greater TFP growth in those countries with lower initial levels of TFP, especially after 2007. We find evidence of TFP beta-convergence among EU countries. Some conditioning variables, that proxy for structural differences across countries, play a role. We find evidence that conditional-beta convergence

in TFP is greater than unconditional beta convergence, as convergence is greater among similar countries. We estimate that the implied speed of annual convergence is about 5 per cent per year, although it is higher in the post-crisis period. Some of the indicators with a greater role in promoting TFP growth are R&D intensity along with some indicators of governance quality.

- We also review a recently developed body of literature which focuses on the influence of misallocation on aggregate productivity, and which links this to public policy. We find that policies in labour markets, product markets and financial markets all have a potential role to play in promoting allocative efficiency. The most evident case is perhaps that of labour market regulations governing firing taxes, and in the case of the product market regulations governing market entry. Here, a range of studies have shown that countries can obtain sizeable gains in TFP by lowering these barriers to market adjustment.

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DATA ANNEX

A.1 Data sources

The Amadeus database

The work undertaken on the Amadeus database has allowed us to obtain a sample that can be reliably used for the descriptive and regression analysis. All the variables necessary for the construction of the TFP indicator have been computed, either directly from the information available or by imputations. Here we provide details on the type of imputations and assumptions we have applied.

We largely follow Gal (2013), who proposes a thorough methodology for the imputation of a number of key variables to ensure that the computation of TFP is feasible for the largest number of companies possible (see also Gonnard and Ragoussis, 2013). They propose the use of other information contained in Amadeus in combination with a range of external industry-level data sources (such as OECD’s STAN). These imputations significantly improve the original coverage of Amadeus. As a check on the reliability of the imputation approach followed, we are able to compare the TFP measures derived using imputed values with those that do not require the use of imputed values, for some countries with good data coverage.

We also provide some useful information with regards to our sample composition. Table A.1 provides information on the characteristics of the list of industries covered, as well as on the availability of variables for the calculation of TFP (both in its un-weighted and population-weighted versions). Tables A.5 to A.11 provide information

on the size and coverage of the TFP sample. Tables A.5 and A.6 show the number of firms for which it is feasible to construct TFP indicators, as well as the employment accounted for by these firms. The sample comprises approximately 1.3 million firms and accounts for 38 million employees (in those years with highest coverage). The employment covered is approximately 27% of total employment in the EU (Table A.7), although there is a large variation across countries. Reassuringly, our sample is largely coherent with that in Gal (2013) for the overlapping countries. Tables A.8-A.10 show similar information to tables A.5-A.7, on an industry-by-industry basis. Finally, table A.11 includes a count of firms by industry and country for the most recent year available (2014).

The under-representation of smaller and younger firms is a limitation which we aim to overcome with the use of re-sampling weights (based on administrative sources). To ensure comparability of productivity measures across countries and over time, currency conversion based on PPPs and deflation are also applied.

The EFIGE database

Specifically, the EFIGE dataset covers over 14,000 manufacturing firms. However, data on productivity are only available for about half of the sampled firms. Productivity indicators have been obtained by matching the original EFIGE sample with information drawn from company balance sheets (Amadeus dataset). Levels of total factor productivity (TFP) are computed as a Solow residual, assuming a Cobb Douglas production function and using the semi-parametric procedure as devised by Levinsohn and Petrin (2003)[58]. In the earliest release, TFP data were available up to 2008; however, as a recent development, Bruegel has extended such series until 2014 and these will be employed in our regression analysis.

UK's Annual Respondent Database

The main data source used for the decomposition analysis is **the Annual Respondents Database (ARD),** which pulls together information from the Inter-Departmental Business Register (IDBR), Annual Business Inquiry, Annual Business Survey and the Business Register Employment Survey (BRES). The ARD holds information on the nature of production in British establishments and is essentially a census of larger establishments and a stratified random sample of establishments with less than 250 employees. Details of the ARD data can be found in Bovill (2012), and additional discussion is available in Riley and Rosazza-Bondibene (2016).

The sampling frame for the ARD is the IDBR, a list of all incorporated businesses and other businesses registered for tax purposes. The ARD includes basic information (e.g. industry, ownership structure, and indicative employment) for all establishments in the sampling frame. These population data allow us to determine

[58] See Altomonte et al. (2012) for further details

entry and exit, which cannot be calculated from the surveyed sample alone (Disney *et al.*, 2003), and allow us to calculate grossing weights.

We undertake our analysis at the level of the reporting unit, which is the sampling unit. This is similar to the unit of analysis used in many other studies. Note that reporting unit identifiers may change with ownership changes so that entry and exit of reporting units might reflect genuine market entry or exit, but might also reflect mergers and acquisitions that appear as changes within and between continuing plants or holding companies.

The ARD covers businesses in the non-financial non-agricultural market sectors. The ARD includes partial coverage of the agricultural sector (we exclude these businesses) as well as businesses in "non-market" service sectors such as education, health and social work. As in similar analysis for the UK we exclude businesses in these latter sectors where inputs and outputs are thought not to be directly comparable, making productivity analysis difficult to undertake. We also exclude businesses in the mining and quarrying, and utilities sectors (typically very large businesses with erratic patterns of output) and in the real estate sector, where output mostly reflects imputed housing rents. Data are available for these market sectors 1997-2013 (a preliminary version of the data for 2014 is also available).

We measure total factor productivity (TFP) as in previous sections using a Solow approach. Unlike the Company Accounts data, the ARD does not include measures of firms' capital stocks. In order to construct measures of TFP we therefore need first to construct measure of firms' capital stocks using available information on firms' capital investments. We do this using a standard PIM model. Estimates of firms' capital stocks are particularly sensitive for young (i.e., entering) firms. This is because for these firms capital stock estimates are particularly sensitive to the estimate of starting stocks. We discuss the sensitivity of our estimates to these initial assumptions.

A.2 Definition of variables and characterisation of the sample

The data required for the calculation of firm-specific TFP has been extracted from the commercial database Amadeus (Bureau van Dijk), containing financial information on around 21 million companies across the EU. Table A.1 shows details on the number of European Union firms included in the Amadeus database in the year 2012 (around 8.5 million firms).

Apart from balance sheet information, other firm-specific information includes, for example, the year of creation, the number of employees, the (self-reported) type of economic activity, stock prices, a number of corporate governance indicators, and details of international operations and multinational status.

Although a full 4-digit industry classification is available in Amadeus, the industry classification in this report is limited to the market non-farm/agricultural sectors[59] (see table A.2). This is dictated by the fact that we need to obtain price indices and data for employment by industries and size classes. Additionally, only unconsolidated statements are used to avoid double-counting. The main period of analysis is 2003-2014, although in 2003 and 2014 the coverage of the sample is significantly smaller. All EU Member States will be covered, although not uniformly throughout the period.

In the following paragraphs we describe both the variables and procedure to estimate TFP. We follow the Gal (2013) approach closely, which is at present the most detailed methodology available to create robust TFP indicators using Amadeus/Orbis data[60].

Value added (VA): Amadeus includes information on the VA variable defined as:[61]

VA= PL + DEPR +TAXA +INTE + STAF (Profit for period + Depreciation + Taxation + Interest paid + Cost of employees).

In Amadeus, a large proportion of firms do not report VA. Gal (2013) proposes a twofold procedure to impute VA, using other available information.[62]

1. Internal imputation of VA*(VA)^{I}* using variables in Amadeus only.

VA^{II} =Cost of employees (*STAF*) + EBITDA (*EBTA*)

2. External imputation of VA using other sources. We draw from Eurostat's National Accounts database[63] to estimate labour costs for those firms in Amadeus that do not report such information. To this end, the employment figures (of such firms in Amadeus) (*EMPL*) is multiplied by an estimate of the average labour costs per worker obtained from Eurostat. Two different average labour costs per worker are applied:

[59] The financial sector is not included in the sample either given that Amadeus dataset does not generally include banks, which at the core of most of European financial sectors. Therefore, the coverage would not representative of the industry as a whole. The sample does not include either NACE rev. 2 industries A, B and O to P due to the lack of information in Eurostat Structural Business Statistics to calculate sampling weights.

[60] Orbis is a global database also produced by Bureau van Dijk (including almost all countries in the world), which includes Amadeus data and other databases.

[61] Variables in italics refer to the original variables included in Amadeus.

[62] The imputation procedure allows recovering approximately 25% firms that do not have VA.

[63] Gal (2013) uses data from OECD's SDBS to estimate these values. However, in this study the OECD databases are replaced by Eurostat statistics given the fact that the objective here is to include all the EU member states.

a. Eurostat's National Accounts (*NA*) average ratio of total labour costs (compensation of employees) to total employees ($\overline{w}_{ktc}^{NA\ Eurostat}$) is applied to Eurostat firms in the corresponding year, country and industry.[64]

b. To account for differences in salaries within industries, a second procedure is applied. Firms' wage differentials from the NA industry average $\overline{w}_{ktc}^{NA\ Eurostat}$ are predicted using the information from those firms in Amadeus, for which data to calculate the wage per employee are available. That is, $\hat{w}_{iktc}^{AMADEUS} = w_{iktc}^{AMADEUS} - \overline{w}_{ktc}^{NA\ Eurostat}$ is estimated by estimating the following cross section models for each country, year and 2-digit industry. All these models are specified as a quadratic function of firm size, profit per employee, and age:

$$\hat{w}_{iktc}^{AMADEUS} = \beta_0 + \beta_1 size_{iktc} + \beta_2 size_{iktc}^2 + \beta_3 \left(\Pi / L\right)_{iktc} + \beta_4 \left(\Pi / L\right)_{iktc}^2 + \beta_5 Age_{iktc} + \beta_6 Age_{iktc}^2 + \beta_7 size_{iktc} \left(\Pi / L\right)_{iktc} + \beta_8 size_{iktc} Age_{iktc} + \beta_9 \left(\Pi / L\right)_{iktc} Age_{iktc} + u_{iktc} \quad \text{(A.4)}$$

Where *size* is the log of the number of employees (*EMP*), □*/L* is profits (*PL*) per employee (*EMP*) –as proxy for labour productivity– and *Age* is the age of the firm. The estimated values of $\hat{w}_{ktc}^{AMADEUS}$ are computed for all firms. Once the estimated mean deviation of average salaries is computed, the following average salary for each firm is calculated:

$$\hat{w}_{iktc}^{NA\ Eurostat\ ,AMADEUS} = \overline{w}_{ktc}^{NA\ Eurostat} + \hat{w}_{iktc}^{AMADEUS} \quad \text{(A.5)}$$

Given the two alternatives for the computation of average labour costs per employee, two externally imputed value added (VA^{EI}) indicators are defined:

$$\text{VA}^{\text{EI } a \text{ or } b\cdot} = w^{a \text{ or } b} * EMPL + \text{EBITDA } (EBTA) \quad \text{(A.6)}$$

where *a* and *b* refer to procedures *a* and *b* above for the external imputation and w^a and w^b refer to $\overline{w}_{ktc}^{NA\ Eurostat}$ and $\overline{w}_{iktc}^{NA\ Eurostat,AMADEUS}$, respectively.

The indicator of value added is therefore created as follows. First, the *A* variable is taken directly from Amadeus (when possible). If the *VA* figure is not available, the internal imputation is used. If the internal imputation is not feasible either, the external imputation *b* for the labour costs will then be used to create the indicator of VA. Finally, external imputation of labour costs will be used as a last alternative.

Nominal value added is transformed into real terms using the industry VA deflator from the National Accounts statistics. Table A.3 shows that VA deflators are available for all industries included in Table A.2 consistently across countries.

L: Employment. Employment is defined as the number of employees (*EMPL*).

[64] Average salary is calculated from NA instead of Eurostat Structural Business Statistics (SBS), the equivalent data to OECD's SDBS, because NA is harmonized in terms of NACE rev. 2 and Nace rev. 1.1.

s^L: Labour share. The shares of labour costs to value added are calculated with information from Eurostat NA information, available for 64 industries. The main advantage of NA statistics over SBS is that they are homogeneous in terms of the NACE rev. 2 classifications, and it is therefore not necessary to convert the data from NACE rev. 1.1 to NACE rev. 2. Two set of shares are defined: a) per industry-country, and b) per industry (common to all countries).

Table A.3 summarizes the availability of data on employment, compensation of employees, value added available in Eurostat's National Accounts.

K: Capital. As in Gal (2013) capital is calculated using the Perpetual Inventory Method (PIM). Capital for a firm *i* in year *t* is defined as:

$$K_{it} = K_{i,t-1}\left(1-\delta_{it}\right)+I_{it} \quad \text{(A.7)}$$

Real investment is defined as:

$$I_{it} = \left(K_{it}^{BV} - K_{it-1}^{BV} + DEPR_{it}^{BV}\right)/PI_t \quad \text{(A.8)}$$

where K^{BV} is the book value of tangible fixed assets (*TFAS*), $DEPR^{BV}$ is the book value of depreciation (*DEPR*) and PI is the Gross Fixed Capital Formation (GFCF) deflator at the industry level. The depreciation rate is defined as:

$$\delta_{it} = DEPR_{it}^{BV}/K_{it-1}^{BV} \quad \text{(A.9)}$$

Capital is calculated by applying the PIM starting in the first year (*t=0*) that the firm is included in the sample. The initial capital stock is calculated according to equation (A.10):

$$K_{i0} = K_{i0}^{BV}/PI_0 \quad \text{(A.10)}$$

Firms in Amadeus often do not report consistent information for K^{BV}, and there are many missing observations. When this is the case, the following adjustments are applied. For firm in a given year *t (*different to *t=0)*, when there is no data on capital in *t-1,* information on t-2 is used. If data on K^{BV} exists for *t-2*, K^{BV} for *t-1* is then interpolated using data for *t* and *t-2*. In the event that the gap is larger than two years, the data previous to *t* are discarded. The same criterion is applied to the book value of depreciation. Additionally, we reject observations where the depreciation is negative, where investment is equal or lower to 0 and where the investment is lower than the depreciation.

Gross fixed capital formation deflators at industry level are used to transform nominal values of investment into real terms. These deflators are obtained from Eurostat's National Accounts statistics. Table A.3 shows that GFCF deflators are available for all industries in all countries.

A.3 Deflation and derivation of comparable price levels (PPP):

All variables (X_{ikct}) in Amadeus are obtained in nominal thousands of euros. These figures are converted back to national (local) currencies by using the EXCHANGE_RATE variable in Amadeus (euro/local currency for country-year):

$$X_{ikct}^{local} = \frac{X_{ikct}^{\in}}{ER(\in / local)_{ct}} \qquad (A.11)$$

Then, nominal values for all firms in each country (*c*) are converted in 2010 real terms using the industry (*k*) deflators described above (P_{ktc}^{2010}):

$$X_{ikct}^{local,2010} = \frac{X_{ikct}^{local}}{P_{kct}^{2010}} \qquad (A.12)$$

where P_{kct}^{2010} is the deflator (with reference year *2010*) in year *t*, country *c* and industry *k*.

To achieve comparability over time and across countries, original currency-real values of each variable are transformed into international comparable 2010 PPP according to the following equation:

$$X_{ikct}^{\in,PPP2010} = \frac{X_{ikct}^{local,2010}}{PPP^{2010}} \qquad (A.13)$$

PPPs are obtained directly from Eurostat. Common PPPs are applied to all firms in a country regardless of the industry. Inklaar and Timmer (2014) present multilateral PPPs covering 35 industries in 42 countries for the year 2005, but these industries are grouped in seven categories (market economy, goods-producing, manufacturing, other goods, services, market services and non-market services) following NACE rev. 1. Inklaar and Timmer (2014) propose to aggregate the 35 industries into four groups (other goods, manufacturing, market services and non-market services) to convert PPPs into NACE rev. 2 classification. Instead of using these highly aggregated PPPs we choose to use country specific PPPs.

A.4 Applying weights

As in Gal (2013) sampling weights are introduced to minimize the under representativeness of small firms present in Amadeus. These weights are created using information from the Eurostat SBS database. A sampling weight is assigned for each firm-year observation in order to mimic the true structure of firms. A time-varying re-sampling weight (which is always greater or equal to one), is assigned to each firm in the sample. Thus we make sure that firms in Amadeus are not lost. The sampling weights will replicate the number of employees by country, industry, year and firm-size class. The sampling weights are created for each firm for which TFP is to be calculated.

The sampling weights for a firm *i* in a year *t* are defined as:

$$w_{it} = 1 + \left[\frac{L_{ckts}^{SBS} - L_{ckts}^{AMADEUS}}{L_{ckts}^{AMADEUS}} \right] + z_{it} \qquad \text{(A.14)}$$

Where *k* are industries, *c* countries, and *s* size classes,[65] [*x*] is the integer value smaller or equal to x, and z_{it} ={0,1} is a Bernoulli distribution with expected probability of success of:

$$\Pr(z_{it}) = \frac{\mathrm{mod}\left(L_{ckts}^{SBS}, L_{ckts}^{AMADEUS}\right)}{L_{ckts}^{AMADEUS}}, \qquad \text{(A.15)}$$

which can alternatively be expressed as:

$$\Pr(z_{it}) = \frac{L_{ckts}^{SBS}}{L_{ckts}^{AMADEUS}} - \left(1 + \left[\frac{L_{ckts}^{SBS} - L_{ckts}^{AMADEUS}}{L_{ckts}^{AMADEUS}} \right] \right) \qquad \text{(A.16)}$$

This procedure ensures that the weights are always higher than one, and that $E(w_{ij})=L_{ckts}^{SBS}/L_{ckts}^{AMADEUS}$, i.e. the expected value of the weights of all firms in a cell defined by the country,*industry*year*size class, is equal to the observed difference between the actual employment according to SBS and the one accounted for by the Amadeus sample.

Finally, re-sampling implicitly assumes that firms in Amadeus within a specific country*industry*year*sizeclass cell are representative of the true population within that cell. This is the justification for random replication of firms within cells. Re-sampling can correct for potential discrepancies between the true population and the Amadeus sample only across those cells. However, it cannot correct for potential selection bias concerning the firms included in Amadeus along other dimensions (e.g. age, profitability) or across more detailed size classes and industries than the ones in SBS. Consequently, analyses related to firm demographics (entry, exit, etc.) present strong limitations.

A.5 Balancing the SBS Database.

The Eurostat's Structural Business Statistics (SBS) is used as the benchmark when constructing the resampling weights by cells. Table A.4 summarizes the industry availability for the different employment size classes in the SBS. In general, information is available for the non-farm market sector, and we are not able to construct the sampling weights for the Nace Rev. 2 industries A, B, K and O-U.

[65] The following size classes will be considered according to the number of employees: 0-9, 10-49, 50-249, 250+.

There are two employment variables available in SBS: number of employees and number of persons engaged. The difference can be quite substantial for small firm size classes, as the latter captures also managers. The number of employees is closer to the definition in Amadeus and, hence, it is our preferred option. However, this data is often not reported for country*industry*size class*years cells. Estimation procedures are employed to impute the missing data. In the case of services and trade, the number of employees is not available at all by size classes. Therefore, we use the percentage of persons engaged in each country and industry by size classes to disaggregate total employees by size classes. In the case of Malta, there is no information available by size classes. In this case, the weights have been created using only cells by industry and year. In some cases, there is no information for a cell of country*industry*size class* year in Amadeus, whereas in the SBS contains employment in that cell. In these cases, this cell is merged with the adjacent cell in terms of size classes to calculate the weights.

Table A.1. Number of firms by country and year in the EU-28; Amadeus database.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Austria	3.847	32.918	39.944	70.279	80.789	88.270	88.073	98.289	113.741	119.716	126.657	68.545
Belgium	224.162	239.375	219.637	239.553	256.821	275.381	291.285	310.422	333.416	353.619	368.159	319.964
Bulgaria	11.794	13.078	78.097	92.876	116.494	134.381	165.141	188.633	228.232	262.538	276.359	282.310
Croatia	45.425	48.910	46.367	52.391	56.781	64.100	73.928	76.869	80.884	89.607	93.287	87.757
Cyprus	0	0	128	119	145	187	246	330	432	381	257	35
Czech Republic	36.734	47.566	61.813	75.346	93.197	114.901	131.985	142.338	150.900	152.158	142.243	67.927
Denmark	0	0	0	0	0	0	24.705	163.286	177.078	190.222	204.659	169.948
Estonia	31.280	35.757	36.956	42.794	50.005	56.674	62.607	70.843	80.131	88.578	92.943	87.150
Finland	67.683	71.429	58.568	70.153	93.704	111.295	119.712	130.405	142.619	142.778	144.772	142.973
France	477.958	530.194	515.928	573.661	635.823	703.779	765.911	850.235	956.818	1.063.036	1.102.793	625.740
Germany	42.389	75.171	400.655	642.270	675.501	752.600	816.128	853.873	919.543	633.585	516.399	98.441
Greece	16.561	17.632	14.460	15.186	16.017	16.926	17.715	19.083	20.973	22.273	20.420	13.607
Hungary	15.998	187.075	176.909	51.818	139.424	158.497	269.765	278.534	322.362	372.545	398.260	391.631
Ireland	60.774	66.366	64.443	71.589	79.382	85.812	91.619	98.525	107.096	114.774	117.690	47.587
Italy	162.608	343.978	317.842	354.349	537.256	587.323	638.147	699.753	765.782	793.550	816.808	600.660
Latvia	5.176	28.597	29.457	33.510	38.502	39.424	46.538	66.372	79.223	88.447	97.344	100.566
Lithuania	2.725	3.052	4.247	5.093	5.294	4.613	4.976	9.217	10.662	9.829	9.867	5.860
Luxembourg	2.137	2.660	3.485	4.980	6.088	7.717	10.618	11.878	13.606	13.455	11.973	3.527
Malta	1.559	1.958	1.660	1.907	2.201	6.319	7.333	8.415	9.483	3.990	1.223	112
Netherlands	197.504	221.558	284.901	376.352	416.809	458.356	492.808	526.062	567.390	600.237	628.437	251.250
Poland	18.775	19.821	22.671	43.017	53.895	67.070	71.745	83.749	104.570	119.025	103.139	27.521
Portugal	53.997	59.211	54.971	202.752	219.053	235.076	249.293	264.072	280.741	290.849	301.853	302.746
Romania	195.357	231.504	263.563	256.447	351.646	362.358	370.270	399.337	453.192	494.852	566.150	602.013
Slovakia	3.943	5.234	21.528	30.270	36.076	37.284	95.817	110.584	125.099	137.493	149.177	161.475
Slovenia	6.892	8.118	7.897	8.992	9.089	8.969	10.466	50.375	54.756	59.376	61.958	40.477
Spain	423.901	446.506	411.469	451.854	434.160	520.958	570.049	612.244	671.997	685.459	624.809	340.291
Sweden	158.649	169.403	160.372	175.703	192.698	214.603	232.375	254.252	290.074	321.534	349.948	304.322
United Kingdom	672.737	770.823	736.232	825.136	935.019	1.034.545	1.139.804	1.278.059	1.444.274	1.640.040	1.850.764	1.105.554
European Union-28	**2.940.565**	**3.677.894**	**4.034.200**	**4.768.397**	**5.531.869**	**6.147.418**	**6.859.059**	**7.656.034**	**8.505.074**	**8.863.946**	**9.178.348**	**6.249.989**

Source: Amadeus database, own calculations.

Table A.2. Industry breakdown based on Nace Rev. 2 codes.

Industry description[1]	EU KLEMS (NACE Rev.2) Classsification	Classification to be used in the report
Agriculture, forestry and fishing	A	
Mining and quarrying	B	
Manufacture of food products; beverages and tobacco products	C10-C12	C10-C12
Manufacture of textiles, wearing apparel, leather and related products	C13-C15	C13-C15
Manufacture of wood, paper, printing and reproduction	C16-C18	C16-C18
Manufacture of coke and refined petroleum products	C19	C19
Manufacture of chemicals and chemical products	C20	C20
Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	C21
Manufacture of rubber and plastic products and other non-metallic mineral products	C22_C23	C22_C23
Manufacture of basic metals and fabricated metal products, except machinery and equipment	C24_C25	C24_C25
Manufacture of computer, electronic and optical products	C26	C26
Manufacture of electrical equipment	C27	C27
Manufacture of machinery and equipment n.e.c.	C28	C28
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	C29_C30	C29_C30
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31-C33	C31-C33
Electricity, gas, steam and air conditioning supply	D	D
Water supply; sewerage, waste management and remediation activities	E	E
Construction	F	F
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	G45
Wholesale trade, except of motor vehicles and motorcycles	G46	G46
Retail trade, except of motor vehicles and motorcycles	G47	G47
Transport and storage	H49_H52	H49_H52
Postal and courier activities	H53	H53
Accommodation and food service activities	I	I
Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	J58-J60	J58-J60
Telecommunications	J61	J61
Computer programming, consultancy, and information service activities	J62_J63	J62_J63
Financial and insurance activities	K	
Real estate activities	L	L
Professional, scientific and technical activities; administrative and support service activities	M_N	M_N
Public administration and defence; compulsory social security	O	
Education	P	
Human health and social work activities	Q	
Arts, entertainment and recreation	R	
Other service activities	S	
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	T	
Activities of extraterritorial organisations and bodies	U	

[1] The sectoral coverage is dictated by availability in the main databases (AMADEUS, EUROSTAT sources).

[2] The grey shaded area refers to that industry sectors included in the TFP measurement report.

Table A.3. Additional variables used in the calculation of TFP; Data availability matrix. Source: EUROSTAT (2003-2014). Data available for 37 industries in NACE Rev.2.

Country	Employees[1]	Compensation of employees[2]	VA[3]	VA (price index - implicit deflator)[4]	Gross fixed capital (price index - implicit deflator)[5]
Austria	√	√	√	√	√
Belgium	√	√	√	√	√
Bulgaria	√	√	√	√	√
Croatia	√	√	√	√	√
Cyprus	√	√	√	√	√
Czech Republic	√	√	√	√	√
Denmark	√	√	√	√	√
Estonia	√	√	√	√	√
Finland	√	√	√	√	√
France	√	√	√	√	√
Germany	√	√	√	√	√
Greece	√	√	√	√	√
Hungary	√	√	√	√	√
Ireland	√	√	√	√	√
Italy	√	√	√	√	√
Latvia	√	√	√	√	√
Lithuania	√	√	√	√	√
Luxembourg	√	√	√	√	√
Malta	√	√	√	√	√
Netherlands	√	√	√	√	√
Poland	√	√	√	√	√
Portugal	√	√	√	√	√
Romania	√	√	√	√	√
Slovakia	√	√	√	√	√
Slovenia	√	√	√	√	√
Spain	√	√	√	√	√
Sweden	√	√	√	√	√
United Kingdom	√	√	√	√	√
European Union-28	√	√	√	√	√

General comments

[1] Sectoral coverage (NACE Rev.2) for all countries: Sections A-T.
Countries without Section T: Bulgaria, Estonia, Malta, Romania and Slovakia.

[2] Sectoral coverage (NACE Rev.2) for all countries: Sections A-T.
Countries without Section T: Bulgaria, Estonia, Latvia, Malta, Romania and

[3] Sectoral coverage (NACE Rev.2) for all countries:Sections A-T.
Countries with Section U: Ireland.
Countries without Section T: Bulgaria, Estonia, Romania and Slovakia.

[4] Sectoral coverage (NACE Rev.2) for all countries: Sections A-T.
Countries with Section U: Ireland.
Countries without Section T: Bulgaria, Estonia, Romania and Slovakia.

[5] Sectoral coverage (NACE Rev.2) for all countries:Sections A-S.
Countries with Section U: Luxembourg.

Table A.4. Employment by country, industry and year, Source: Structure Business Statistics (SBS- Eurostat); matrix of data availability 2003-2014.

Industry description[1]	EU KLEMS (NACE Rev.2) Classsification	Variable: Employees	Variable: Persons employed	Comment
Agriculture, forestry and fishing	A	X	X	
Mining and quarrying	B	X	X	
Manufacture of food products; beverages and tobacco products	C10-C12	√	√	
Manufacture of textiles, wearing apparel, leather and related products	C13-C15	√	√	
Manufacture of wood, paper, printing and reproduction	C16-C18	√	√	
Manufacture of coke and refined petroleum products	C19	√	√	
Manufacture of chemicals and chemical products	C20	√	√	
Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	√	√	
Manufacture of rubber and plastic products and other non-metallic mineral products	C22_C23	√	√	
Manufacture of basic metals and fabricated metal products, except machinery and equipment	C24_C25	√	√	
Manufacture of computer, electronic and optical products	C26	√	√	
Manufacture of electrical equipment	C27	√	√	
Manufacture of machinery and equipment n.e.c.	C28	√	√	
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	C29_C30	√	√	
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31-C33	√	√	
Electricity, gas, steam and air conditioning supply	D	√	√	
Water supply; sewerage, waste management and remediation activities	E	√	√	
Construction	F	√	√	
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	X	√	[2]
Wholesale trade, except of motor vehicles and motorcycles	G46	X	√	[2]
Retail trade, except of motor vehicles and motorcycles	G47	X	√	[2]
Transport and storage	H49_H52	X	√	[2]
Postal and courier activities	H53	X	√	[2]
Accommodation and food service activities	I	X	√	[2]
Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	J58-J60	X	√	[2]
Telecommunications	J61	X	√	[2]
Computer programming, consultancy, and information service activities	J62_J63	X	√	[2]
Financial and insurance activities	K	X	X	
Real estate activities	L	X	√	[2]
Professional, scientific and technical activities; administrative and support service activities	M_N	X	√	[2]
Public administration and defence; compulsory social security	O	X	X	
Education	P	X	X	
Human health and social work activities	Q	X	X	
Arts, entertainment and recreation	R	X	X	
Other service activities	S	X	X	
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	T	X	X	
Activities of extraterritorial organisations and bodies	U	X	X	

[1] The grey shaded area refers to that industry sectors included in the TFP measurement report.

[2] Employees by size class will be calculated applying the porcentual structure of persons employed to total employees for each sector.

Table A.5. Employment by country and year in the sample used for TFP measurement; Amadeus database, 2003-2014.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Austria	946	10.993	2.109	3.460	4.458	38.208	165.047	161.560	168.822	185.643	186.877	72.128
Belgium	1.389.786	1.372.397	1.075.719	1.138.534	1.162.377	1.167.590	1.116.051	1.135.047	1.153.985	1.155.780	1.145.792	1.030.227
Bulgaria	526.639	508.166	510.597	554.837	611.564	600.360	546.964	499.802	525.088	606.179	589.878	562.889
Croatia	538.265	526.754	555.390	470.341	501.188	512.783	492.031	464.766	456.675	446.394	440.521	418.731
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	1.283.198	1.565.085	1.430.379	1.501.446	1.585.356	1.388.642	1.631.729	1.663.391	1.704.326	1.657.732	1.574.765	859.598
Denmark	0	0	0	0	0	0	42.756	507.002	451.865	410.296	400.238	334.600
Estonia	181.709	188.189	179.331	181.532	184.896	179.796	150.888	143.267	148.418	150.150	153.544	150.554
Finland	575.585	555.686	314.406	364.880	365.831	329.552	337.321	324.641	364.586	363.666	367.567	354.931
France	6.011.820	5.905.716	4.867.173	4.585.785	4.620.747	4.025.991	3.693.248	3.955.973	3.623.160	3.104.075	3.383.227	2.746.635
Germany	2.301.935	2.354.035	1.864.242	2.908.616	3.170.745	3.219.353	3.106.037	3.116.389	3.202.705	3.259.103	3.157.916	541.346
Greece	518.111	519.272	268.833	261.349	269.097	280.149	329.039	342.631	324.224	311.354	298.081	260.994
Hungary	15.731	70.794	219.003	357.714	914.122	677.570	1.073.296	1.028.890	1.064.762	1.126.383	1.118.416	1.145.425
Ireland	0	568	6.757	19.427	26.915	31.197	33.779	36.222	39.573	50.909	43.027	11.802
Italy	4.067.698	3.384.261	2.336.487	2.989.413	3.120.187	3.593.467	3.000.016	2.827.175	3.941.199	3.969.912	3.874.104	3.183.680
Latvia	20.142	21.429	7.562	7.867	7.447	6.845	5.514	5.911	6.315	6.729	6.587	6.757
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0
Luxembourg	932	772	455	2.649	15.621	25.418	29.505	33.189	31.489	30.835	27.749	15.030
Malta	0	35	308	336	741	946	952	942	1.245	633	435	0
Netherlands	218.788	228.332	161.446	157.133	164.247	130.117	129.724	119.053	124.139	172.161	109.577	57.812
Poland	1.367.187	1.351.251	1.141.644	1.465.176	1.537.992	1.713.317	2.236.542	1.455.526	1.184.416	804.014	418.559	89.929
Portugal	181.476	186.779	47	1.575.451	1.624.159	1.648.505	1.595.660	1.567.168	1.532.771	1.419.651	1.353.496	1.283.452
Romania	1.617.646	1.837.269	1.857.782	1.357.014	1.881.572	1.882.767	1.816.252	1.590.372	1.656.343	1.676.299	1.636.033	1.635.998
Slovakia	271.243	277.441	470.211	601.495	612.569	635.733	668.298	679.580	623.549	617.394	622.923	572.722
Slovenia	255.079	266.137	246.766	268.161	274.899	277.284	270.536	344.888	345.044	333.659	321.306	138.805
Spain	5.068.294	5.131.729	4.129.319	4.304.239	4.269.889	4.305.146	4.111.057	4.090.862	4.062.902	3.834.646	3.640.338	2.052.768
Sweden	1.298.475	1.263.495	977.449	1.000.425	1.051.296	1.132.549	1.058.165	1.050.365	1.070.224	1.057.535	1.041.390	904.578
United Kingdom	6.141.174	6.091.857	5.547.710	5.577.001	5.726.991	5.608.988	5.622.530	5.643.010	5.769.993	5.718.537	5.564.091	3.108.314
European Union-28	**33.851.859**	**33.618.442**	**28.171.125**	**31.654.281**	**33.704.906**	**33.412.273**	**33.262.937**	**32.787.622**	**33.577.818**	**32.469.669**	**31.476.437**	**21.539.705**

[1] The sample includes only firms with data of VA (availabe or that can be imputed), data on fixed assets, depreciation, and employment.

Table A.6. Employment by country and year in the sample used for TFP measurement (Percentage over National Accounts employment), 2003-2014.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Austria	0,04	0,49	0,09	0,15	0,19	1,60	7,05	6,87	7,00	7,56	7,57	2,89
Belgium	67,21	66,05	51,04	53,23	53,08	52,23	50,67	51,39	51,52	51,77	51,88	46,70
Bulgaria	33,81	31,25	29,99	30,82	32,12	30,02	28,25	27,09	29,00	34,40	34,04	32,62
Croatia	61,40	59,37	61,61	50,38	54,14	51,79	51,35	51,74	52,31	52,11	52,84	48,51
Cyprus	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Czech Republic	45,19	54,87	48,16	49,75	50,91	43,44	52,38	54,61	56,28	54,21	51,09	27,65
Denmark	0,00	0,00	0,00	0,00	0,00	0,00	2,84	35,09	31,03	28,22	27,45	22,53
Estonia	50,67	53,54	47,64	46,16	46,90	44,24	44,04	44,98	42,36	43,15	43,33	41,82
Finland	45,32	43,59	24,14	27,51	26,78	23,51	25,46	24,88	27,53	27,20	27,76	27,24
France	41,65	40,92	33,58	31,36	31,07	26,94	25,33	27,24	24,74	21,20	23,27	18,94
Germany	10,27	10,50	8,38	12,95	13,78	13,73	13,35	13,36	13,44	13,45	12,92	2,19
Greece	30,92	30,59	15,65	14,93	14,89	15,01	17,89	19,52	20,37	21,22	21,27	18,50
Hungary	0,65	2,96	8,98	14,47	36,64	27,19	44,85	43,26	44,18	46,67	46,06	44,72
Ireland	0,00	0,06	0,65	1,77	2,36	2,85	3,52	3,99	4,44	5,76	4,79	1,28
Italy	38,30	31,92	21,59	26,97	27,52	31,41	26,79	25,66	35,61	36,11	36,13	29,73
Latvia	3,74	3,85	1,33	1,30	1,14	1,06	1,05	1,19	1,26	1,32	1,26	1,31
Lithuania	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Luxembourg	0,53	0,43	0,25	1,37	7,71	11,96	13,92	15,39	14,21	13,65	12,12	6,42
Malta	0,00	0,04	0,37	0,39	0,85	1,07	1,10	1,08	1,40	0,70	0,46	0,00
Netherlands	4,82	5,16	3,63	3,45	3,48	2,70	2,77	2,61	2,69	3,76	2,44	1,28
Poland	22,14	20,95	17,01	20,79	20,13	21,14	27,70	18,70	15,06	10,19	5,33	1,11
Portugal	6,58	6,76	0,00	56,56	57,94	58,70	59,11	58,62	58,65	58,24	57,07	52,60
Romania	37,06	38,84	41,20	29,30	40,84	39,86	39,91	36,50	37,26	40,48	39,09	37,94
Slovakia	22,53	23,74	39,10	48,40	47,95	48,48	53,38	55,49	49,13	48,02	48,90	43,90
Slovenia	45,43	47,26	44,20	47,03	46,06	45,08	45,87	61,03	62,69	61,83	61,64	26,42
Spain	49,81	48,09	36,73	36,37	34,52	34,86	36,72	37,73	38,88	39,13	38,75	21,53
Sweden	54,70	54,02	41,51	41,86	42,27	44,45	43,14	42,35	41,79	40,85	39,92	34,19
United Kingdom	38,66	38,24	34,53	34,51	35,13	34,14	35,38	35,94	36,55	35,84	34,37	18,75
European Union-28	**29,43**	**28,94**	**23,96**	**26,36**	**27,32**	**26,66**	**27,43**	**27,47**	**27,99**	**27,23**	**26,52**	**17,91**

[1] The sample includes only firms with data of VA (availabe or that can be imputed), data on fixed assets, depreciation, and employment.

Table A.7. Number of firms by industry and year in the sample used for TFP measurement; 2003-2014. Source: Amadeus database.

Industry description	EU KLEMS (NACE Rev.2) Classsification	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Manufacture of food products; beverages and tobacco products	C10-C12	26.173	27.896	25.820	30.633	32.649	33.066	36.275	35.833	37.854	37.613	36.828	26.758
Manufacture of textiles, wearing apparel, leather and related products	C13-C15	18.072	16.034	13.887	19.098	20.332	20.666	20.724	19.349	22.917	22.947	22.365	18.410
Manufacture of wood, paper, printing and reproduction	C16-C18	25.234	24.826	21.964	26.259	27.998	27.708	29.677	28.179	30.342	30.127	28.510	21.622
Manufacture of coke and refined petroleum products	C19	316	289	250	290	305	318	308	321	344	339	330	238
Manufacture of chemicals and chemical products	C20	6.323	5.913	5.415	6.289	6.520	6.544	6.739	6.426	6.956	6.871	6.693	4.937
Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	1.152	1.069	923	1.061	1.089	1.058	1.109	1.097	1.107	1.102	1.114	734
Manufacture of rubber and plastic products and other non-metallic mineral products	C22_C23	20.647	19.651	17.706	22.251	24.025	24.339	25.226	23.699	26.277	25.781	24.544	18.759
Manufacture of basic metals and fabricated metal products, except machinery and equipment	C24_C25	39.570	36.854	33.992	42.634	45.823	46.585	48.337	46.404	53.228	52.694	51.085	39.324
Manufacture of computer, electronic and optical products	C26	5.464	4.672	4.103	4.848	5.265	5.102	5.425	5.008	5.492	5.478	5.125	3.640
Manufacture of electrical equipment	C27	5.936	5.137	4.687	5.845	6.273	6.326	6.597	6.177	7.114	6.952	6.588	4.716
Manufacture of machinery and equipment n.e.c.	C28	16.144	13.894	12.681	15.611	16.772	16.777	17.008	16.181	18.795	18.728	17.949	13.167
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	C29_C30	5.169	5.020	4.568	5.322	5.671	5.716	5.907	5.691	6.246	6.084	5.871	4.284
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31-C33	26.753	26.458	23.508	27.461	29.130	29.137	30.876	29.578	32.441	31.965	30.561	20.072
Electricity, gas, steam and air conditioning supply	D	2.782	2.899	2.748	3.224	3.463	3.665	4.176	4.284	4.757	5.055	4.917	3.561
Water supply; sewerage, waste management and remediation activities	E	5.933	5.951	5.840	7.068	7.559	7.595	8.705	8.249	9.293	9.482	9.174	6.993
Construction	F	145.902	150.186	131.881	157.272	167.324	173.584	182.800	176.015	190.869	182.026	171.033	122.416
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	45.490	47.203	43.156	50.614	53.391	53.134	58.255	57.522	60.335	59.265	57.022	42.969
Wholesale trade, except of motor vehicles and motorcycles	G46	143.964	131.245	117.450	138.510	143.195	142.733	151.501	143.136	151.250	149.006	140.397	102.664
Retail trade, except of motor vehicles and motorcycles	G47	121.549	125.933	110.184	131.429	141.215	138.506	153.945	147.291	154.227	152.480	146.822	110.793
Transport and storage	H49_H52	51.632	51.002	46.316	58.136	61.224	62.130	65.624	64.894	71.654	72.884	72.177	57.957
Postal and courier activities	H53	799	772	659	755	811	886	1.048	1.033	1.222	1.272	1.219	1.002
Accommodation and food service activities	I	52.608	61.399	56.074	74.916	80.395	85.701	95.123	96.829	108.040	106.147	104.402	76.095
Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	J58-J60	12.930	11.586	9.786	11.003	11.333	11.054	12.065	11.224	11.516	11.272	10.257	7.258
Telecommunications	J61	2.190	2.254	2.008	2.151	2.371	2.313	2.735	2.619	2.830	2.913	2.788	1.978
Computer programming, consultancy, and information service activities	J62_J63	21.224	18.909	16.597	19.625	20.971	22.243	23.741	22.153	25.255	25.649	23.636	17.064
Real estate activities	L	41.964	44.226	44.488	54.157	56.869	57.196	60.617	54.144	57.073	59.433	53.942	39.649
Professional, scientific and technical activities; administrative and support service activities	M_N	136.828	135.115	121.391	143.802	149.713	151.644	169.470	163.667	171.311	170.439	157.419	114.463
TOTAL	**TOTAL**	**982.748**	**976.393**	**878.082**	**1.060.264**	**1.121.686**	**1.135.726**	**1.224.013**	**1.177.003**	**1.268.745**	**1.254.004**	**1.192.768**	**881.523**

[1] The sample includes only firms with data of VA (availabe or that can be imputed), data on fixed assets, depreciation, and employment.

Table A.8. Employment by industry and year in the sample used for TFP measurement; 2003-2014. Source: Amadeus database.

Industry description	EU KLEMS (NACE Rev.2) Classsification	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Manufacture of food products; beverages and tobacco products	C10-C12	1.436.715	1.466.919	1.303.829	1.440.103	1.497.970	1.484.775	1.544.655	1.545.632	1.554.089	1.503.835	1.508.212	1.009.886
Manufacture of textiles, wearing apparel, leather and related products	C13-C15	950.166	912.294	730.537	804.076	877.398	811.741	788.604	745.307	792.771	775.770	769.276	632.596
Manufacture of wood, paper, printing and reproduction	C16-C18	800.485	823.842	740.762	805.637	851.216	822.755	817.752	794.430	804.752	770.708	748.465	514.990
Manufacture of coke and refined petroleum products	C19	86.551	86.194	40.338	45.704	49.908	42.515	46.400	49.967	44.502	43.660	43.584	30.573
Manufacture of chemicals and chemical products	C20	561.380	556.327	413.846	446.123	455.707	452.118	452.318	439.796	443.153	416.270	433.836	294.145
Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	286.181	280.861	229.672	255.665	252.217	254.923	254.100	255.266	245.467	240.298	252.894	181.824
Manufacture of rubber and plastic products and other non-metallic mineral products	C22_C23	1.120.234	1.148.570	1.023.738	1.166.076	1.246.869	1.203.867	1.176.475	1.160.348	1.171.517	1.108.038	1.083.579	777.812
Manufacture of basic metals and fabricated metal products, except machinery and equipment	C24_C25	1.643.334	1.609.207	1.405.083	1.657.023	1.785.851	1.747.832	1.711.184	1.666.906	1.765.736	1.727.025	1.670.967	1.169.863
Manufacture of computer, electronic and optical products	C26	572.859	517.220	367.846	431.158	445.807	427.303	405.264	425.286	408.532	397.273	381.174	247.954
Manufacture of electrical equipment	C27	714.181	501.273	441.649	533.385	549.877	542.378	528.380	521.153	527.811	508.094	495.458	315.330
Manufacture of machinery and equipment n.e.c.	C28	976.189	936.485	815.923	956.703	1.029.640	1.011.400	964.521	973.903	1.027.753	1.024.771	1.014.458	632.379
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	C29_C30	1.661.714	1.329.554	1.153.119	1.212.849	1.272.137	1.243.359	1.153.549	1.190.042	1.206.023	1.145.095	1.173.196	837.571
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31-C33	890.078	910.959	806.687	884.095	945.000	924.578	901.423	898.262	913.862	868.584	857.443	566.633
Electricity, gas, steam and air conditioning supply	D	632.896	542.792	378.989	419.167	448.747	437.408	430.545	424.948	404.797	415.599	404.597	294.797
Water supply; sewerage, waste management and remediation activities	E	435.794	471.538	414.420	468.160	504.440	501.806	521.318	525.530	534.037	504.200	500.956	362.451
Construction	F	2.953.359	2.999.541	2.417.573	2.795.872	2.951.242	2.989.230	2.888.453	2.752.716	2.754.445	2.546.008	2.344.299	1.676.106
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	807.300	876.226	798.998	913.917	972.332	948.518	969.508	981.175	990.583	954.062	923.209	621.097
Wholesale trade, except of motor vehicles and motorcycles	G46	2.790.951	2.744.398	2.491.837	2.800.241	2.945.722	3.092.382	2.937.642	2.892.045	2.903.880	2.799.649	2.690.462	1.752.031
Retail trade, except of motor vehicles and motorcycles	G47	3.233.789	3.545.826	3.201.648	3.467.581	3.805.638	4.004.101	4.269.592	4.184.115	4.300.239	4.245.879	4.080.680	2.701.888
Transport and storage	H49_H52	2.304.573	2.366.065	1.983.801	2.183.430	2.390.774	2.385.236	2.344.851	2.301.896	2.386.142	2.356.816	2.331.377	1.664.718
Postal and courier activities	H53	567.031	803.077	337.585	327.773	327.436	325.708	318.206	311.677	301.439	287.007	281.828	259.173
Accommodation and food service activities	I	1.464.622	1.548.292	1.491.661	1.678.247	1.767.103	1.695.226	1.786.947	1.805.474	1.954.503	1.890.132	1.862.711	1.326.862
Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	J58-J60	471.611	406.222	319.185	337.383	343.525	390.245	321.133	333.307	299.052	275.952	263.648	156.986
Telecommunications	J61	630.505	567.864	231.262	237.193	224.453	239.255	238.464	237.744	224.369	228.253	205.708	134.237
Computer programming, consultancy, and information service activities	J62_J63	695.698	697.349	455.736	505.945	515.944	527.595	535.718	536.569	553.191	544.315	529.311	355.497
Real estate activities	L	660.998	630.622	573.965	653.243	648.868	576.420	597.045	495.358	456.749	450.221	412.088	251.797
Professional, scientific and technical activities; administrative and support service activities	M_N	4.502.665	4.338.925	3.601.437	4.227.532	4.599.085	4.329.599	4.358.890	4.338.770	4.608.424	4.442.155	4.213.021	2.770.509
TOTAL	**TOTAL**	**33.851.859**	**33.618.442**	**28.171.125**	**31.654.281**	**33.704.906**	**33.412.273**	**33.262.937**	**32.787.622**	**33.577.818**	**32.469.669**	**31.476.437**	**21.539.705**

[1] The sample includes only firms with data of VA (availabe or that can be imputed), data on fixed assets, depreciation, and employment.

Table A.9. Employment by industry and year in the sample used for TFP measurement - Percentage over National Accounts employment.

Industry description	EU KLEMS (NACE Rev.2) Classsification	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Manufacture of food products; beverages and tobacco products	C10-C12	30,57	31,29	28,15	31,37	32,47	30,81	32,55	33,83	34,08	33,45	33,76	22,52
Manufacture of textiles, wearing apparel, leather and related products	C13-C15	27,19	27,84	23,49	27,33	29,68	29,79	33,47	32,39	34,71	35,26	36,05	29,17
Manufacture of wood, paper, printing and reproduction	C16-C18	27,01	28,21	25,69	28,51	29,98	29,34	31,93	32,40	33,59	33,43	33,59	22,70
Manufacture of coke and refined petroleum products	C19	43,80	45,68	22,29	25,60	27,82	23,94	29,15	35,27	31,16	30,07	30,56	21,23
Manufacture of chemicals and chemical products	C20	42,86	42,86	32,62	35,38	35,97	35,70	37,64	37,49	37,43	35,66	37,58	25,32
Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	51,05	50,05	41,29	45,62	44,79	45,67	46,00	46,32	44,43	42,60	44,90	32,24
Manufacture of rubber and plastic products and other non-metallic mineral products	C22_C23	33,81	34,78	31,32	35,57	37,85	36,35	38,46	40,18	40,46	38,77	38,58	27,43
Manufacture of basic metals and fabricated metal products, except machinery and equipment	C24_C25	34,27	33,55	29,27	33,80	36,25	34,70	36,34	37,06	38,89	38,61	38,16	26,42
Manufacture of computer, electronic and optical products	C26	40,93	37,30	26,98	31,37	32,28	31,41	33,01	36,14	34,37	33,55	32,81	21,12
Manufacture of electrical equipment	C27	45,30	31,80	28,21	33,55	34,42	33,65	35,53	35,38	35,20	34,27	33,85	21,39
Manufacture of machinery and equipment n.e.c.	C28	32,54	31,51	27,34	31,50	33,73	31,92	32,65	34,63	35,76	35,15	34,74	21,66
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	C29_C30	50,93	41,09	36,14	38,03	39,70	38,78	38,06	41,21	40,53	38,37	38,62	27,80
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31-C33	26,63	27,58	24,58	27,08	28,81	28,06	28,07	28,55	29,23	28,02	27,82	18,32
Electricity, gas, steam and air conditioning supply	D	48,94	42,06	29,82	33,10	35,33	33,67	32,74	32,70	31,25	32,90	32,45	23,49
Water supply; sewerage, waste management and remediation activities	E	32,29	33,89	29,42	32,63	35,05	34,14	35,35	34,03	33,67	32,02	31,58	22,64
Construction	F	24,90	24,83	19,36	21,46	21,73	21,99	22,63	22,95	23,73	22,95	22,00	15,91
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	26,17	27,75	25,23	28,49	29,46	28,44	30,01	29,39	29,82	29,21	28,64	18,99
Wholesale trade, except of motor vehicles and motorcycles	G46	32,78	31,63	28,30	31,07	31,77	32,42	32,01	32,61	32,98	32,20	31,23	20,09
Retail trade, except of motor vehicles and motorcycles	G47	22,38	24,31	21,88	23,23	24,78	25,58	27,31	26,64	27,22	26,91	25,94	17,02
Transport and storage	H49_H52	29,73	30,18	24,95	27,11	28,85	28,38	28,35	28,18	28,98	28,71	28,36	20,01
Postal and courier activities	H53	32,85	46,37	19,33	18,86	18,31	18,31	17,86	17,69	17,39	17,05	16,76	15,21
Accommodation and food service activities	I	19,73	20,24	18,92	20,79	21,27	19,99	21,03	21,09	22,42	21,37	20,91	14,47
Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	J58-J60	29,97	25,95	20,53	21,38	21,20	24,31	20,26	21,60	19,73	18,21	17,70	10,20
Telecommunications	J61	51,62	47,17	19,65	20,18	18,60	20,02	20,77	21,84	20,97	21,64	19,74	12,50
Computer programming, consultancy, and information service activities	J62_J63	30,61	30,03	18,93	19,85	19,71	19,26	19,28	19,10	19,01	18,13	17,00	11,35
Real estate activities	L	37,79	35,07	30,84	33,53	32,05	27,60	29,63	24,61	22,80	22,59	20,54	12,27
Professional, scientific and technical activities; administrative and support service activities	M_N	26,77	24,98	19,83	22,14	22,83	20,80	21,45	21,06	21,80	20,78	19,47	12,44
TOTAL	**TOTAL**	**29,43**	**28,94**	**23,96**	**26,36**	**27,32**	**26,66**	**27,43**	**27,47**	**27,99**	**27,23**	**26,52**	**17,91**

[1] The sample includes only firms with data of VA (availabe or that can be imputed), data on fixed assets, depreciation, and employment.

Table A.10. Number of firms by industry and country in the sample used for TFP measurement; Amadeus database, 2014.

Industry description	NACE Rev.2	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Netherlands	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	United Kingdom	European Union-28
Manufacture of food products; beverages and tobacco products	C10-C12	15	1.598	511	583	0	306	159	203	341	3.453	68	568	2.003	2	5.334	7	0	3	0	34	46	2.836	2.608	486	245	4.192	845	312	**26.758**
Manufacture of textiles, wearing apparel, leather and related products	C13-C15	6	422	479	242	0	160	38	271	130	484	27	152	827	0	6.343	11	0	1	0	4	6	4.020	2.138	261	148	1.884	262	94	**18.410**
Manufacture of wood, paper, printing and reproduction	C16-C18	11	995	361	513	0	327	117	456	599	1.259	49	168	1.742	1	5.049	26	0	1	0	23	17	2.121	2.147	614	554	2.836	1.394	242	**21.622**
Manufacture of coke and refined petroleum products	C19	1	14	6	4	0	3	1	1	3	13	4	16	4	0	117	0	0	0	0	0	1	5	11	5	1	9	10	9	**238**
Manufacture of chemicals and chemical products	C20	3	260	99	76	0	88	30	22	69	438	53	106	245	3	1.578	4	0	3	0	16	4	281	269	89	37	808	168	188	**4.937**
Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	3	60	11	13	0	20	11	4	10	71	19	24	37	3	178	0	0	0	0	0	2	41	47	16	3	79	32	50	**734**
Manufacture of rubber and plastic products and other non-metallic mineral products	C22_C23	10	791	365	371	0	439	154	140	376	1.144	85	283	1.361	1	6.117	4	0	6	0	17	27	1.592	1.416	502	392	2.227	681	258	**18.759**
Manufacture of basic metals and fabricated metal products, except machinery and equipment	C24_C25	16	1.514	388	547	0	816	269	419	1.121	2.293	123	226	2.615	1	14.434	6	0	9	0	23	25	3.161	1.824	1.074	851	4.554	2.580	435	**39.324**
Manufacture of computer, electronic and optical products	C26	6	125	53	97	0	87	38	26	81	254	44	19	436	3	1.322	0	0	0	0	2	2	78	215	104	60	284	169	135	**3.640**
Manufacture of electrical equipment	C27	10	140	88	78	0	214	46	36	88	241	37	60	314	3	2.012	1	0	1	0	2	3	213	200	193	71	353	196	116	**4.716**
Manufacture of machinery and equipment n.e.c.	C28	9	453	157	151	0	372	210	46	353	577	131	72	926	2	5.961	1	0	4	0	25	5	532	398	296	185	1.348	705	248	**13.167**
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	C29_C30	3	126	24	63	0	178	34	35	116	378	27	18	285	1	1.242	3	0	0	0	6	4	258	292	121	45	505	374	146	**4.284**
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31-C33	4	824	405	382	0	404	156	499	622	1.930	32	98	1.675	1	6.191	13	0	0	0	20	12	2.143	1.799	435	503	0	1.424	500	**20.072**
Electricity, gas, steam and air conditioning supply	D	13	53	389	87	0	219	54	58	177	141	145	48	137	1	633	7	0	2	0	0	1	112	208	148	58	568	220	82	**3.561**
Water supply; sewerage, waste management and remediation activities	E	2	306	85	297	0	238	59	111	241	635	50	41	597	1	1.892	2	0	4	0	8	5	358	738	237	70	588	321	107	**6.993**
Construction	F	31	10.294	1.596	1.768	0	1.499	986	2.164	5.526	14.749	95	389	7.652	21	26.027	40	0	10	0	76	40	8.910	7.047	2.342	2.198	15.839	12.351	766	**122.416**
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	14	3.434	774	643	0	445	397	732	1.079	5.176	127	246	3.921	9	6.478	31	0	3	0	50	8	4.976	3.593	791	658	5.843	3.008	533	**42.969**
Wholesale trade, except of motor vehicles and motorcycles	G46	62	6.858	3.417	2.409	0	1.912	1.113	1.008	1.717	6.694	324	1.746	7.428	21	22.374	32	0	12	0	232	102	10.115	8.019	3.109	1.535	16.991	4.268	1.166	**102.664**
Retail trade, except of motor vehicles and motorcycles	G47	33	8.298	2.605	1.534	0	691	677	975	1.902	11.801	157	395	11.625	23	16.898	60	0	14	0	71	31	15.853	12.979	3.028	955	14.333	5.384	471	**110.793**
Transport and storage	H49_H52	27	2.552	3.433	1.009	0	588	364	1.535	2.723	3.373	133	271	4.037	15	8.505	56	0	8	0	51	15	4.014	9.913	1.620	1.401	6.064	5.738	512	**57.957**
Postal and courier activities	H53	0	82	85	6	0	4	15	25	32	15	1	6	124	2	98	0	0	1	0	0	0	106	172	33	12	140	33	10	**1.002**
Accommodation and food service activities	I	15	5.888	1.098	1.457	0	438	271	841	1.211	12.062	17	786	4.247	23	15.230	19	0	2	0	11	3	10.206	4.409	1.071	1.446	10.158	4.579	607	**76.095**
Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	J58-J60	1	261	189	177	0	57	73	157	266	654	12	94	799	9	1.184	2	0	3	0	3	1	620	595	226	102	870	748	155	**7.258**
Telecommunications	J61	0	61	62	41	0	42	27	36	41	105	12	13	261	1	234	1	0	1	0	4	5	112	373	59	50	279	87	71	**1.978**
Computer programming, consultancy, and information service activities	J62_J63	4	752	503	341	0	173	169	400	427	752	38	52	1.402	4	5.711	19	0	2	0	11	8	1.085	1.234	693	324	1.447	1.223	290	**17.064**
Real estate activities	L	9	1.638	2.069	346	0	1.001	267	528	1.069	2.199	143	100	4.201	10	8.073	21	0	3	0	5	11	2.675	2.715	1.487	241	6.960	3.614	264	**39.649**
Professional, scientific and technical activities; administrative and support service activities	M_N	35	7.670	2.679	2.701	0	1.356	841	2.312	3.855	8.782	171	385	10.304	126	16.986	83	0	21	0	62	25	12.292	9.135	4.666	2.252	16.491	9.601	1.632	**114.463**
TOTAL	**TOTAL**	**343**	**55.469**	**21.931**	**15.936**	**0**	**12.077**	**6.576**	**13.040**	**24.175**	**79.673**	**2.124**	**6.382**	**69.205**	**287**	**186.201**	**449**	**0**	**114**	**0**	**756**	**409**	**88.715**	**74.494**	**23.706**	**14.397**	**115.650**	**60.015**	**9.399**	**881.523**

[1] The sample includes only firms with data of VA (availabe or that can be imputed), data on fixed assets, depreciation, and employment.

Table A.11. List of variables and summary statistics, EFIGE database.

	Label	***Nature***	***Description***	***Mean***	***SD***
	Dep. Variable:				
1	TFFG	numeric	Avg annual rate of TFP change	-0.025	0.213
	Frontier TFP growth and gap terms				
2	maxiTFPg	numeric	Avg annual rate of TFP change of the global frontier firm	1.570	1.800
3	maxicTFPg	numeric	Avg annual rate of TFP change of the national frontier firm	0.210	0.538
4	cigap	numeric	Productivity distance between national and global frontier firms	0.230	0.361
5	icgap	numeric	Productivity distance between laggard and national frontier firms	1.275	0.553
	Policy variables				
6	all_public_support	dummy	Firms benefiting from some public support	0.970	0.171
7	public_inv	dummy	Firm benefiting from public support to investment	0.265	0.441
8	public_rd	dummy	Firm benefiting from public support to R&D	0.191	0.393
9	public_exp	dummy	Firm benefiting from public support to export	0.040	0.197
10	pub_rdcoll	dummy	Firms undertaking R&D with public R&D centres/Univ.	0.942	0.234
11	main_type_pub	dummy	Firms with shared held by public sector	0.002	0.048
	Firm controls used in the main specifications				
12	age_1	dummy	Firm aged less than 6 years	0.057	0.232
13	age_2	dummy	Firm aged between 6 and 20	0.355	0.478
14	age_3	dummy	Firm aged 20 and over	0.588	0.492
15	firm_size_1	dummy	Firm with less than 50 employees	0.683	0.465
16	firm_size_2	dummy	Firm with between 50 and 250 employees	0.232	0.422
17	firm_size_3	dummy	Firm with 250 employees and over	0.085	0.279
18	natgroup	dummy	Firm belonging to a national group	0.155	0.362
19	forgroup	dummy	Firm belonging to a foreign group	0.100	0.300
20	family_cont	dummy	Family controlled firm	0.691	0.462
21	sale_red	dummy	Firm experiencing a marked sales reduction	0.749	0.433
22	graduates	share	Graduated workers/Total employment	0.065	0.099
23	do_rd	dummy	Firm undertaking R&D projects	0.529	0.499
24	exporter	dummy	Firm exporting abroad from the home country	0.704	0.457
25	inv_int	share	Physical investment/Sales	0.102	0.136
	Alternative firm controls used				
26	training	share	Workers under training/Total employment	0.229	0.293
27	rdexp_int	share	R&D expenses/Total sales	0.035	0.072
28	rdocc_int	share	R&D workers/Total employment	0.101	0.173
29	head	dummy	Head-quarter	0.041	0.198
30	acquired	dummy	Firm that has been acquired by other firms	0.038	0.190
31	acquiring	dummy	Firm that has acquired other firms	0.097	0.297
32	main_type_indiv	dummy	Firm with first shareholder being an individual entrepreneur	0.692	0.462
33	main_type_indus	dummy	Firm with first shareholder being an industrial company	0.101	0.301
34	main_type_hold	dummy	Firm with first shareholder being a holding company	0.117	0.321
35	main_type_bank	dummy	Firm with first shareholder being a bank	0.003	0.052
36	family_manag	dummy	Family managed firm	0.602	0.489
37	internal_manag	dummy	Firm with management selected internally	0.040	0.195
38	external_manag	dummy	Firm with management hired externally	0.035	0.183
39	inv_red	dummy	Firm experiencing a sales reduction during the crisis	0.387	0.487
40	inn_red	dummy	Firm experiencing an investment reduction during the crisis	0.384	0.486
41	do_inn	dummy	Firm experiencing an innovation reduction during the crisis	0.670	0.470
42	findipex	dummy	External finance dependent firm	0.539	0.498
43	banks	numeric (log)	Number of banks serving the firm	1.120	0.625
44	do_prodinn	dummy	Firm introducing product innovation	0.489	0.500
45	do_procinn	dummy	Firm introducing process innovation	0.462	0.499
46	patent	dummy	Firm applying for patent protection	0.146	0.354
47	oth_ipr	dummy	Firm adopting other IPR tools (trademark, copyright)	1.000	0.000

48	innov_sales	share	Turnover due to innovative products	0.207	0.215
49	fdi	dummy	Firm undertaking FDI	0.051	0.220
50	tot_do_rd	numeric (log)	Number of R&D-doing firms in the NUTS2 region	4.230	1.199
51	tot_patent	numeric (log)	Number of patenting firms in the NUTS2 region	2.884	1.230
52	snumber	share	Proportion of firms in the same industry in the NUTS2 region	0.151	0.109

Table A.12. Additional firm characteristics of global and national frontier firms

	Global	National frontier firms						
Description	Frontier	AT	FR	DE	HU	IT	ES	UK
Alternative firm controls used								
Workers under training/Total employment	0.323	0.580	0.263	0.361	0.277	0.153	0.359	0.583
R&D expenses/Total sales	0.041	0.033	0.014	0.028	0.020	0.032	0.047	0.023
R&D workers/Total employment	0.070	0.053	0.000	0.060	0.000	0.005	0.086	0.251
Head-quarter	0.063	0.000	0.000	0.105	0.000	0.000	0.098	0.000
Firm that has been acquired by other firms	0.025	0.111	0.000	0.158	0.000	0.000	0.000	0.125
Firm that has acquired other firms	0.228	0.222	0.133	0.105	0.000	0.261	0.171	0.375
Firm with first shareholder being an individual entrepreneur	0.468	0.333	0.400	0.368	0.417	0.609	0.488	0.375
Firm with first shareholder being an industrial company	0.152	0.111	0.333	0.053	0.250	0.000	0.220	0.125
Firm with first shareholder being a holding company	0.203	0.333	0.267	0.421	0.000	0.348	0.073	0.063
Firm with first shareholder being a bank	0.025	0.000	0.000	0.105	0.000	0.000	0.000	0.403
Family managed firm	0.380	0.333	0.267	0.474	0.250	0.565	0.244	0.188
Firm with management selected internally	0.089	0.111	0.000	0.053	0.000	0.087	0.098	0.063
Firm with management hired externally	0.025	0.111	0.200	0.105	0.000	0.000	0.024	0.063
Firm experiencing a sales reduction during the crisis	0.278	0.333	0.467	0.263	0.250	0.130	0.341	0.125
Firm experiencing an investment reduction during the crisis	0.342	0.333	0.533	0.368	0.417	0.174	0.390	0.375
Firm experiencing an innovation reduction during the crisis	0.709	0.889	0.600	0.737	0.750	0.696	0.756	0.625
External finance dependent firm	0.347	0.429	0.133	0.053	0.300	0.333	0.488	0.417
Number of banks serving the firm	1.052	0.955	0.535	0.883	0.323	1.094	1.161	0.602
Firm introducing product innovation	0.494	0.889	0.333	0.474	0.583	0.435	0.512	0.563
Firm introducing process innovation	0.494	0.778	0.400	0.316	0.583	0.435	0.585	0.563
Firm applying for patent protection	0.139	0.444	0.133	0.263	0.083	0.043	0.195	0.063
Firm adopting other IPR tools (trademark, copyright)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Turnover due to innovative products	0.159	0.208	0.172	0.171	0.176	0.161	0.186	0.173
Firm undertaking FDI	0.076	0.333	0.067	0.105	0.083	0.043	0.049	0.188
Number of R&D-doing firms in the NUTS2 region	4.240	3.916	4.698	4.726	2.321	5.182	3.783	4.420
Number of patenting firms in the NUTS2 region	3.056	2.871	3.417	3.472	0.777	3.778	2.643	3.172
Proportion of firms in the same industry in the NUTS2	0.148	0.069	0.096	0.107	0.145	0.107	0.162	0.101

Table A.13. Productivity growth, productivity gap and R&D collaboration with public centres and Universities (cross-section estimates, 2008-14).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ ln $TFP_{G,F}$	-0.004	-0.009	-0.008	-0.007	-0.010	-0.021	-0.012
	(0.006)	(0.033)	(0.006)	(0.034)	(0.035)	(0.035)	(0.035)
$GAP_{G,i}$	-0.039**	-0.095					
	(0.016)	(0.063)					
Δ ln $TFP_{N,F}$			0.024**	0.024**	0.025**	0.025**	0.025**
			(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
$GAP_{G,N}$			-0.018	-0.081*	-0.077	-0.049	-0.066
			(0.024)	(0.048)	(0.048)	(0.053)	(0.044)
$GAP_{N,i}$			-0.039**	-0.094	-0.095	-0.091	-0.090
			(0.016)	(0.072)	(0.071)	(0.075)	(0.072)
Public support		-0.066		-0.067	-0.066	-0.066	-0.068
		(0.069)		(0.072)	(0.072)	(0.074)	(0.072)
Public support * $GAP_{G,i}$		0.060					
		(0.062)					
Public support * $GAP_{G,N}$				0.069	0.066	0.053	0.064
				(0.045)	(0.046)	(0.047)	(0.044)
Public support * $GAP_{N,i}$				0.060	0.060	0.058	0.061
				(0.071)	(0.071)	(0.073)	(0.071)
Economic controls	No	No	No	No	Yes	Yes	Yes
Control for technology transfers							
R&D variable * gap terms						R&D intensity	Human capital
Observations	7,155	7,147	7,142	7,134	7,127	7,128	7,127
R-squared	0.024	0.026	0.026	0.028	0.032	0.034	0.033

Notes: OLS estimates with robust standard errors in parentheses. Dependent variable: average TFP growth between 2008 and 2014. All estimates include country and two-digit sector dummies. Estimates are weighted with absolute sampling weights. Δ ln $TFP_{G,F}$= TFP growth of the global frontier. $GAP_{G,i}$= productivity gap to the global frontier. Δ ln $TFP_{N,F}$= TFP growth of the national frontier. $GAP_{G,N}$= productivity gap between national and global frontier. $GAP_{N,i}$= productivity gap to the national frontier. Economic controls include: dummy variables for small and medium sized firms, dummy variables for young (less than 6 years from establishment) and mature firms (between 6 and 20 years from establishment), dummy variables for firms belonging to national and international business groups, a dummy variable for family controlled firms, a dummy variable for firms experiencing a marked reduction in sales between 2008 and 2009, the percentage of graduated workers; a dummy variable for exporting firms, a dummy variable for R&D doing firms, the share of investment over sales. Controls for technology transfers include; R&D expenses/sales * $GAP_{G,N}$ and R&D expenses/sales * $GAP_{N,I}$ (col. 6); Percentage of graduates * $GAP_{G,N}$ and Percentage of graduates* $GAP_{N,I}$ (col. 7)

Table A.14. Productivity growth, productivity gap and public ownership (cross-section estimates, 2008-14).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ ln $TFP_{G,F}$	-0.004	-0.010	-0.008	-0.009	-0.011	-0.022	-0.013
	(0.006)	(0.033)	(0.006)	(0.034)	(0.035)	(0.035)	(0.035)
$GAP_{G,i}$	-0.039**	-0.039**					
	(0.016)	(0.016)					
Δ ln $TFP_{N,F}$			0.024**	0.024**	0.025**	0.025**	0.025**
			(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
$GAP_{G,N}$			-0.018	-0.017	-0.016	0.002	-0.006
			(0.024)	(0.024)	(0.024)	(0.026)	(0.023)
$GAP_{N,i}$			-0.039**	-0.039**	-0.039**	-0.036**	-0.033**
			(0.016)	(0.016)	(0.016)	(0.017)	(0.015)
Public support		0.130		0.173	0.168	0.164	0.168
		(0.123)		(0.147)	(0.150)	(0.150)	(0.148)
Public support * $GAP_{G,i}$		-0.096					
		(0.084)					
Public support * $GAP_{G,N}$				-0.096	-0.088	-0.103	-0.093
				(0.067)	(0.069)	(0.070)	(0.068)
Public support * $GAP_{N,i}$				-0.177	-0.170	-0.161	-0.171
				(0.172)	(0.175)	(0.176)	(0.173)
Economic controls	No	No	No	No	Yes	Yes	Yes
Control for technology transfers							
R&D variable * gap terms						R&D intensity	Human capital
Observations	7,155	7,120	7,142	7,107	7,100	7,101	7,100
R-squared	0.024	0.024	0.026	0.027	0.031	0.033	0.032

Notes: OLS estimates with robust standard errors in parentheses. Dependent variable: average TFP growth between 2008 and 2014. All estimates include country and two-digit sector dummies. Estimates are weighted with absolute sampling weights. Δ ln $TFP_{G,F}$= TFP growth of the global frontier. $GAP_{G,i}$= productivity gap to the global frontier. Δ ln $TFP_{N,F}$= TFP growth of the national frontier. $GAP_{G,N}$= productivity gap between national and global frontier. $GAP_{N,i}$= productivity gap to the national frontier. Economic controls include: dummy variables for small and medium sized firms, dummy variables for young (less than 6 years from establishment) and mature firms (between 6 and 20 years from establishment), dummy variables for firms belonging to national and international business groups, a dummy variable for family controlled firms, a dummy variable for firms experiencing a marked reduction in sales between 2008 and 2009, the percentage of graduated workers; a dummy variable for exporting firms, a dummy variable for R&D doing firms, the share of investment over sales. Controls for technology transfers include; R&D expenses/sales * $GAP_{G,N}$ and R&D expenses/sales * $GAP_{N,I}$ (col. 6); Percentage of graduates * $GAP_{G,N}$ and Percentage of graduates* $GAP_{N,I}$ (col. 7).

Table A.15. Summary measures of allocative efficiency by broad sector and sub-period, all countries; CompNet data base.

Period	Sector	AE	No. observations
2001-2007	Manufacture of food products	0.54	38,477
2008-2010	Manufacture of food products	0.61	26,950
2011-2014	Manufacture of food products	0.61	17,508
2001-2007	Manufacture of beverages	0.49	2,684
2008-2010	Manufacture of beverages	0.56	1,479
2011-2014	Manufacture of beverages	0.50	848
2001-2007	Manufacture of tobacco products	0.15	34
2008-2010	Manufacture of tobacco products	0.27	18
2011-2014	Manufacture of tobacco products	0.06	12
2001-2007	Manufacture of textiles	0.28	16,710
2008-2010	Manufacture of textiles	0.28	8,505
2011-2014	Manufacture of textiles	0.30	5,021
2001-2007	Manufacture of wearing apparel	0.36	16,980
2008-2010	Manufacture of wearing apparel	0.34	11,836
2011-2014	Manufacture of wearing apparel	0.29	7,031
2001-2007	Manufacture of leather and related products	0.22	8,317
2008-2010	Manufacture of leather and related products	0.23	5,913
2011-2014	Manufacture of leather and related products	0.24	3,965
2001-2007	Manufacture of wood and of products of wood and cork, except furniture.	0.38	16,103
2008-2010	Manufacture of wood and of products of wood and cork, except furniture.	0.40	9,712
2011-2014	Manufacture of wood and of products of wood and cork, except furniture.	0.39	5,639
2001-2007	Manufacture of paper and paper products	0.47	10,167
2008-2010	Manufacture of paper and paper products	0.49	5,681
2011-2014	Manufacture of paper and paper products	0.53	3,608
2001-2007	Printing and reproduction of recorded media	0.25	11,472
2008-2010	Printing and reproduction of recorded media	0.23	5,421
2011-2014	Printing and reproduction of recorded media	0.26	3,234
2001-2007	Manufacture of chemicals and chemical products	0.49	13,964
2008-2010	Manufacture of chemicals and chemical products	0.52	7,963
2011-2014	Manufacture of chemicals and chemical products	0.59	5,171
2001-2007	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.66	2,436
2008-2010	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.69	1,424
2011-2014	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.69	962
2001-2007	Manufacture of rubber and plastic products	0.50	24,713
2008-2010	Manufacture of rubber and plastic products	0.48	16,025
2011-2014	Manufacture of rubber and plastic products	0.50	10,238
2001-2007	Manufacture of other nonmetallic mineral products	0.54	21,037
2008-2010	Manufacture of other nonmetallic mineral products	0.55	12,340

2011-2014	Manufacture of other nonmetallic mineral products	0.59	7,154
2001-2007	Manufacture of basic metals	0.53	10,099
2008-2010	Manufacture of basic metals	0.41	5,747
2011-2014	Manufacture of basic metals	0.40	3,661
2001-2007	Manufacture of fabricated metal products, except machinery and equipment	0.30	61,526
2008-2010	Manufacture of fabricated metal products, except machinery and equipment	0.35	37,576
2011-2014	Manufacture of fabricated metal products, except machinery and equipment	0.33	23,219
2001-2007	Manufacture of computer, electronic and optical products	0.48	12,469
2008-2010	Manufacture of computer, electronic and optical products	0.44	6,937
2011-2014	Manufacture of computer, electronic and optical products	0.50	4,323
2001-2007	Manufacture of electrical equipment	0.50	13,316
2008-2010	Manufacture of electrical equipment	0.58	8,754
2011-2014	Manufacture of electrical equipment	0.57	5,500
2001-2007	Manufacture of machinery and equipment	0.44	39,725
2008-2010	Manufacture of machinery and equipment	0.52	24,740
2011-2014	Manufacture of machinery and equipment	0.51	15,533
2001-2007	Manufacture of motor vehicles, trailers and semitrailers	0.65	10,237
2008-2010	Manufacture of motor vehicles, trailers and semitrailers	0.61	6,664
2011-2014	Manufacture of motor vehicles, trailers and semitrailers	0.56	4,195
2001-2007	Manufacture of other transport equipment	0.53	3,255
2008-2010	Manufacture of other transport equipment	0.45	2,428
2011-2014	Manufacture of other transport equipment	0.51	1,517
2001-2007	Manufacture of furniture	0.34	16,767
2008-2010	Manufacture of furniture	0.40	10,288
2011-2014	Manufacture of furniture	0.37	5,660
2001-2007	Other manufacturing	0.35	8,485
2008-2010	Other manufacturing	0.37	5,015
2011-2014	Other manufacturing	0.33	3,230
2001-2007	Repair and installation of machinery and equipment	0.28	12,593
2008-2010	Repair and installation of machinery and equipment	0.25	7,607
2011-2014	Repair and installation of machinery and equipment	0.31	5,119
2001-2007	Construction of buildings	0.41	36,947
2008-2010	Construction of buildings	0.48	23,897
2011-2014	Construction of buildings	0.49	12,244
2001-2007	Civil engineering	0.33	14,924
2008-2010	Civil engineering	0.38	12,469
2011-2014	Civil engineering	0.39	7,907
2001-2007	Specialised construction activities	0.28	72,427
2008-2010	Specialised construction activities	0.31	41,359
2011-2014	Specialised construction activities	0.31	24,809
2001-2007	Wholesale and retail trade and repair of motor vehicles and motorcycles	0.44	37,741
2008-2010	Wholesale and retail trade and repair of motor vehicles and motorcycles	0.39	22,917
2011-2014	Wholesale and retail trade and repair of motor vehicles and motorcycles	0.38	14,337

2001-2007	Wholesale trade, except of motor vehicles and motorcycles	0.53	105,156
2008-2010	Wholesale trade, except of motor vehicles and motorcycles	0.59	68,400
2011-2014	Wholesale trade, except of motor vehicles and motorcycles	0.58	44,160
2001-2007	Retail trade, except of motor vehicles and motorcycles	0.65	64,193
2008-2010	Retail trade, except of motor vehicles and motorcycles	0.64	45,826
2011-2014	Retail trade, except of motor vehicles and motorcycles	0.67	29,729
2001-2007	Land transport and transport via pipelines	0.39	42,830
2008-2010	Land transport and transport via pipelines	0.44	27,986
2011-2014	Land transport and transport via pipelines	0.47	18,015
2001-2007	Water transport	0.44	949
2008-2010	Water transport	0.47	696
2011-2014	Water transport	0.34	409
2001-2007	Air transport	0.39	214
2008-2010	Air transport	0.51	114
2011-2014	Air transport	0.28	90
2001-2007	Warehousing and support activities for transportation	0.47	18,876
2008-2010	Warehousing and support activities for transportation	0.50	12,126
2011-2014	Warehousing and support activities for transportation	0.48	7,930
2001-2007	Postal and courier activities	0.66	903
2008-2010	Postal and courier activities	0.85	408
2011-2014	Postal and courier activities	0.74	264
2001-2007	Accommodation	0.35	14,368
2008-2010	Accommodation	0.39	9,938
2011-2014	Accommodation	0.43	6,874
2001-2007	Food and beverage service activities	0.56	19,545
2008-2010	Food and beverage service activities	0.52	13,851
2011-2014	Food and beverage service activities	0.54	9,944
2001-2007	Publishing activities	0.43	6,642
2008-2010	Publishing activities	0.40	4,365
2011-2014	Publishing activities	0.36	2,734
2001-2007	Motion picture, video and television programme production, sound recording and music publishing activities	0.39	1,835
2008-2010	Motion picture, video and television programme production, sound recording and music publishing activities	0.38	1,010
2011-2014	Motion picture, video and television programme production, sound recording and music publishing activities	0.49	697
2001-2007	Programming and broadcasting activities	0.69	787
2008-2010	Programming and broadcasting activities	0.62	545
2011-2014	Programming and broadcasting activities	0.84	336
2001-2007	Telecommunications	0.94	1,789
2008-2010	Telecommunications	1.02	1,466
2011-2014	Telecommunications	0.95	982
2001-2007	Computer programming, consultancy and related activities	0.45	12,982
2008-2010	Computer programming, consultancy and related activities	0.49	9,755
2011-2014	Computer programming, consultancy and related activities	0.46	6,952

2001-2007	Information service activities	0.46	3,021
2008-2010	Information service activities	0.42	1,979
2011-2014	Information service activities	0.46	1,387
2001-2007	Legal and accounting activities	0.37	7,261
2008-2010	Legal and accounting activities	0.41	4,182
2011-2014	Legal and accounting activities	0.37	2,924
2001-2007	Activities of head offices; management consultancy activities	0.44	4,040
2008-2010	Activities of head offices; management consultancy activities	0.53	3,074
2011-2014	Activities of head offices; management consultancy activities	0.42	2,367
2001-2007	Architectural and engineering activities; technical testing and analysis	0.28	13,002
2008-2010	Architectural and engineering activities; technical testing and analysis	0.33	8,757
2011-2014	Architectural and engineering activities; technical testing and analysis	0.36	5,638
2001-2007	Scientific research and development	0.39	1,095
2008-2010	Scientific research and development	0.34	817
2011-2014	Scientific research and development	0.36	611
2001-2007	Advertising and market research	0.32	5,284
2008-2010	Advertising and market research	0.33	3,133
2011-2014	Advertising and market research	0.33	1,898
2001-2007	Other professional, scientific and technical activities	0.20	1,948
2008-2010	Other professional, scientific and technical activities	0.20	1,475
2011-2014	Other professional, scientific and technical activities	0.24	1,106
2001-2007	Veterinary activities	0.10	13
2008-2010	Veterinary activities	0.09	33
2011-2014	Veterinary activities	0.16	23
2001-2007	Rental and leasing activities	0.50	3,790
2008-2010	Rental and leasing activities	0.53	2,253
2011-2014	Rental and leasing activities	0.57	1,493
2001-2007	Employment activities	0.37	5,609
2008-2010	Employment activities	0.40	4,383
2011-2014	Employment activities	0.38	3,452
2001-2007	Travel agency, tour operator and other reservation service and related activities	0.33	1,260
2008-2010	Travel agency, tour operator and other reservation service and related activities	0.31	914
2011-2014	Travel agency, tour operator and other reservation service and related activities	0.31	528
2001-2007	Security and investigation activities	0.36	5,103
2008-2010	Security and investigation activities	0.45	4,827
2011-2014	Security and investigation activities	0.50	3,085
2001-2007	Services to buildings and landscape activities	0.32	17,892
2008-2010	Services to buildings and landscape activities	0.36	12,072
2011-2014	Services to buildings and landscape activities	0.39	8,266
2001-2007	Office administrative, office support and other business support activities	0.32	6,516
2008-2010	Office administrative, office support and other business support activities	0.37	5,239
2011-2014	Office administrative, office support and other business support activities	0.41	3,971