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## Abstract

In this article we characterize Total Factor Productivity (TFP) frontier firms at the industry level within the European Union during the period 2003-2014, and explore the determinants of the firms' distance to the frontier. We find that larger, more capital-intensive, and more labour skilled firms are closer to the productivity frontier. In contrast, older firms are further away from the frontier. In addition, we obtain that a number of countries' economic and institutional factors, such as tertiary education, trade openness, easiness in getting credit and governance quality, all positively affect the catching up of laggards towards the productivity frontier. We also examine the moderating effect of the Great Recession on these determinants and obtain differentiated patterns.

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## **1 Introduction.**

During the last decade, especially after the 2008 financial crisis, there has been a renewed interest in understanding the factors driving productivity differences across countries, industries and firms. A number of papers have 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). Some studies have also addressed the factors explaining these productivity differentials, as well as the determinants of their persistence (Syverson 2011). However, little is known about the drivers behind convergence of laggards to the best performing firms in their industry (technological frontier firms). There is also little evidence on the role of the Great Recession as a moderating factor affecting how firm and country heterogeneity explains the productivity gap between frontier and non-frontier firms and, thus, the within-industry productivity catching-up process.

The aim of this paper is to fill this gap by providing fresh evidence on the factors making firms to converge to the most productive firms in their industry at the European level. In particular, we analyse the factors determining the distance of laggard firms to the technological frontier. With this aim, we test how firms' characteristics and countries' economic and institutional features may influence a firm's TFP relative position to the frontier. We also take into account the moderating effect of the Great Recession in the impact of these factors and check whether different patterns emerge when distinguishing among firms in manufacturing, non-financial market services and other production. Finally, we aim also at providing guidance on how policy makers may further stimulate the productivity growth of firms lagging behind the productivity frontier. Fostering the productivity level of laggard firms within industries is an important policy issue, especially in countries with more skewed industrial structures where more firms linger far from technological excellence. In this context, it is crucial to understand the factors determining the distance-to-frontier of laggard firms.

Using European firm-level data from the AMADEUS dataset for the period 2003 to 2014, we identify the technological frontier firms by industry within the

European Union, and explore which firm and country-level characteristics determine the distance of other firms in the same industry to the EU frontier firms. To analyse the determinants of the within-industry distance to the TFP frontier we first provide a description of the characteristics of the most productive firms, that is, the frontier firms, in comparison with the non-frontier firms. We then analyse the determinants of firms' TFP gaps. To take into account the moderating effect of the Great Recession, we analyse two different sub periods, namely, the period prior to the last financial crisis, which we call pre-recession period, 2003-2007, and the recession period, 2008-2014.

This paper contributes to the scarce existing literature on the characteristics of firms operating at the productivity frontier and on the determinants of the distance to the frontier using firm-level data. Andrews et al. (2016) analyse productivity divergence from frontier firms using a dataset of firms in OECD countries. Other related papers using firm-level data to analyse the catching up to the technological frontier are Bartelsman et al. (2008) for a group of five European countries and the US, Iacovone and Crespi (2010) for México, and Van der Wiel et al. (2012) for the Netherlands. However, to our knowledge there is no prior study attempting to capture the determinants of the catching up to the EU technological frontier, and the moderating role of the Great Recession.

Our main findings may be summarized as follows. The regression analysis of the determinants of the TFP gap between EU frontier and non-frontier firms within industries suggests that, in general, larger, more capital-intensive and more labour skilled firms are closer to the frontier. In contrast, older firms are further away from the frontier. At the country level, we obtain that a number of economic and institutional factors, such as tertiary education, trade openness, easiness in obtaining credit and governance quality, all play a significant role in reducing the distance of laggards to the frontier. As regards the role of the Great Recession in moderating the effect of these factors, we obtain differentiated patterns for the two considered sub periods. Thus, being a larger and a more labour skilled firm is more relevant for catching up in the recession period. However, firm's capital intensity plays a more important role for the catching up process in the pre-recession period. Further, the role of firm's age in explaining divergence from the frontier is reinforced in the recession period for manufacturing and other

production, and is non-significant for non-financial market services in the same period. Country factors such as tertiary education, which may capture absorptive capacity at the country level, has a stronger positive effect on catching up in the pre-recession period (except for other production). However, trade openness has a slightly sounder positive effect on catching up in the recession period, easiness in getting credit a similar effect in both periods (although non-significant for other production), and governance quality a relevant effect in favouring the catching up process only during the recession period (this is true for manufacturing and non-financial market services, since other production enjoys a similar positive effect in the two periods).

The rest of the paper is organized as follows. Section 2 presents the data we use, and describes the measurement of firms' productivity. Section 3 provides a careful characterization of the best performing or EU frontier firms versus non-frontier firms. Section 4 presents a regression analysis of the determinants of TFP gaps, looking at firm specific and country level factors. Finally, section 5 concludes.

## **2. Data and measurement of productivity.**

The data we analyse are drawn from AMADEUS, a database providing firms' balance sheet information, such as value added, assets, age, and number of employees, for all EU countries. We use this information to estimate TFP at the firm level in a cross-country setting.

Following Arnold et al. (2008), Gal (2013), and Andrews et al. (2015), we focus on the set of firms with more than 20 employees as this helps to obtain a 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. Andrews

et al. (2015) for ORBIS highlight a similar problem, and also exclude firms with less than 20 employees.<sup>1</sup>

Further, to ensure that the computation of TFP is feasible for the largest possible number of firms we follow Gal (2013), who suggests an imputation methodology, improving the original coverage of AMADEUS. Our working sample is largely coherent with that in Gal (2013) for the overlapping countries. In addition, following Gal (2013), currency conversion based on PPPs and deflation are applied to ensure comparability of productivity measures across countries and over time.

The data we analyse correspond to the period 2003 to 2014. The coverage of EU member states is subject to data availability in AMADEUS. Thus, our data cover 23 EU Member States. Cyprus and Lithuania are excluded as there is no information. Luxembourg, Malta, and Latvia are also excluded due to insufficient observations. The industry classification is based on NACE Rev. 2, limited to the market sectors and excluding agricultural, mining, real estate and financial sectors.<sup>2</sup> These sectors are more prone to issues in accurately measuring output and they are more affected by lack of information. As for the financial sector, since AMADEUS does not generally include banks, the coverage would not be representative of this sector at the European level and, therefore, it is excluded. After cleansing the data from missing values in relevant variables and keeping company accounts with valid information for our analysis,<sup>3</sup> we have a sample of 1,040,504 observations, corresponding to 102,405 firms.

In order to estimate productivity, we first estimate a Cobb-Douglas value added production function using the methodology proposed by Wooldridge (2009) and the demand for intermediate materials as a control function as proposed by Levinshon and Petrin (2003). We consider the log version of the production function as follows:

$$y_{iptc} = \beta_{0p} + \beta_{Lp} l_{iptc} + \beta_{Kp} k_{iptc} + \omega_{iptc} + \eta_{iptc} \quad (1)$$

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<sup>1</sup> A drawback of ORBIS and AMADEUS 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.

<sup>2</sup> See Table A.1 in the Appendix for a classification of the industries used.

<sup>3</sup> We closely follow Kalemli-Ozcam et al. (2015) and Andrews et al. (2016) for filtering our data.

where  $y_{iptc}$  is the natural log of value added for firm  $i$  in sector  $p$  at time  $t$  and in country  $c$ ,  $l_{iptc}$  is the natural log of labour and  $k_{iptc}$  is the natural log of capital. As for the unobservables,  $\omega_{iptc}$  is the firm productivity (not observed by the econometrician but observable or predictable by firms) and  $\eta_{iptc}$  is a standard i.i.d. error term that is neither observed nor predictable by the firm.<sup>4</sup>

The production function in (1) is estimated separately for each industry  $p$  but pooled across all countries, controlling for country and year fixed effects. This implies the estimation of time constant and sector-specific coefficients for labour and capital that are common across all countries. This allows for technological differences across industries, while simultaneously facilitating both international and over time comparability of the resulting productivity levels. We obtain estimates of firms' TFP as the residuals from the estimated production functions:

$$\hat{\omega}_{iptc} = y_{iptc} - \hat{\beta}_{Lp} l_{iptc} - \hat{\beta}_{Kp} k_{iptc} \quad (2)$$

where  $\hat{\omega}_{iptc}$  is the estimate of the log TFP for firm  $i$  belonging to industry  $p$  in period  $t$  and country  $c$ .

### 3 Descriptive analysis of EU frontier firms.

There is a renewed interest in understanding the factors behind productivity growth and in particular the drivers of productivity convergence among EU countries. There are two main perspectives in the study of catching-up mechanisms to the frontier: the macroeconomic and the microeconomic approach. In the former, the unit of analysis is either the country or the region (Barro and Sala-i-Martin 1992) and the objective is to identify the frontier at the country or region level, and to test whether productivity growth in other territories is related to the existing gap to the frontier (see Acemoglu et al. 2006; Aghion et al. 2008; Amable et al. 2010; Griffith et al. 2004a; Kneller and Stevens 2006; Sala-i-Martin 1996, among others). Under this approach, it is assumed that all firms in a given region catch-up and

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<sup>4</sup> Estimation of the above production function using the Wooldridge (2009) strategy has three advantages: it solves the problem of identification of the labour coefficient in the first stage of Levinshon and Petrin (2003) and Olley and Pakes (1996), noted by Akerberg et al. (2007); it increases efficiency relatively to two-step procedures; and, finally, it makes unnecessary the use of bootstrapping for the calculus of standard errors.

converge towards the frontier, disregarding heterogeneity across firms and ignoring the fact that growth may be influenced by mechanisms of selection and reallocation, as well as uncertainty (Jovanovic 1982; Melitz 2003).

The microeconomics approach, instead, aims at overcoming some of these limitations, and in particular the heterogeneity across firms (Acemoglu et al. 2007; Alvarez and Crespi, 2007; Andrews et al. 2015; Bartelsman et al. 2008; Bartelsman et al. 2015; Ding et al. 2016; Griffith et al. 2004b). The unit of analysis is the firm, and it is based on the identification of a best-practice frontier firm (or group of firms) reflecting the most advanced technology within an industry and country (or groups of countries). 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 catching up differs across types of firms, they may not be able to correctly identify the ‘true’ frontier, which in many industries may depend upon firms operating in neighbouring countries.

In light of these considerations, micro data for all (potentially relevant) countries within a given geographical area or development level is useful in identifying the “global” frontier, which may differ from the national frontier firms. The scarce literature using firm-level data in a multi-country analysis uses a small number of countries to identify the global frontier firms. 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. (2012) 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. An exception to these studies are Andrews et al. (2015, 2016), who analyse the global frontier considering a sample of 23 OECD countries over the period 2001 to 2009 or 24 OECD countries over the period 1997 to 2014, respectively.

In this paper we use a microeconomic approach to derive the “EU frontier firms”, considering the EU as a well-defined area to be analysed. Following Andrews et al. (2016), for the definition of industry productivity frontier firms we use a fixed number of firms per industry across time that corresponds to the 5% of the

median number of firms (across years) of a given industry.<sup>5</sup> This allows frontier firms to change over time, the frontier size to vary across industries, and avoids potential problems that may arise as the coverage of firms by Amadeus expands over time.

Once the EU frontier firms have been identified, we first characterize the EU frontier firms, analyse its composition by country of origin and, then, examine firms' persistence in the EU frontier.

### **3.1. A characterization of the EU frontier firms.**

To analyse the EU frontier firms, we describe cross-sectional differences in key characteristics between EU frontier and non-frontier firms along a number of measurable dimensions. This part of the analysis is merely descriptive. The main dimensions considered include: TFP (measured as described in section 2), age, employment, value added, capital intensity, earnings,<sup>6</sup> profits and wages per employee. A test of the difference in means over these dimensions determines the extent to which EU frontier firms differ significantly from non-frontier firms.

Table 1 reports these differences in average characteristics at aggregate level over the period 2003 to 2014. In addition, this table provides cross-sectional differences in average characteristics for the years 2006 (pre-recession) and 2013 (recession), respectively. Table 1 also shows these differences over the total period by the three aggregate groups of industries: manufacturing, non-financial market services and other production.<sup>7</sup> In all cases the differences in means between frontier and non-frontier firms are based on the classification according to the TFP productivity measure.

[Insert Table 1 around here]

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<sup>5</sup> In particular, we calculate the median number of firms across years for each industry, and the 5% of this median number is the number of firms that we keep constant across years for each industry to identify the most productive firms at the EU level (within each industry and year).

<sup>6</sup> Earnings are measured by EBITDA (*earnings before interest, taxes, depreciation and amortization*).

<sup>7</sup> The industry classification is based on NACE Rev. 2, limited to the market non-farm/agricultural non-financial sectors (that is, excluding industries A, B, and O to P due to the lack of information). See the Appendix for a classification of industries.

Over the period 2003 to 2014, firms at the EU frontier are on average four times more productive than non-frontier firms, indicating that the TFP gap between frontier and non-frontier-firms is considerable and, therefore, suggesting that the potential for catching up in TFP remains enormous.<sup>8</sup> In addition, EU frontier firms are on average older,<sup>9</sup> larger, more capital intensive, have higher value added, earnings and profits, and pay higher wages per employee than non-frontier firms (a similar characterisation is also obtained by Andrews et al. 2016, for the global frontier firms using a sample of 24 OECD countries). These features also hold when we look separately at manufacturing, non-financial market services and other production.

Comparing the reported statistics for the year 2006 (pre-recession) and the year 2013 (recession), we observe that there is a reduction in the average TFP of both frontier and non-frontier firms. Also from 2006 to 2013 both frontier and non-frontier firms experience a reduction in value added, earnings and profits. Finally, frontier firms increased in size, as measured by the number of employees, and decreased its wages per employee.

### **3.2. The EU frontier composition by country of origin.**

Table 2 shows the percentage of firms in the EU frontier by country in the two selected years (2006 as pre-recession and 2013 as recession years). In particular, the figures presented in this table are calculated following the two steps procedure in Gal (2013): First, the percentage of EU frontier firms of a given industry from a given country (per year) is calculated.<sup>10</sup> Second, the average across industries of this percentage is calculated for each country. A higher value than 5 means the country is overrepresented in the EU top 5% of firms. For example, in 2013, on average across industries, 12.88% of firms in Germany are in the EU top 5%. Countries in the table are ranked according to their 2013 values, from the best to the worst. The information is provided

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<sup>8</sup> Note that TFP is measured in logs, therefore, relative to non-frontier firms, frontier firms are on average  $\exp(5.8-4.4)=\exp 1.4=4.05$  times more productive.

<sup>9</sup> Although the significant difference in age is lost over time.

<sup>10</sup> More precisely, the percentage in Top 5%<sub>(country, year)</sub> is calculated as the number of firms<sub>(country, industry, year)</sub> that belong to the EU-frontier<sub>(industry, year)</sub> over the total number of firms<sub>(country, year)</sub>.

separately for manufacturing, non-financial market services and other production, but also for the total of these sectors.

By looking at the country composition of the EU frontier in 2013 for the total of sectors, we observe that those countries with higher participation (above 5%) are Austria, the Netherlands, Belgium, Germany, Denmark, Ireland, and the UK, while firms in France, Sweden, Spain, Slovakia, Italy, and Hungary are less represented in the top 5% (from 3.29% for Hungary to 4.69% for France). The remaining countries are clearly underrepresented, with the last three being Romania, Greece, and Estonia.

By sectors, the general results hold with few exceptions. Now, France belongs to the group of countries overrepresented in the top 5% in manufacturing, the same happens to Sweden and Slovakia for non-financial market services, to Spain for other production, and to Ireland both for manufacturing and other production.

We also observe that from 2006 to 2013, the Netherlands enjoys a noticeable increase in its participation among the EU frontier firms (from 10.48% to 16.76%). However, there are also relevant decreases for countries such as Spain, Hungary, Italy and Greece. The increase for the Netherlands comes both from manufacturing and non-financial market services. The decreases for Spain and Greece affect the three sectors. In Hungary the decrease comes from manufacturing and non-financial market services and, finally, in Italy from other production and especially from non-financial market services.

[Insert Table 2 around here]

### **3.3. Persistence of EU frontier and non-frontier firms.**

An additional feature we are interested in is the analysis of firms' persistence in the EU frontier. In Tables 3 and 4 we present the percentages of firms remaining at the frontier and lagging behind the frontier, respectively, after one, two and five years. We report the results for all sectors and separately for manufacturing, non-financial market services and other production. The information in these tables corresponds to three different samples. Sample 1 follows (frontier and non-

frontier) firms from 2003 onwards. Sample 2 follows (frontier and non-frontier) firms from 2006 onwards and, therefore, minimizes potential coverage problems of Sample 1 due to the expansion over time in the number of firms in AMADEUS. Finally, Sample 3 follows firms (frontier and non-frontier) from 2006 onwards but restricting the sample to a balanced panel of firms that remain in AMADEUS from 2006 to 2013. As compared to Samples 1 and 2, Sample 3 eliminates the effect of firms' exit from AMADEUS in the computation of persistence.<sup>11</sup> The purpose of examining these three samples is to provide a robustness check as regards the analysis of firms' persistence.

[Insert Table 3 around here]

Table 3 reports firms' persistence in the EU frontier. We observe that the degree of persistence according to Samples 1 and 2 is quite similar, although persistence is higher according to Sample 3 as expected. As mentioned above, persistence is higher due to the fact that balancing the sample we avoid the effects of attrition in the AMADEUS database. In Sample 3, results indicate that on average 51.78% of firms remain at the EU frontier after five years (the percentages are 66.05 and 74.88 after two and one years, respectively). In general, persistence is higher among frontier firms in non-financial market services than among firms in manufacturing and other production.

[Insert Table 4 around here]

Table 4 reports persistence in the non-EU frontier. According to our Sample 3, the average percentage of firms that remain at the non-EU frontier after one year is 93.97%, and after five years is 70.45%. By sectors, in Samples 1 and 2, the highest persistence in this status is for firms in manufacturing, whereas in Sample 3 the highest persistence corresponds to firms in other production and non-financial market services.

Another proxy for persistence in the frontier (non-frontier) status is the average number of years a firm remains at the frontier (away from the frontier). We have

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<sup>11</sup> For several countries, there is a relevant drop in observations and coverage in AMADEUS from the year 2013 to 2014 (also highlighted by Andrews et al. 2016). For this reason, the criteria for balancing the sample in Sample 3 considers the year 2013 but not the year 2014. However, data corresponding to 2014 are included in the estimations.

calculated these mean values for frontier (non-frontier) firms during the period 2006-2014, but using only information on firms belonging to Sample 3. We find that those firms at the frontier (for at least one year) remain there for around 61.65% of the years analysed, and the mean number of years they remain there is around 3.31 years. Furthermore, we find that non-frontier firms (for at least one year) remain at the non-frontier status around 97% of the years analysed, and the mean number of years they remain there is around 5.24 years.

#### 4. Determinants of the distance to the frontier.

In Table 5 we report the evolution of the average TFP for all firms, and also for frontier and non-frontier firms during the period analysed. We observe that the average TFP gap between frontier and non-frontier firms is approximately equal to 4 during the sample period (ranging from the lowest, 3.71 in 2005, to the highest, 4.18 in 2009). This means that, on average, frontier firms are four times more productive than non-frontier firms.

[Insert Table 5 around here]

In this section we analyse the factors determining the distance-to-frontier of laggard firms. With this aim, we test how firms' characteristics and country's economic and institutional features may influence a firm's TFP relative position to the frontier. As stated earlier, frontier firms are identified at the EU level (within each industry and year). We estimate a model with the distance to the frontier (or technology gap) on the left hand side and firms' and country's characteristics and other controls (such as industry, country and year dummies) on the right hand side, as follows:

$$\ln \frac{TFP_{iptc}}{TFP_{pt}^F} = \alpha + \beta' Z_{iptc} + \delta' X_{ct} + \gamma_p + \gamma_c + \gamma_t + \varepsilon_{iptc} \quad (3)$$

where subscript  $i$  denotes firm, subscript  $p$  industry, subscript  $t$  time period and  $c$  the country. 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 firms at the frontier of the same industry and year. Firms' characteristics are captured by  $Z_{iptc}$

(including size –measured by the number of employees–, age, capital intensity, and skilled labour –proxy by wage per employee).<sup>12</sup>  $X_{ct}$  is a vector of variables capturing economic and institutional characteristics at the country-year level. The  $\gamma_s$  are industry, country and year dummies, respectively, and  $\varepsilon_{iptc}$  is a standard i.i.d. error term.

Among the variables at the country-year level we include the following. First, we include a measure of human capital, which is the percentage of 15-64 years old population with *Tertiary Education*, drawn from *Eurostat*. We expect this variable to be related to the ability of the country to absorb ideas and knowledge from the technological frontier and, therefore, to have a positive impact on the technological catching up of laggards. We also include a measure of *Trade Openness* (calculated as the ratio of the sum of imports plus exports over GDP) from the World Development Indicators. According to Melitz (2003), exposure to trade is an important driver contributing to a better resource allocation, thereby affecting within-industry productivity dispersion.<sup>13</sup>

In addition, from the World Bank's dataset *Doing Business* we use an indicator capturing the distance to frontier (DTF) between a particular country's performance and the world's best practice regarding the ease in getting credit (*DTF getting credit*). This indicator tries to capture two types of related issues: the strength of credit systems and the effectiveness of collateral and bankruptcy laws in facilitating lending.<sup>14</sup> By construction, higher values of this indicator imply greater ease in conducting business, thereby we expect this variable to positively affect TFP growth.

Finally, from the *Worldwide Governance Indicators* we use different indicators in order to obtain a summary measure of each country's *Governance Quality*:

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<sup>12</sup> We use wages as a proxy for skills at the firm level. 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).

<sup>13</sup> It has been documented that more exposure to trade implies selection of the most productive firms into the export markets and market share reallocation by the exit of less efficient firms (Amiti and Konings 2007; Fernandes 2007).

<sup>14</sup> In particular, this indicator measures two types of institutions and systems that may facilitate access to finance and improve its allocation: (i) Legal rights of borrowers and lenders in secured transactions and bankruptcy laws. (ii) Coverage, scope and quality of credit information available through credit registries and bureaus.

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. 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, Control of Corruption captures perceptions of the extent to which public power is exercised for private gain, including both minor and grand forms of corruption, as well as "capture" of the state by elites and private interests. Given the high correlation among these four variables, we apply factor analysis to obtain a synthetic measure, *Governance Quality*, which is a weighted sum of the original indicators.

The estimation results obtained by linear regression are presented in Table 6. 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 for frontier-firms was set to zero. Coefficient estimates for the regressors at the firm-level have the interpretation of elasticities since both the dependent variable and firm-level regressors are in log form.

[Insert Table 6 around here]

In Column (1) of Table 6 we estimate the regression in expression (3) above. Regarding firms' characteristics, we find that larger, more capital intensive, and more skilled-labour firms decrease the distance to the frontier. For instance, a one per cent increase in size (as measured by the number of employees) reduces the distance to the frontier by 0.18 per cent, and a one per cent increase in capital intensity reduces the distance to the frontier by 0.026 per cent. In addition, age increases the distance to the frontier. These results are consistent with the findings of Andrews et al. (2015) for OECD countries, and also with

Conway et al. (2015) for New Zealand, who find that frontier firms are more likely to be younger.

As regards to country-level economic and institutional factors, we find that they play an important role as determinants of firms' distance to the EU TFP frontier. In particular, we obtain that higher tertiary education, trade openness, easiness in getting credit, and quality of governance significantly affect the technological catching up of laggards to the frontier. These results are in line with existing literature. For instance, Iacovone and Crespi (2010) provide evidence on the role of trade openness in the catching up of laggards towards the frontier. Arnold et al. (2001) document how product market regulations that restrain competitive pressure negatively affect firms' productivity, implying that a weak market and institutional framework may impose a burden on productivity growth of firms.

In Column (2) we include the same regressors and controls than in Column (1), but we also interact the regressors with a dummy variable taking value 1 for the recession years (2008-2014). Hence, the estimates for non-interacted regressors in this column correspond to the reference category, pre-recession years (2003-2007).<sup>15</sup> For pre-recession years we obtain both for firm-level and country-level variables the same patterns than in Column (1), with the only exception of governance quality that is non-significant. For recession years, results indicate that size and skilled-labour decrease the distance to the frontier more than in the pre-recession period. Differently, capital intensity reduces the gap less than in the pre-recession years. As for age, it increases the gap more than in the pre-recession period. In addition, regarding country-level economic and institutional factors, we find that they also play an important role in reducing firms' distance to the TFP frontier during the recession period, although the effect is weaker for tertiary education, slightly stronger for trade openness, equal for easiness in getting credit and, interestingly, we uncover that the overall effect of governance quality in reducing the gap is driven by the effect of this variable in the recession years (as in the pre-recession period its effect is statistically non-significant).

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<sup>15</sup> For recession years we should add the coefficients for interacted regressors to the corresponding ones for the reference category (pre-recession).

Finally, in Column (3) we check the relevance of distinguishing among manufacturing, non-financial market services, and other production, taking also into account the role of the recession as a moderating factor of the impact of the different determinants. We interact all the regressors of Column (1) both with dummies of pre-recession and recession years, and also with dummies corresponding to the three aggregated sectors. Hence, in this final column, coefficients have a direct interpretation and do not need to be interpreted with regards to reference categories.<sup>16</sup> Starting with firms' characteristics, we find that some results in column (2) also hold individually for the three sectors. First, being a larger and a more labour skilled firm is even more relevant for catching up in the recession period. Second, capital intensity has a stronger role for the catching up process in the pre-recession period.

Though, the role of age in getting further away from the frontier is reinforced in the recession period for manufacturing and other production, and is non-significant for non-financial market services in that period.

Regarding economic and institutional characteristics at the country level, our findings suggest that similarly to column (2), tertiary education has a stronger positive effect on catching up in the pre-recession period, but only for manufacturing and non-financial market services (for other production the effect is similar in both periods). However, trade openness has a slightly stronger positive effect on catching up in the recession period (also similar to column 2). Furthermore, easiness in getting credit contributes positively to catching up in a similar way in both periods. Finally, and once again as in column (2), governance quality has an effect in favouring the catching up process only during the recession period (this result is driven by manufacturing and non-financial market services, since the positive and statistically significant effect of governance quality for other production is similar in both periods).

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<sup>16</sup> To properly assess the moderating role of the recession, we perform tests on the equality of coefficients in the two periods for each variable and separately for manufacturing, non-financial market services, and other production. In the majority of the cases we reject the null that they are equal at a standard level of significance.

## **5. Concluding remarks.**

In this paper we have analysed the determinants of within-industry distance to the TFP frontier across EU economies. We first provide a description of the characteristics of the best performing firms in terms of productivity, that is, the frontier firms, in comparison with the non-frontier firms. We further analyse the determinants of firms' TFP gaps between frontier and non-frontier firms, including factors at the firm and country levels.

The analysis of the determinants of the TFP gap between frontier and non-frontier firms within industries shows that larger, more capital intensive and more labour skilled firms are closer to the frontier. In contrast, older firms are further away from the frontier. At the country level, in general, trade openness, tertiary education, the easiness of getting credit and governance quality play a positive role in reducing firms' distance to the frontier.

In addition, our results indicate that it is important to consider the moderating role of the recession when analysing the effects of the determinants of the distance to the TFP frontier. In this respect, for firm characteristics the direction of the effects is the same in the recession period than in the pre-recession one, but their magnitude becomes larger or smaller depending on the considered variable. Hence, the effect of size and skilled-labour in the catching up process becomes stronger during the recession period, while this effect becomes weaker for capital intensity. Furthermore, the effect of age in increasing firms' distance to the frontier is stronger in the recession years. As for countries' economic and institutional factors, the effect of trade openness in approaching the frontier is slightly larger in the recession period, while this effect for tertiary education becomes weaker. For easiness of getting credit the effect is similar in both periods. A quite differentiated effect is found for governance quality, since its role in decreasing the distance to the frontier is only relevant during the recession period (before it is statistically non-significant).

Finally, breaking down the analysis by sectors (manufacturing, non-financial market services, and other production) we obtain the same patterns as before, with few exceptions. The most remarkable one is that governance quality reduces the distance to the frontier only during the recession period for manufacturing and

non-financial market services, while it reduces similarly this distance in both periods for other production.

Although is difficult to provide a well-targeted policy guidance, our findings suggest a number of implications. First, given the characteristics of firms at the technological frontier, it seems advisable to pursue active policies promoting size growth, labour quality and capital intensity at the firm level. Second, macroeconomic policies towards the increase in the level of education of countries and the promotion of trade openness, by helping at absorbing advanced technologies and a better reallocation of resources, may also serve to enhance the technological catching up of laggards towards the frontier. Our results on the importance of the easiness in getting credit also point towards the need to implement policies that stimulate a more competitive banking system, with a reduction in informational asymmetries between lenders and borrowers (eliminating borrowing constraints). Finally, our findings also suggest that improving the quality of governance seems to be an important institutional factor, especially relevant in the recession period, which policy makers should consider.

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## Appendix.

**Table A.1. Industry classification.**

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**Manufacturing**

Manuf. of food, beverages and tobacco  
Manuf. of textiles, wearing apparel, leather  
Manuf. of wood, paper, printing  
Manuf. of coke and refined petroleum prod.  
Manuf. of chemicals and chemical prod.  
Manuf. of pharmaceutical products  
Manuf. of rubber, plastic and non-metallic  
Manuf. of basic and fabricated metal prod.  
Manuf. of computer, electronic and optical  
Manuf. of electrical equipment  
Manuf. of machinery and equipment n.e.c.  
Manuf. of motor vehicles, trailers  
Manuf. of furniture; jewellery, musical prod.

**Non-financial market services**

Wholesale and retail trade of motor vehicles  
Wholesale trade, except of motor vehicles  
Retail trade, except of motor vehicles  
Transport and storage  
Postal and courier activities  
Accommodation and food service activities  
Publishing, motion picture, video, television  
Telecommunications  
Computer programming, consultancy  
Professional, scientific and technic. activities

**Other production**

Electricity, gas, steam and air cond. supply  
Water suppl.; sewerage, waste management  
Construction

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**Table 1. Means and differences in means of firm characteristics: EU frontier firms vs. non-frontier firms.**

|                                      | <i>TFP</i> |          | <i>Age</i> |          | <i>Employment</i> |           | <i>Value Added</i> |          | <i>Capital intensity</i> |          | <i>Earnings</i> |          | <i>Profits</i> |          | <i>Wage p.e.</i> |          |
|--------------------------------------|------------|----------|------------|----------|-------------------|-----------|--------------------|----------|--------------------------|----------|-----------------|----------|----------------|----------|------------------|----------|
|                                      | <i>NF</i>  | <i>F</i> | <i>NF</i>  | <i>F</i> | <i>NF</i>         | <i>F</i>  | <i>NF</i>          | <i>F</i> | <i>NF</i>                | <i>F</i> | <i>NF</i>       | <i>F</i> | <i>NF</i>      | <i>F</i> | <i>NF</i>        | <i>F</i> |
| <b>Average 2003-2014</b>             | 4.4        | 5.8***   | 24.1       | 31.9***  | 107.5             | 857.3***  | 4422               | 70157*** | 43.7                     | 122.6*** | 1230            | 29023*** | 338            | 14149*** | 30.9             | 57.6***  |
| <b>Pre-recession: 2006</b>           | 4.4        | 5.8***   | 23.4       | 30.5***  | 109.7             | 789.4***  | 4558               | 66895*** | 39.4                     | 120.8*** | 1265            | 28629*** | 381            | 14366*** | 31.1             | 65.2***  |
| <b>recession: 2013</b>               | 4.3        | 5.7***   | 26.6       | 34.9***  | 105.2             | 855.8***  | 4383               | 67638*** | 49.4                     | 130.7*** | 1141            | 27258*** | 307            | 13431*** | 31.8             | 59.7***  |
| <b>By sectors (2003-2014):</b>       |            |          |            |          |                   |           |                    |          |                          |          |                 |          |                |          |                  |          |
| <b>Manufacturing</b>                 | 4.3        | 5.6***   | 25.7       | 36.2***  | 107.0             | 662.6***  | 4639               | 66638*** | 43.6                     | 82.8***  | 1402            | 27160*** | 376            | 13232*** | 30.2             | 54.5***  |
| <b>Non-financial market services</b> | 4.5        | 5.5***   | 22.9       | 28.5***  | 89.9              | 499.2***  | 4463               | 66950*** | 62.8                     | 253.8*** | 1490            | 32965*** | 420            | 15992*** | 33.5             | 58.1***  |
| <b>Other production</b>              | 4.5        | 6.0***   | 22.9       | 28.9***  | 113.1             | 1134.4*** | 4210               | 74267*** | 38.5                     | 123.1*** | 997             | 29652*** | 279            | 14482*** | 30.7             | 60.5***  |

Note: To identify EU frontiers, we calculate the median number of firms across years for each industry, and the 5% of this median number is the number of firms that we keep constant across years for each industry to identify the most productive firms at the EU level (within each industry and year). *F* is the average of frontier firms; *NF* is the average of non-frontier (all other) firms. TFP is measured in logs, employment by the number of employees. Value added, capital, earnings, profits and wages measured in thousands of euros. Earnings are measured by EBITDA (earnings before interest, taxes, depreciation and amortization). Test in mean differences with \*\*\* significant at 1%, \*\* significant at 5%, and \* significant at 10%.

**Table 2. Percentage of firms in the EU frontier by country of origin in selected years.**

|             | Total  |        | Manufacturing |        | Non-financial<br>Market Services |        | Other Production |        |
|-------------|--------|--------|---------------|--------|----------------------------------|--------|------------------|--------|
| Country     | 2006   | 2013   | 2006          | 2013   | 2006                             | 2013   | 2006             | 2013   |
| Austria     | --     | 22.82% | --            | 29.73% | --                               | 18.86% | --               | 12.50% |
| Netherlands | 10.48% | 16.76% | 13.04%        | 19.44% | 10.75%                           | 16.67% | --               | --     |
| Belgium     | 11.75% | 13.10% | 14.12%        | 16.98% | 10.65%                           | 9.95%  | 9.53%            | 14.96% |
| Germany     | 14.01% | 12.88% | 16.28%        | 14.89% | 13.84%                           | 12.53% | 8.67%            | 8.36%  |
| Denmark     | --     | 12.60% | --            | 11.37% | --                               | 12.23% | --               | 17.65% |
| Ireland     | --     | 9.89%  | --            | 15.00% | --                               | 7.46%  | --               | 25.00% |
| UK          | 9.27%  | 9.55%  | 8.40%         | 7.23%  | 9.14%                            | 10.53% | 13.51%           | 12.92% |
| France      | 4.21%  | 4.69%  | 4.30%         | 5.33%  | 3.84%                            | 4.51%  | 5.12%            | 4.02%  |
| Sweden      | 3.28%  | 4.61%  | 3.56%         | 4.09%  | 3.43%                            | 5.30%  | 2.35%            | 4.04%  |
| Spain       | 9.92%  | 3.64%  | 10.18%        | 3.48%  | 8.87%                            | 3.11%  | 15.28%           | 7.86%  |
| Slovakia    | 3.50%  | 3.61%  | 2.33%         | 2.29%  | 4.79%                            | 5.53%  | 4.14%            | 2.40%  |
| Italy       | 5.01%  | 3.57%  | 4.99%         | 4.16%  | 5.03%                            | 2.83%  | 5.05%            | 3.00%  |
| Hungary     | 5.35%  | 3.29%  | 5.70%         | 2.95%  | 5.74%                            | 3.67%  | 2.94%            | 2.89%  |
| Croatia     | 1.71%  | 2.52%  | 1.44%         | 2.41%  | 2.38%                            | 3.23%  | 0.98%            | 1.06%  |
| Slovenia    | 2.40%  | 2.28%  | 1.28%         | 1.23%  | 4.15%                            | 3.23%  | 0.84%            | 2.13%  |
| C Republic  | 1.94%  | 1.88%  | 1.81%         | 1.08%  | 2.65%                            | 2.96%  | 0.00%            | 0.44%  |
| Poland      | 1.92%  | 1.87%  | 1.34%         | 1.99%  | 2.70%                            | 1.79%  | 0.89%            | 1.83%  |
| Finland     | 2.63%  | 1.83%  | 3.24%         | 2.06%  | 2.38%                            | 1.80%  | 1.72%            | 1.32%  |
| Portugal    | --     | 1.66%  | --            | 1.06%  | --                               | 2.15%  | --               | 2.75%  |
| Bulgaria    | 2.65%  | 1.54%  | 1.66%         | 1.34%  | 3.53%                            | 1.36%  | 3.23%            | 3.85%  |
| Romania     | 0.59%  | 0.89%  | 0.43%         | 0.65%  | 0.84%                            | 1.34%  | 0.81%            | 0.93%  |
| Greece      | 3.57%  | 0.85%  | 3.62%         | 0.56%  | 3.51%                            | 0.99%  | 4.17%            | 2.38%  |
| Estonia     | 1.58%  | 0.72%  | 0.75%         | 0.35%  | 2.40%                            | 0.90%  | 1.04%            | 1.32%  |

Notes:

1. Austria, Denmark, Ireland and Portugal have no coverage in AMADEUS for the year 2006 in the sample used for TFP measurement. The Netherlands has no coverage in AMADEUS for both years in the sample used for TFP measurement for the sector other production.
2. The percentages are calculated in two steps: First, the percentage of EU frontier firms of a given industry in a given country (per year) is calculated. Second, we calculate the average across industries of these percentages for each country. A higher value than 5 means the country is overrepresented in the EU top 5% of firms. Countries are ranked according to their 2013 values, from the best to the least well-represented one in the EU top 5%.

**Table 3. Persistence in the EU frontier.**

| Percentage of firms staying in the frontier after several years |                 |        |        |                 |        |        |                 |        |        |
|-----------------------------------------------------------------|-----------------|--------|--------|-----------------|--------|--------|-----------------|--------|--------|
| Industry                                                        | Sample 1        |        |        | Sample 2        |        |        | Sample 3        |        |        |
|                                                                 | Number of years |        |        | Number of years |        |        | Number of years |        |        |
|                                                                 | 1               | 2      | 5      | 1               | 2      | 5      | 1               | 2      | 5      |
| <b>Total</b>                                                    | 71.61%          | 51.33% | 31.12% | 66.03%          | 51.28% | 32.96% | 74.88%          | 66.05% | 51.78% |
| <b>Manufacturing</b>                                            | 69.05%          | 50.82% | 30.48% | 67.12%          | 51.57% | 33.54% | 74.25%          | 61.04% | 47.32% |
| <b>Services</b>                                                 | 74.89%          | 53.54% | 33.59% | 67.37%          | 53.25% | 33.64% | 77.64%          | 72.27% | 56.71% |
| <b>Other Production</b>                                         | 69.01%          | 44.44% | 23.68% | 57.44%          | 43.04% | 28.48% | 66.17%          | 62.41% | 51.13% |

Notes: To identify EU frontiers, we calculate the median number of firms across years for each industry, and the 5% of this median number is the number of firms that we keep constant across years for each industry to identify the most productive firms at the EU level (within each industry and year). Sample 1 follows frontier firms from 2003 onwards. Sample 2 follows frontier firms from 2006 onwards. Finally, Sample 3 follows frontier firms from 2006 onwards but restricting the sample to a balanced panel of firms that stay in AMADEUS database from 2006 to 2013.

**Table 4. Persistence in the non-EU frontier.**

| Percentage of firms staying away from the frontier after several years |                 |        |        |                 |        |        |                 |        |        |
|------------------------------------------------------------------------|-----------------|--------|--------|-----------------|--------|--------|-----------------|--------|--------|
| Industry                                                               | Sample 1        |        |        | Sample 2        |        |        | Sample 3        |        |        |
|                                                                        | Number of years |        |        | Number of years |        |        | Number of years |        |        |
|                                                                        | 1               | 2      | 5      | 1               | 2      | 5      | 1               | 2      | 5      |
| <b>Total</b>                                                           | 85.78%          | 57.43% | 40.64% | 81.91%          | 64.98% | 47.18% | 93.97%          | 83.40% | 70.45% |
| <b>Manufacturing</b>                                                   | 85.80%          | 59.54% | 44.64% | 85.46%          | 68.39% | 51.85% | 94.11%          | 81.80% | 68.42% |
| <b>Services</b>                                                        | 85.64%          | 55.93% | 37.73% | 78.92%          | 62.08% | 43.61% | 93.50%          | 84.42% | 72.12% |
| <b>Other Production</b>                                                | 86.19%          | 55.90% | 38.02% | 80.68%          | 63.84% | 44.30% | 95.05%          | 85.59% | 72.02% |

Notes: Non-EU Frontier firms are all firms that are not EU frontiers. To identify EU frontiers, we calculate the median number of firms across years for each industry, and the 5% of this median number is the number of firms that we keep constant across years for each industry to identify the most productive firms at the EU level (within each industry and year). Sample 1 follows non-frontier firms from 2003 onwards. Sample 2 follows non-frontier firms from 2006 onwards. Finally, Sample 3 follows non-frontier firms from 2006 onwards but restricting the sample to a balanced panel of firms that stay in AMADEUS database from 2006 to 2013.

**Table 5. Evolution of TFP of EU frontier and non-frontier firms.**

| Year                     | All firms |      | Frontier firms |      | Non-frontier firms |      | TFP gap |
|--------------------------|-----------|------|----------------|------|--------------------|------|---------|
|                          | Mean      | s.d. | Mean           | s.d. | Mean               | s.d. |         |
| <b>2003</b>              | 4.41      | 0.72 | 5.78           | 0.60 | 4.36               | 0.67 | 4.14    |
| <b>2004</b>              | 4.45      | 0.75 | 5.80           | 0.60 | 4.38               | 0.69 | 4.14    |
| <b>2005</b>              | 4.48      | 0.76 | 5.71           | 0.57 | 4.40               | 0.70 | 3.71    |
| <b>2006</b>              | 4.51      | 0.75 | 5.77           | 0.58 | 4.44               | 0.69 | 3.78    |
| <b>2007</b>              | 4.50      | 0.75 | 5.80           | 0.58 | 4.43               | 0.70 | 3.94    |
| <b>2008</b>              | 4.45      | 0.74 | 5.75           | 0.59 | 4.38               | 0.68 | 3.94    |
| <b>2009</b>              | 4.34      | 0.76 | 5.71           | 0.59 | 4.28               | 0.70 | 4.18    |
| <b>2010</b>              | 4.43      | 0.74 | 5.75           | 0.59 | 4.37               | 0.68 | 3.97    |
| <b>2011</b>              | 4.41      | 0.73 | 5.76           | 0.57 | 4.35               | 0.68 | 4.10    |
| <b>2012</b>              | 4.39      | 0.75 | 5.73           | 0.57 | 4.32               | 0.69 | 4.10    |
| <b>2013</b>              | 4.40      | 0.75 | 5.74           | 0.58 | 4.34               | 0.70 | 4.06    |
| <b>2014</b>              | 4.39      | 0.75 | 5.62           | 0.57 | 4.30               | 0.67 | 3.74    |
| <b>Average 2003-2014</b> | 4.43      | 0.75 | 5.75           | 0.58 | 4.36               | 0.69 | 4.01    |

Notes: To identify EU frontiers, we calculate the median number of firms across years for each industry, and the 5% of this median number is the number of firms that we keep constant across years for each industry to identify the most productive firms at the EU level (within each industry and year). TFP is measured in logs. Values corresponding to 2014 should be taken with caution given the smaller number of observations in the sample. TFP gap is calculated as the difference in average TFP of frontier and non-frontier firms. Note that TFP is measured in logs, so that, for instance, the TFP gap in 2003 is  $\exp(5.78-4.36)=4.14$ , i.e., in 2003 frontier firms are on average 4.14 times more productive than non-frontier firms.

**Table 6. Distance to the EU Frontier.**

| Dep. Variable: $\ln \frac{TFP_{iptc}}{TFP_{pt}^F}$ | (1)               | (2)               | (3)               |
|----------------------------------------------------|-------------------|-------------------|-------------------|
| <u>Firm Size</u>                                   | 0.182*** (0.001)  | 0.152*** (0.001)  | -                 |
| Size 2008-2014                                     | -                 | 0.044*** (0.001)  | -                 |
| Size Manuf. 2003-07                                | -                 | -                 | 0.160*** (0.002)  |
| Size Manuf. 2008-14                                | -                 | -                 | 0.206*** (0.002)  |
| Size Serv. 2003-07                                 | -                 | -                 | 0.156*** (0.002)  |
| Size Serv. 2008-14                                 | -                 | -                 | 0.197*** (0.001)  |
| Size Other 2003-07                                 | -                 | -                 | 0.141*** (0.003)  |
| Size Other 2008-14                                 | -                 | -                 | 0.180*** (0.003)  |
| <u>Firm Age</u>                                    | -0.009*** (0.001) | -0.007*** (0.001) | -                 |
| Age 2008-2014                                      | -                 | -0.003** (0.001)  | -                 |
| Age Manuf. 2003-07                                 | -                 | -                 | -0.012*** (0.002) |
| Age Manuf. 2008-14                                 | -                 | -                 | -0.016*** (0.001) |
| Age Serv. 2003-07                                  | -                 | -                 | -0.005*** (0.002) |
| Age Serv. 2008-14                                  | -                 | -                 | -0.001 (0.001)    |
| Age Other 2003-07                                  | -                 | -                 | -0.016*** (0.003) |
| Age Other 2008-14                                  | -                 | -                 | -0.020*** (0.003) |
| <u>Firm Capital intensity</u>                      | 0.026*** (0.001)  | 0.041*** (0.001)  | -                 |
| Capital intensity 2008-2014                        | -                 | -0.022*** (0.001) | -                 |
| Capital intens. Manuf. 2003-07                     | -                 | -                 | 0.030*** (0.001)  |
| Capital intens. Manuf. 2008-14                     | -                 | -                 | 0.009*** (0.001)  |
| Capital intens. Serv. 2003-07                      | -                 | -                 | 0.048*** (0.001)  |
| Capital intens. Serv. 2008-14                      | -                 | -                 | 0.030*** (0.001)  |
| Capital intens. Other 2003-07                      | -                 | -                 | 0.017*** (0.002)  |
| Capital intens. Other 2008-14                      | -                 | -                 | 0.003 (0.002)     |
| <u>Firm Skilled-labour</u>                         | 0.848*** (0.003)  | 0.826*** (0.003)  | -                 |
| Skilled-labour 2008-2014                           | -                 | 0.036*** (0.003)  | -                 |
| Skilled-labour Manuf. 2003-07                      | -                 | -                 | 0.862*** (0.005)  |
| Skilled-labour Manuf. 2008-14                      | -                 | -                 | 0.883*** (0.005)  |
| Skilled-labour Serv. 2003-07                       | -                 | -                 | 0.824*** (0.004)  |
| Skilled-labour Serv. 2008-14                       | -                 | -                 | 0.855*** (0.003)  |
| Skilled-labour Other 2003-07                       | -                 | -                 | 0.808*** (0.010)  |
| Skilled-labour Other 2008-14                       | -                 | -                 | 0.836*** (0.012)  |
| <u>Country Tertiary education</u>                  | 0.013*** (0.001)  | 0.016*** (0.001)  | -                 |
| Tertiary education 2008-2014                       | -                 | -0.005*** (0.000) | -                 |
| Tertiary educ. Manuf. 2003-07                      | -                 | -                 | 0.014*** (0.001)  |
| Tertiary educ. Manuf. 2008-14                      | -                 | -                 | 0.009*** (0.001)  |
| Tertiary educ. Serv. 2003-07                       | -                 | -                 | 0.017*** (0.001)  |
| Tertiary educ. Serv. 2008-14                       | -                 | -                 | 0.011*** (0.001)  |
| Tertiary educ. Other 2003-07                       | -                 | -                 | 0.012*** (0.001)  |
| Tertiary educ. Other 2008-14                       | -                 | -                 | 0.012*** (0.001)  |
| <u>Country Trade openness</u>                      | 0.001*** (0.000)  | 0.001*** (0.000)  | -                 |
| Trade openness 2008-2014                           | -                 | 0.0002*** (0.000) | -                 |
| Trade open. Manuf. 2003-07                         | -                 | -                 | 0.0005*** (0.000) |
| Trade open. Manuf. 2008-14                         | -                 | -                 | 0.0006*** (0.000) |
| Trade open. Serv. 2003-07                          | -                 | -                 | 0.0008*** (0.000) |
| Trade open. Serv. 2008-14                          | -                 | -                 | 0.0009*** (0.000) |
| Trade open. Other 2003-07                          | -                 | -                 | 0.0004*** (0.000) |
| Trade open. Other 2008-14                          | -                 | -                 | 0.0005*** (0.000) |
| <u>Country DTF Getting credit</u>                  | 0.0002* (0.000)   | 0.001*** (0.000)  | -                 |
| DTF Getting credit 2008-2014                       | -                 | 0.00001 (0.000)   | -                 |
| DTF Get. Cre. Manuf. 2003-07                       | -                 | -                 | 0.001*** (0.000)  |
| DTF Get. Cre. Manuf. 2008-14                       | -                 | -                 | 0.001*** (0.000)  |
| DTF Get. Cre. Serv. 2003-07                        | -                 | -                 | 0.001*** (0.000)  |
| DTF Get. Cre. Serv. 2008-14                        | -                 | -                 | 0.001*** (0.000)  |
| DTF Get. Cre. Other 2003-07                        | -                 | -                 | 0.000001 (0.000)  |
| DTF Get. Cre. Other 2008-14                        | -                 | -                 | -0.0002 (0.000)   |

|                              |           |         |           |         |           |         |
|------------------------------|-----------|---------|-----------|---------|-----------|---------|
| Country Governance quality   | 0.049***  | (0.004) | -0.002    | (0.004) | -         |         |
| Governance q. 2008-2014      | -         |         | 0.047***  | (0.002) | -         |         |
| Govern. qual. Manuf. 2003-07 | -         |         | -         |         | -0.002    | (0.005) |
| Govern. qual. Manuf. 2008-14 | -         |         | -         |         | 0.037***  | (0.004) |
| Govern. qual. Serv. 2003-07  | -         |         | -         |         | -0.034*** | (0.005) |
| Govern. qual. Serv. 2008-14  | -         |         | -         |         | 0.031***  | (0.004) |
| Govern. qual. Other 2003-07  | -         |         | -         |         | 0.050***  | (0.008) |
| Govern. qual. Other 2008-14  | -         |         | -         |         | 0.050***  | (0.006) |
| Constant                     | -5.609*** | (0.017) | -5.603*** | (0.019) | -5.562*** | (0.022) |
| Observations                 | 1,040,504 |         | 1,040,504 |         | 1,040,504 |         |
| R-squared                    | 0.771     |         | 0.773     |         | 0.775     |         |

Notes: To identify EU frontiers, we calculate the median number of firms across years for each industry, and the 5% of this median number is the number of firms that we keep constant across years for each industry to identify the most productive firms at the EU level (within each industry and year). Size refers to the number of employees. All specifications include industry, country and year dummies. Robust standard errors clustered by firm in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.