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Regulations and technology gap in Europe: the role of firm dynamics*

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Abstract

In this paper, we develop a new firm-level measure of distance to the productivity frontier that accounts for international technology spillovers stemming from the use of imported intermediate goods. The trade-weighted technological distance to frontier is matched with sector- and country-level data on regulation and firm dynamics (entry and exit rates) of 16 European countries. Using our measure of trade-adjusted technology gap, we investigate the role of labour, capital, and product market regulatory frameworks in the technology catch-up process, gauging the effect of firms' dynamics in mediating and moderating the impact of regulation on the technology gap.

Our study offers a novel perspective and insights to the analysis of the link between framework conditions and technological distance to frontier. While most scholars argue that less regulation always favours productivity growth and the diffusion of technology, our results provide a more nuanced picture. Deregulation is not a one-size-fits-all solution that leads to faster technology diffusion, instead heterogeneity in business dynamism and countries' regulatory structures need to be considered.

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1 Introduction

Despite the slowdown in aggregate productivity growth in Europe, differences in productivity between frontier and non-frontier firms have been growing since 2000 (Andrews et al., 2015; Berlingieri et al., 2020), and innovation is progressively more concentrated among few actors and places. The two prevailing hypotheses for the concentration in innovation and productivity are winner-takes-all dynamics and inhibited technology diffusion (Andrews et al., 2015, 2016b). In the first case, the benefits from innovation and productivity gains are increasingly concentrated among frontier firms; a mechanism continually reinforced by the process of globalisation, which contributes to increase the productivity gap between the so-called "superstar" firms and the rest. In the second case, the rising gap may be due to stalling technological diffusion and the increased complexity of technologies requiring higher absorption capacity (i.e. prior accumulated knowledge and adequate skills endowment Andrews et al., 2015; Brynjolfsson and McAfee, 2012).

Economic theory emphasises the role of framework conditions in removing obstacles to the efficient allocation of resources, e.g. capital and labour, thereby favouring productivity growth and the diffusion and take-up of technology. The standard argument is that reducing rigidities in product and factors' markets and freeing international trade are important components of an inclusive strategy to increase and sustain economic growth. Specifically, empirical studies show that the stricter the product market regulation, the lower the productivity growth, due to excessive burden on companies which discourages investments (Scarpetta and Tressel, 2002; Scarpetta et al., 2002). Similarly, barriers to access to finance and rigidities in the labour market (e.g. more stringent restrictions regulating hiring and firing) may slow down the reallocation of capital and labour to more productive firms, with a negative effect on the aggregate firm performance (Thum-Thysen et al., 2017; McGowan and Andrews, 2015; Martin and Scarpetta, 2012). On the other hand, low regulation in the labour market may decrease firms' incentives to invest in human capital formation (Lucidi, 2012; Égert, 2016).

Finally, regulatory frameworks affect innovation diffusion and productivity growth through their impact on business dynamics. Excessive burdens and bureaucratic barriers tend to discourage new companies to enter the market due to increased transaction and entry costs. This is particularly relevant for small firms engaging in risky activities, such as innovations, as they face tighter barriers to access to finance compared to the incumbent firms (Scarpetta et al., 2002; Acs et al., 2009; Agénor and Canuto, 2017).

The emphasis on the role of business dynamics (entry and exit) as one of the channels through which regulatory reforms may reduce the distance to frontier (EC, 2018;

De Haan and Parlevliet, 2018) is not sufficiently reflected in the empirical analyses on productivity differences and regulations. This paper contributes to the existing literature by assessing the impact of regulatory frameworks on the distance to frontier, taking into account the role of business dynamics.

Differently from the existing literature on regulation and productivity differences (Nicoletti and Scarpetta, 2003; Buccirossi et al., 2013; Santacreu, 2015, 2017), we develop a new measure of distance to technological frontier that accounts for international technology spillovers arising from the utilisation of imported intermediate inputs.[1] The embodied transfer of knowledge and technology through trade in intermediate inputs is increasingly relevant as new products, technologies, and components are often used across different sectors and production activities (e.g. dual use technologies, key enabling technologies, etc.). Specifically, we take the weighted average distance in total factor productivity (TFP) between a firm and all the country-sector frontiers that are trade-related to the country and sector of that firm. Weights are constructed using data on trade in intermediate inputs between countries' sectors from the World Input Output Data (WIOD). To calculate the TFP index, we use balance-sheet information at the firm-level from the Orbis database (Bureau van Dijk, BvD). Firm-level data on productivity differences is then aggregated to match country- and sector-level data on business dynamics, human capital, and regulatory frameworks, covering the three dimension of product, labour, and capital (access to finance) market regulation from different sources.

With this paper, we contribute to the existing literature on regulations, institutions and productivity with a new methodological approach and insights on the role of business dynamics in the relationship between regulation in product and labour market, access to finance and technology diffusion. In addition, the research question and findings of our paper are relevant for policy considerations in the European context. The slowdown in productivity growth have affected all European regions, even if with heterogeneous intensity. Member states have been asked to implement structural reforms in order to promote growth in Europe, with a specific focus on innovation as the main lever to boost productivity gains[2]. These reforms target product, labour, and capital markets as some of the main bottlenecks to improved economic performance. This work provides evidence in support of these policies, while also providing fine-grained insights on the impact of

[1]Studies show that access to foreign inputs has increased firm productivity in several countries, such as India (Goldberg et al., 2010), Indonesia (Amiti and Konings, 2007), Colombia (Kugler and Verhoogen, 2009), China (Feng et al., 2016), Hungary (Halpern et al., 2015), Ghana (Okafor et al., 2017) to name a few. However, these studies focus on a single country. Multi-country data on firms' imports of intermediate inputs is generally unavailable.

[2]See for instance https://ec.europa.eu/info/business-economy-euro/growth-and-investment/structural-reforms/structural-reforms-economic-growth_en.

regulatory framework on technology diffusion, the latter being recently acknowledged as a key factor behind those trends (Andrews et al., 2016b).

The rest of this paper is organised as follows. Section 2 introduces the related literature our work draws on, Section 3 illustrates the empirical strategy and describes the data. Section 4 describes the results, and Section 5 concludes.

2 Related literature

2.1 Technology diffusion

Our measure of trade-adjusted distance to productivity frontier draws from the international technology diffusion literature, which upholds the view that domestic productivity growth is influenced by foreign sources of technology. Keller (2004) reviews the channels for international diffusion of technology. The first channel is international trade and FDI. Domestic final products embody foreign technology via the use of foreign intermediate goods in the production of final output (Rivera-Batiz and Romer, 1991; Grossman and Helpman, 1993; Santacreu, 2017). Theoretical models of international technology diffusion underpin the role of R&D in adopting foreign technology, embodied in imported products (Eaton and Kortum, 1999; Santacreu, 2015). Countries that are far from the technological frontier increase their productivity by importing superior foreign technologies, while countries close to the frontier get even closer by developing new technologies through R&D investment, leading to further concentration of innovation among few countries.

International R&D spillovers are another channel of technology diffusion that is not necessarily linked to any particular transmission form, but it simply stems from the global stock of technology. Current R&D builds on previous R&D performed globally (Keller, 2004). However, the partially tacit nature of technology makes its diffusion incomplete and more geographically localised (Von Hippel, 1994). The more geographically distant the foreign knowledge is, the higher the costs and capabilities needed to absorb it (Bahar et al., 2014; Caragliu and Nijkamp, 2016). Since spillovers cannot be directly observed, the majority of studies measure them by relating the R&D of domestic firms to the TFP (Keller, 2002), patents (Jaffe et al., 1993; Verspagen, 1997; Mancusi, 2008), or inward FDI (Aitken and Harrison, 1999) of foreign firms (Coe and Helpman, 1995). R&D collaboration is also considered an important channel for technology diffusion (d'Aspremont and Jacquemin, 1988; Nadiri, 1993). Empirical studies confirm that technological collaboration allows small and medium-sized enterprises (SMEs) to close the innovation gap with firms at the frontier (Nieto and Santamaría, 2010; Andrews et al., 2015).

Proponents of the evolutionary economics of innovation (Dosi, 1982; Malerba, 2002) investigate the role of sectoral characteristics to explain differences in productivity, arguing that differences across industries are only in part related to spillovers and technology diffusion, and depend on a more complex set of structural factors and sector-specific techno-economic conditions. For example, Castellacci (2007) shows that sectoral differentials in productivity growth in Europe are related to cross-industry differences in technological opportunities, human capital, market size, degree of openness, and appropriability conditions. Moreover, when appropriability conditions are low, that is when it is more difficult to protect innovations from imitation, there is a greater opportunity for intra-industry knowledge diffusion and a positive effect on productivity growth. Other studies combine both firm- and sector-level determinants of productivity catch-up (Álvarez and Crespi, 2007; Jung and Lee, 2010). For example, Jung and Lee (2010) find that the catch-up occurs more likely in sectors where the technology is explicit and embodied in the equipment (such as electronics), and in sectors characterised by vertically integrated monopolistic market structures. They also find evidence that sectoral determinants of catch-up affect only the international catch-up, while national convergence is entirely driven by firm-level factors.

Finally, some studies have focused on the role of technological diffusion as one of the possible drivers of the European productivity slowdown (Acemoglu et al., 2006; Van Ark et al., 2008; Andrews et al., 2016b). Andrews et al. (2016b) argue that the growing dispersion of firm productivity drives the slowdown in aggregate productivity growth,[3] due to some firms experiencing fast productivity gains, while others lag behind (van Ark et al., 2018), resisting to move from a production-based economy to a knowledge/service-based economy (Van Ark et al., 2013; Andrews et al., 2016a).

2.2 Framework conditions

A substantial part of the economic policy literature has explored the role that framework conditions have in affecting technology diffusion, business dynamics, productivity differences, and economic growth (Lynn et al., 1996; Nickell, 1997; Blanchard, 2004; Acemoglu et al., 2005; Buccirossi et al., 2013; Escribá-Pérez and Murgui-García, 2018). Rules and policies that relate to the functioning of product, labour, and capital markets can prevent companies to benefit from innovation outcomes. Indeed, regulations may affect

[3] This increasing dispersion may be caused by the dissipating growth effect of the ICT revolution (Cette et al., 2016) or by the mis-measurement of productivity across industries and firms, due to the difficulty in capturing the digital and immaterial transformation of contemporary economies (Syverson, 2016).

firms investment decisions and whether to enter or to leave the market. High transaction and entry costs may discourage small, young, and innovative companies, which are usually unable to get sufficient capital or to overcome cost- and non-cost related barriers to entry. Therefore, framework conditions can alter the diffusion of technology and the efficient allocation of resources.

The general consensus is that restrictive product market regulation hinders technology transfer and has a negative impact on productivity (Crafts, 2006; Scarpetta and Tressel, 2002). Specifically, stringent regulatory settings in the product market have a negative impact on TFP and, partially, on market access as well (Scarpetta and Tressel, 2002).

The effects of labour market regulation are, however, less clear-cut. On the one hand, there is support of the view that too stringent regulation has negative effects on employment prospects, labour reallocation, and aggregate productivity growth. Tressel and Scarpetta (2004) analyse labour market institutions in 18 Organisation for Economic Co-operation and Development (OECD) countries and find that high labour adjustment costs (proxied by the strictness of employment protection legislation) decrease industry-level productivity. They argue that, when non-wage labour costs (hiring and firing costs) are high, and labour market regulation does not allow for the flexible adjustment of wages, the incentives for innovation and adoption of new technologies are hindered, eventually leading to lower productivity performance. Moreover, these costs tend to discourage the entry of firms (especially SMEs) into most markets (Scarpetta et al., 2002). Consistently with this view, Thum-Thysen et al. (2017) find that excessive restrictions in firing and hiring negatively affect TFP in the long term, and Balta et al. (2014) report that policies aimed at reducing employment protection legislation may foster productivity growth in economies engaged in a catching-up process.

On the other hand, loose regulation in hiring and firing may provide companies with disincentives to invest in technology upgrade and adoption, incentivising choices favouring cost-competitiveness gains (Lucidi, 2012; Correia and Gouveia, 2017). Égert (2016) reports evidence of a positive link between employment protection and TFP, suggesting that restrictions in hiring and firing may encourage companies to invest in human capital and preserve high-skilled employment. Finally, reforms that increase the flexibility of labour markets and reduce workers bargaining position may have harmful effects in terms of inequality, by increasing the gap between the top income employment shares and the rest (Jaumotte and Osorio, 2015; Dosi et al., 2018).

While the aforementioned studies focus mainly on the links between regulations and productivity dynamics, a clear link with innovation diffusion and adoption emerges through incentives to invest in human capital, skills and absorption capabilities in the medium and long term. Recently, Revoltella et al. (2019), focusing on the business environment across European regions, show that improving framework conditions[4] leads to better firm innovation performance, reduces the gap between frontier and lagging firms, and boosts the aggregate performance of regions in Europe.

Difficult access to finance is, among the framework condition barriers, a fundamental obstacle to companies' investments, in particular for young firms engaging in innovation activities (Hall and Lerner, 2010; Agénor and Canuto, 2017; Berlingieri et al., 2020). Innovative companies face greater difficulties in getting access to standard bank-based capital, given that their value largely lies in intangible assets, such as human capital and knowledge created by R&D activities, both weak form of collateral (Hall and Lerner, 2010; Brown et al., 2012). Agénor and Canuto (2017) show that the lack of access to finance not only negatively affects innovation activities, but it also provides firms with adverse incentives to invest in skills, therefore reducing their absorptive capacity. More developed financial markets, such as equity markets that do not require collateral, may partially solve this issue, however the wedge between the returns expected by external investors and those provided by entrepreneurs may still be large, preventing the financing of innovative investments (Hall and Lerner, 2010). Gorodnichenko and Schnitzer (2013) find that financially constrained companies in developing and transition economies are less innovative and less likely to catch up with the innovation frontier compared to foreign firms. Overall, favourable conditions for accessing finance may help lagging companies in reducing their gap with the leading firms, in particular in digital and knowledge intensive sectors, where the slowdown in technological diffusion seems to be more severe (Berlingieri et al., 2020).

2.3 Business dynamism

Firm dynamics, such as entry and exit, positively affects productivity growth and innovation outcomes, as it contributes to the renewal of the business population. Consistently with the Schumpeterian argument, the higher the entry rates, the more the existing firms are likely to innovate to preserve their innovation rents (Aghion et al., 2005, 2009). While the intense competition is positively related to the productivity and innovation of leading firms, it can be a deterrent for companies that are lagging behind (Aghion et al., 2014). At the sectoral level, the Shumpeterian hypothesis finds support in highly

[4]The authors also account for the quality of local institutions and governance, following an established literature in economic geography (see Charron et al., 2014 and Rodríguez-Pose and Di Cataldo, 2015 among others.

dynamic and competitive sectors, but it does not hold true in sectors lagging behind the technological frontier (Aghion et al., 2009).

Firm dynamics are strongly affected by the regulatory framework wherein firms operate. However, while studies on firm dynamics and productivity show that the entry and exit of firms significantly contribute to innovation and aggregate productivity growth (Foster et al., 2006), the available evidence is less conclusive concerning the relationship between business dynamism and framework conditions. Acs et al. (2009) link firms entry decisions to knowledge spillovers and lower barriers to entrepreneurship, such as legal and bureaucratic constraints and labour market rigidities. Fuentelsaz et al. (2015) investigate how framework conditions contribute to explain differences between incumbent firms and new entrants. In particular, they show how the informal advantages of being incumbent firms (renowned by investors, trade associations and banks, and holding central positions in knowledge networks) provide them with a greater probability of survival and market share advantages. This is especially true in the context of weak market-supporting institutions, including property rights protection or the presence of financial intermediaries facilitating capital and information flows within the market. Indeed, "in situations where market-supporting institutions are not sufficiently developed, informal ties acquire an important role in supporting economic exchanges. When formal institutions are weak, informal relationships have a greater influence on driving firm strategies and performance" (Fuentelsaz et al., 2015, p.1782). These mechanisms at play are linked to the phenomenon of the survival of 'zombie' firms in the market, due to their advantage as incumbents (McGowan et al., 2017). Excessive burdens to entry, information asymmetries, and lack of access to credit may discourage competition, allowing existing firms to stay in the market rather than being forced to leave. Klapper et al. (2004) investigate the impact of business regulation in relation to entry in different industries across European regions. Their findings suggest that excessive regulation tends to hamper entry also in industries where the churn rate (entry plus exit) is high. Their results hold even when accounting for labour market regulation and access to finance, two variables which are relevant for our paper.

3 Empirical strategy

In this section, we illustrate how we measure the TFP index and how we construct a trade-adjusted measure of technology gap. We then present a simultaneous equations model to explore the role of business dynamics in the relationship between product and input markets regulation and technology diffusion, and the data used for the empirical analysis.

3.1 TFP index

To measure the TFP, we follow the non-parametric method of Good et al. (2017), who propose a multilateral productivity index that has the desirable property of transitivity, i.e. it allows for comparisons across firms and time periods.

The TFP index for firm i in year t is defined as

$$\begin{aligned}\ln TFP_{it} = {} & (\ln Y_{it} - \ln \overline{Y_t}) + \sum_{s=2}^{t} (\ln \overline{Y_s} - \ln \overline{Y_{s-1}}) \\ & - \Bigg[\sum_{\theta=L,M,K} \frac{1}{2}(S_{i\theta t} + \overline{S_{\theta t}})(\ln X_{i\theta t} - \ln \overline{X_{\theta t}}) \\ & + \sum_{\theta=L,M,K} \sum_{s=2}^{t} \frac{1}{2}(\overline{S_{\theta s}} + \overline{S_{\theta s-1}})(\ln \overline{X_{\theta s}} - \ln \overline{X_{\theta s-1}}) \Bigg]\end{aligned} \tag{1}$$

where Y and X are quantities of output (turnover) and inputs, respectively (labour, materials, and capital). S_θ is the expenditure share of input θ. $\ln \overline{Y_t}$, $\ln \overline{X_{\theta t}}$, and $\overline{S_{\theta t}}$ are the arithmetic means of the corresponding firm level variable over all firms in year t (in a given industry and country). The TFP index for a given firm and year is expressed in relation to the hypothetical firm in the base time period 2007. This chained multilateral TFP index also provides a decomposition of TFP change into two components that exploit between and within panel data variations.

The standard assumption in the theoretical and empirical literature is that the TFP captures many elements such as differences in technology, quality of the capital or the output, managerial ability, firm age.[5] In this paper, we do not aim at explaining why TFP varies across firms but rather how regulations and business dynamics affect firms relative distance to the frontier.

The distribution of firm productivity measured by Eq. (1) is summarised in Fig. 1 with kernel density estimates. Separate densities are drawn for two years, 2008 and 2016. There is a clear leftward shift in the productivity distribution over time, with a larger mass of firms with relatively low productivity in 2016. This confirms the general finding that the productivity in Europe has slowed down as the number of 'zombie'[6]

[5] The advantages and drawbacks of TFP are well known and have been discussed since the contribution of Abramovitz's (1962), however the related discussion goes beyond the scope of this work.

[6] From McGowan et al., 2017, p.6: "Zombie firms are defined as old firms that have persistent problems meeting their interest payments [...] and stifling labour productivity growth."

firms has risen (McGowan et al., 2017).

3.2 Trade-adjusted distance to frontier

As reviewed in Section 2, there are many ways to proxy knowledge diffusion. In this paper, we propose a new methodology that combines the approach of distance to technology frontier (Nelson and Phelps, 1966; Benhabib and Spiegel, 2005) with the theoretical foundations of international trade in intermediate inputs (Caselli and Coleman, 2001; Keller, 2002; Sadik, 2008).

In particular, in line with the technology gap literature, we capture the potential for technology diffusion via the difference between firm i's TFP and the technological frontier in country c and sector j at time t. In each country-sector-year, the technological leader is defined as the top 99th percentile of TFP. The potential for technology diffusion is typically specified as

$$\ln TFP_{it} - \ln \overline{TFP}_t^{jc}; \tag{2}$$

where $\overline{TFP}_t^{jc}$ is the TFP of the frontier firm in sector j of country c.

Differently from previous studies on the distance to technology frontier (Bartelsman et al., 2008; Andrews et al., 2016a), we explicitly account for the possibility that technology is transferred through trade in intermediate goods (Eaton and Kortum, 1999; Rivera-Batiz and Romer, 1991; Grossman and Helpman, 1993), and that the intensity of technology diffusion is proportional to the intensity of trade between two sectors j and k of any given pair of countries c and q. Therefore, our measure of technology distance is defined as

$$TD_{i,kq,t} c \in C j \in J w_{jc,kq,t} \left[\ln TFP_{i,kq,t} - \ln \overline{TFP}_t^{jc} \right] \tag{3}$$

$$w_{jc,kq,t} = \frac{Z_{jc,kq,t}}{\sum_{c \in C} \sum_{j \in J} Z_{jc,kq,t}} \qquad \text{and} \qquad \sum_{c \in C} \sum_{j \in J} w_{jc,kq,t} = 1,$$

where $w_{jc,kq,t}$ is a weight measuring the global intermediate use by sector k of country q of products Z of sector j of country c (of the leader firm) at time t.[7]

[7]Data on the use of intermediate inputs is extracted by the World InputOutput Tables from the World Input-Output Database (WIOD). We constructed a matrix of weights by taking the ratio between elements of the matrix and the sum over its rows to have the use of frontier technology in downstream

Equation (3) can be decomposed as the sum of the traditional distance to the frontier, plus all other distances to frontiers that are trade-related to firms in sectors that import products of the frontier's sector:

$$TD_{i,kq,t} = w_{jc,jc,t}\left[\ln TFP_{i,jc,t} - \ln \overline{TFP}_t^{jc}\right] + \sum_{jc\neq kq} w_{jc,kq,t}\left[\ln TFP_{i,kq,t} - \ln \overline{TFP}_t^{jc}\right]. \tag{4}$$

When $w_{jc,jc} = 0$ (no trade, therefore $w_{jc,jc} = 1$), equation (4) reduces to the classical distance to technological frontier as in eq. (2). Using the intensity of trade in intermediate inputs to weigh the distances to country/sector-specific frontiers allows to relate firms and frontiers operating in two different sectors that are nevertheless trading intermediate products with embodied technology. To give an example, the manufacturing sector of plastic and rubber products provides on average 11% of their products to the manufacturing sectors of computer, electronic and optical products, and 12% to the manufacturing of motor vehicles.

Figure 2 shows the difference between the trade-weighted and non-trade-weighted distributions of distance to technological frontiers (TFP gaps). The traditional, non-weighted distribution is skewed to right, with more observations closer to the frontier, compared to the distribution of the trade-weighted technological distance. In fact, accounting for international and intersectoral productivity distances widens the gap, as firms are now compared to other countries and sectors. Figure 3 reports mean distances to frontier by country. The traditional distance to frontier (solid cranberry line) underestimates the average distance for transition countries such as Slovakia, Czechia, Latvia, Hungary, and Bulgaria, which are penalised by trading and importing intermediate inputs from e.g. Germany, an advanced economy with higher levels of TFP. Conversely, the traditional TFP gap overestimates the average distance for firms of advanced economies such as Sweden, Denmark, and UK, whose firms are on average more productive then firms in other countries from where they import (e.g. Spain, Italy).

Finally, Figure 4 plots the evolution over time of the distance from the technological frontier of the top 5% of the distribution (firms close to the frontier) and of the bottom 95% of the distribution (far from the frontier). Consistently with the outward shift of the left tail of TFP reported above (Fig. 1), our measure suggests that the most productive companies have improved their performance and progressively reduced their gap with respect to the technological leaders. Such decline in distance to the technology

sectors and countries.

frontier is mostly concentrated in the years following the crisis of 2008, until 2012 when it plateaus. In contrast, the least productive firms have been keeping lagging behind, further increasing their TFP gap. This trend is in line with the recent empirical evidence on the rising productivity gap between the leaders and the laggards (Andrews et al., 2016b, 2015; Berlingieri et al., 2020; OECD, 2015). It also provides additional evidence on the increasing distance from the frontier of those firms that are already the farthest away, reducing the potential for technology diffusion.

3.3 Direct and indirect impact of framework conditions

A channel through which product, labour, and capital markets regulations may have an impact on the process of technology diffusion is firm dynamics, such entry and exit, and business churn (entry rate plus exit rate). The churn rate is often associated with economic growth, as it facilitates the reallocation of resources from less productive (and eventually exiting) firms to more productive firms (De Haan and Parlevliet, 2018). More flexible labour markets tend to facilitate the reallocation, as well as they may limit the negative effects of economic downturns. Further, the presence of a monopolistic structure found in many sectors and/or barriers to finance could prevent the entry of adopters of superior technology (Parente and Prescott, 1999).

To investigate the role of firm dynamics on the distance to TFP frontier, we use a simultaneous equations model:

$$TD_{jt} = f(TD_{jt-1}, Dynamics_{jt-1}, Reg_{jct-1}, HC_{ct}, \theta_{jt,TD}, X_{jct}) \tag{5}$$

$$Dynamics_{jt} = h(Reg_{jct-1}, X_{jct}) \tag{6}$$

$$Dynamics_{jt} = \begin{cases} Churn_{jt} = h^1(Reg_{jct-1}, X_{jct}, n_{jt-1}, n^2_{jt-1}) \\ Entry_{jt} = h^2(Exit_{jt-1}, Reg_{jct-1}, X_{jct}, n_{jt-1}, n^2_{jt-1}) \\ Exit_{jt} = h^3(Entry_{jt-1}, Reg_{jct-1}, X_{jct}, n_{jt-1}, n^2_{jt-1}) \end{cases}$$

where TD_{jt} is the measure of technology distance defined in eq. (4), aggregated at sectoral level[8] to match the level of aggregation of the main explanatory variables. The latter include the three indicators of labour and product market regulation and access to capital, $Reg = (LabFlex, ProdMarkReg, CapFlex)$, and firms dynamics, $Dynamics$, which is either the churn rate, or entry or/and exit rates. When the entry and exit equations are estimated simultaneously, it is a three equations model. HC is a proxy

[8] Both classical and trade-adjusted measures of technology distance are aggregated at sector-country level to match the level of aggregation of the explanatory variables of the regression model in section 3.3. To retain the salient features of the distributions, we use the following aggregation statistics per sector-country pair: mean, median, standard deviation, and skewness.

of human capital (a detailed description of all the right-hand-side variables is given in section 3.4). $\theta_{jt,TD}$ includes the standard deviation and skewness, $\sigma_{jt,TD}, \tilde{\mu}_{jt,TD}$, of the distance to TFP frontier. All regression equation include sector, year, country dummies X_{jct}. The firm dynamics equations have two exclusion restriction variables, namely the log number (and its square) of active firms per sector n_{jt-1}, n^2_{jt-1}.

We estimate a system of simultaneous equations with a 3-stage least squares (3SLS), where the error terms of each equation are assumed to be correlated.

3.4 Data and variables

For this study, we use an unbalanced firm-level panel data set of European firms from the Orbis database (BvD) for the years 2007 to 2017, belonging to 16 member states of the European Union[9] matched to sector- and country-level indicators of business dynamics and framework conditions.

To compute the TFP index, the output of each firm is measured by its turnover. We use the stock of fixed assets to measure the capital input, while materials are measured by expenditure in intermediate inputs, and labour is measured as number of employees. As input shares in equation (1) are cost-based, we also collect information on the expenditures on each of these inputs. The cost of labour input is measured by the real wage bill, the cost of capital is measured by the user cost of capital (proxied by interest rates plus depreciation and amortisation) and the cost of materials is calculated as material expenditure.

Sector-specific information about business dynamics (entry, exit, churn rate, i.e. the sum of firm entry and exit rates) is provided by the Structural Business Statistics (SBS, Eurostat). SBS covers the 'business economy' (NACE Rev. 2 Sections B to N and Division 95) which includes industry, construction, and distributive trades and services. The data are reported at 2-digit level for most of the economic activities, however, some of them are reported as groups (e.g. '05–09' mining and quarrying or '10–12' manufacture of food products, beverages and tobacco products; see Table 8 in Appendix A for a detailed description of the sectors).

The three dimensions of framework conditions (product and labour market regulation and access to finance) come from different data sources. To measure the degree of regulation in the product market, we use the Regulatory Impact Indicator developed by Égert and Wanner (2016) for the OECD[10], with normalised values between 0 (low

[9] In Appendix B, we report the detailed download strategy, the coverage of the downloaded sample by country and year, the assessment of its representativeness compared to official statistics, and the selection criteria.

[10] The indicator follows the same rationale of the Product Market Regulation indicator developed

regulation) and 1 (high regulation). The indicator measures the indirect impact of regulatory barriers to firm entry, business activities, and competition in the Energy, Transport and Communication (ETC) sectors on all other sectors in the economy (via trade networks), covering the period 1975–2013.[11] We use the *wider* definition including retail trade and professional services, as it is more appropriate for analyses aimed at exploiting cross-country and cross-sector variation in the data (see Égert and Wanner, 2016).

To measure the extent of regulation in the labour market, we use two indicators on labour market efficiency from the World Economic Forum's Global Competitive Index: ease of individual and collective dismissals, and regulation of wage setting. From these two indicators, we build a principal component-based weighted index, which takes values smaller (larger) than zero if the labour market is more (less) flexible than the average with respect to wage setting and hiring/firing practices.

In the same way, we derive an index capturing how easy is for companies to access sources of finance. We use three indicators that capture different features of access to credit: 1) ease of access to bank loans, 2) access to equity funding for financing innovative and risky projects, and 3) access to finance by issuing bonds or shares on the capital market.[12] The access to finance indicator takes values larger (smaller) than zero if the performance of the capital market is better (worse) than the average country's.

In addition to the above framework conditions, we control for the absorptive capacity by using the share of tertiary graduates and workers in science and technology (Eurostat). Main statistics on the variables used for the analysis, including their level of aggregation, are shown in Table 1, while correlations are shown in Table 2.

Figure 5 shows the relationship between the three framework conditions variables. The index of labour market flexibility is on the horizontal axis, while the summary measure for access to finance is on the vertical axis. The size of the bubbles represents the degree of product market regulation. Four groups of countries can be identified in the

by the OECD itself, but has the advantage of being disaggregated by sector (NACE rev.2, 2 digits). The indicator uses input-output matrices to measure the relevance of regulation in upstream sectors for downstream industries of each country. The rationale is that sectors using intermediate inputs from more regulated sectors are more affected by the rigidities in those sectors. We use the country-weighted version since we include country fixed-effects to account for heterogeneity in our estimates.

[11] We imputed data for the years 2014-2016 using a linear regression on the time trend for each sector-country pair.

[12] The three subindicators are part of the Financial markets development indicator of the Global Competitiveness Index, to which they contribute via simple and weighted average. See WEF (2017). Since the three variables represent different forms of access to finance for companies, in our preliminary analysis, we use the three indicators separately. However, they all yield similar results, which are available upon request.

graph, according to the two dimensions of flexibility of the labour markets and access to finance. On the top-right, the United Kingdom and Denmark are characterised by both relatively low regulation of employment relations and high availability of finance to companies. On the top-left, Germany, Belgium, France, Sweden, and Finland have high access to capital (especially Sweden and Finland), but their labour markets are characterised by a relatively more rigid regulation. Eastern European economies mostly lie on the bottom- right corner, with very flexible labour markets but less capital availability. Finally, Southern European countries, together with Slovenia, are characterised by both relatively rigid labour markets and less access to finance. When adding the third dimension of product market regulation, heterogeneity across countries can be observed. It is worth noting that a few countries, such as Sweden, Germany, UK, and Denmark have the lowest levels of product market regulation despite having different labour market institutions. Differently, Italy, France, and Belgium have the most regulated product markets together with relatively less flexible employment legislation. We exploit the pattern found in Fig. 5 in our empirical analysis, to divide the 16 countries into four groups and present estimates for the four groups, i.e. high regulation, low regulation, low market regulation, and high access to finance.

Figures 6 and 7 show the correlation between our trade-weighted measure of technological distance and the churn rate, by countries and sectors, respectively. While the average TFP gap by countries does not appear to be correlated to the churn rate (Fig. 6), sector averages of distance to frontier display a moderate positive correlation with their churn rates (7). Specifically, firms in higher churn rate sectors are farther, on average, from the frontier. This suggests that in these sectors there may be no further gains from increased firms dynamics, as argued for instance by Aghion (2010), and one should resort to other mechanisms to increase technological diffusion. In the next section, we will investigate further this hypothesis by estimating our model also by two groups of sectors: high churn and low churn rate.

4 Results

Table 3 reports the results from a simultaneous equation model. Human capital and access to capital show a negative effect on the distance to frontier, while labour flexibility has an positive effect. In particular, a unit increase in the composite indicator of access to capital corresponds to a 5% to 7% decrease in distance to frontier; a one standard deviation[13] change in the human capital (about 7 ppts) corresponds to more than 0.15%

[13]We standardise the variable to remove multicollinearity.

drop in technology distance.

The churn rate, or the entry and exit rates taken separately (columns 1–3), have no statistically significant effect on the TFP gap. However, when entry and exit are considered simultaneously (column 4) in an recursive three equations model, the entry rate has a negative effect on the distance to the productivity frontier, indicating that favourable framework conditions[14] encourage entrepreneurship and help firms getting closer to the frontier.[15]

As discussed in section 3.4, we divide the sectors into two groups: low and high churn sectors. Table 4 displays the estimated coefficients of a simultaneous three equations model. In the low churn rate group of sectors, the predominant driver of the catch-up process is the replacement entry. Both the entry and exit of firms help these sectors to get closer to the frontier; even just 1 ppt increase in the entry and exit rates leads to a decrease in the TFP gap of 1.5% and 2.2%, respectively. These low churn sectors are also the closer ones to the frontier (see Fig. 7). According to (Aghion, 2010, p. 232), "the closer a firm or sector is to the frontier, the more positively (or the less negatively) it will react to increased entry threat." This result is in contrast to the high churn rate group, where more business dynamism in sectors that are already dynamic does nothing for catching up. Investment in human capital, however, may be a main channel to increase the productivity of these sectors, both directly and indirectly via less flexibility in the labour market. Indeed, more regulated labour markets may favour investments in human capital, as "...labour flexibility impacts on training and human capital accumulation. If labour relationships are expected to be short-lived, there is little incentive for firms to invest in both the general and specific training of their workforces....Workers, for their part, will be reluctant to acquire firm-specific skills if they do not feel a long-term commitment to their employers." (Lucidi, 2012, p.266)

Finally, following the 'organic' division of countries into four groups of regulations regimes (low and high regulation, and either scarce access to capital but high labour market flexibility, or low labour market flexibility and good access to capital; see section 3.4 and Fig. 5), we present the results for the four groups of countries in Table 5.

[14]The estimated effects of framework conditions on firm dynamics are not reported, however the results generally indicate that labour flexibility facilitates entry, while product market regulation, flexible labour market, and access to capital all reduce the exit rate. The (log) number of firms reduces the entry and increases the exit rate.

[15]The coefficients related to the standard deviation and skewness (σ_{jTD}, $\tilde{\mu}_{jTD}$) show that in sectors with low churn, low regulation, or high access to capital, there is more dispersion in the original firm distribution, and that the mean distances would be affected proportionally more by increased variability than in other sectors. A positive skewness (to the left, closer to the frontier) is almost always associated with a decrease in mean distance, a part in low churn sectors, where there is less reallocation, therefore it would only increase the distance between the few firms getting closer to the frontier and the rest.

Low regulated countries (column 1) have a lower degree of persistence in the distance to frontier compared to the high and mixed regulation groups, and are the only countries which are (negatively) affected by product market regulation. That is, more stringent product market regulation widens the distance to TFP frontier. These countries could decrease their technology distance by helping firms survive (therefore reducing the exit rate) and by making the labour market more stringent. Highly regulated countries, on the other hand, would benefit from a higher exit rate (and easier access to finance). Indeed, the increasing survival of low productivity firms that would typically exit in a competitive market (so-called 'zombie firms'), hampers productivity growth by displacing opportunities for more productive and innovative firms. Top countries in terms of share of capital sunk in zombie firms are Greece, Italy, Spain, and Portugal (Andrews et al., 2017), three of which are (largely represented) in our sample and classified as high regulated countries.

Estimations for economies that have insufficient access to capital but flexible labour markets (column 3) show that their catch-up process may speed up by increasing firm dynamics (more entry and exit), and by the development of human capital both in schools, with an increase of the tertiary educated population, and within firms, by increasing labour market regulation and therefore attracting and nurturing a skilled labour force, via firm-sponsored training. The last group of countries has a strict labour market regulation and a good access to capital (column 4). For this last group, the additional increase of access to finance has the desired effect of narrowing the distance to technological frontier.

In Appendix A, we also report the results of GLS estimation of only eq. 6 (Table 6). These results indicate that access to capital is lowering the distance to frontier. Without considering its endogeneity, firm dynamics have no effect or are associated with a increase in distance to the TFP frontier. Human capital has always a diminishing effect on the distance. For comparison, we show the results of a GLS using the traditional distance to frontier (Table 7). The results differ significantly, as access to capital, firm dynamics, and human capital have no effect, while there is a strong effect of product market regulation in increasing the technology distance (a 10 ppts increase in the index corresponds to a 3.2 to a 4.3% increase in distance). Moreover, past values of the traditional distance seems to be explain only about 55-60% of current distance, compared to 80% in the weight-adjusted measure of distance.

Altogether, the results of a simultaneous equation model highlight the mediating and moderating role of business dynamics in the impact of regulations on the technology diffusion.

5 Discussion and conclusions

In an era of increasing globalisation and digitalisation that allow faster-than-ever international knowledge and technology transfer, the gap in productivity between frontier and other firms is widening, opening policy and academic debates on the underlying causes of the malfunctioning technology diffusion process.

Although innovation diffusion is strongly affected by public policy (Stoneman and Diederen, 1994), there are few policy initiatives specifically aimed at changing the speed of technology catch-up, as most of the policy instruments are aimed at improving the technological capabilities.

In this paper, we investigate the effect of labour, capital, and product market regulatory frameworks in the technological catch-up process. Using firm-level data for 16 European countries, we develop a new measure of distance to the productivity frontier that accounts for international technology spillovers, stemming from the use of imported intermediate goods. Specifically, we calculate the weighted average of the distances in TFP between a firm and all the country-sector frontiers that export intermediate inputs to that firm's country-sector. We show that the traditional, unweighted, measure of TFP gap tends to underestimate the distances of transition countries such as Slovakia, Czechia, Latvia, Hungary, and Bulgaria, which are penalised by trading and importing intermediate inputs from advanced economies such as Germany.

Our measure of trade-weighted technological distance is then matched with data on regulation and firm dynamics to explore the role of business dynamism in mediating and moderating the impact of regulation on the distance to technological frontier. Indeed, the European Central Bank highlights the causal link between business dynamism, framework conditions, and technology adoption/diffusion:

> "Market competition and business churning (i.e. the rate of entry and exit of firms)—which are affected by country-specific framework conditions—influence the incentives and costs for firms to invest in new technology or adapt existing technologies." (Masuch et al., 2018)

We show that when considering the entry and exit of firms, our results complement and refine the general findings of the literature that more stringent regulations are associated with lower productivity and less technology diffusion (Scarpetta and Tressel, 2002; Tressel and Scarpetta, 2004; Crafts, 2006). Indeed, while we find no evidence of direct effects of product market regulation on technological distance to frontier per se, we find that easier access to capital may increase the catch-up. However, differently from previous studies, our results show that a stricter employment protection can decrease the distance to frontier. Even Scarpetta and Tressel (2002), who point to a negative relationship between labour market regulation and productivity, find that in highly centralised/centrally coordinated or decentralised countries, the "adjustment of the workforce can be achieved [...] by recurring to the internal labour market via firm-sponsored training, if EPL is strict"[p.23]. Indeed, if a firm's human capital is a key element in its ability to adopt innovations, a more regulated labour market may create incentives for firms to invest in their workers with e.g. on-the-job training (Lucidi, 2012; Égert, 2016). This human capital effect may be accentuated in those sectors characterised by high churn, where imposing a somewhat stricter employment regulation—and therefore reducing the job reallocation–could motivate firms to invest in skills and pay for most of job-related training (Acemoglu and Pischke, 1999; Gersbach and Schmutzler, 2012).

In line with the Schumpeterian growth theory, we find that higher rates of firm entry and exit reduce the distance to the TFP frontier. However, this effect is only found in low churn sectors.

Finally, firm dynamics and regulation have heterogeneous effects on different groups of countries. Low regulated countries are the only ones that are negatively affected by product market regulation, and may get closer to the frontier with a more regulated labour market regulation and a higher survival of firms (less exit). On the other end of the spectrum, firms in highly regulated countries could get closer to the frontier with more firm exits, specifically low productivity firms that would typically exit in a competitive market.

A few implications for policy can be drawn from our findings. First, we do not find evidence that one-size-fits-all regulatory model ensures faster technology diffusion, rather, specific sector and country characteristics need to be taken into account. Furthermore, the entry of new companies tends to be associated with a reduced gap from the technological frontier, as new entrants are quicker in adopting and bringing innovations to the market, as recently highlighted by Howell et al. (2020) in the context of the current Covid-19 crisis. Finally, human capital and access to finance are confirmed as horizontal drivers of technology catch-up and diffusion, across different regulatory regimes and also in those sectors where business dynamism is already high. While policies in this domain are not necessarily thought to directly address innovation diffusion, they are key levers for boosting the adoption rate of innovations, enabling local (research and) innovation systems to produce, absorb and implement new knowledge, to keep pace with global technological change.

The present analysis has several limitations. From a methodological point of view, there is the selection bias deriving from the over-representation of firms with more than 20 employees. Moreover, our interpretation of the effects of labour market regulation on human capital should be considered as an educated guess, as we do not control for capital deepening, nor the the technology or competition level of sectors. Some of these limitations offer avenues for future research. Indeed, the market structure (e.g., concentration, forward and backward linkages, capital intensity) may affect the speed of technology catch-up and the reaction of markets to changes in regulatory schemes.

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Table 1: Summary statistics

	avg	median	sd	min	max	N	Aggr. level[†]
$\ln TFP$	-0.14	-0.16	0.88	-4.08	3.77	15.5 (mln)	i
TD^{trade}	2.33	2.30	0.93	-2.75	8.29	15.5 (mln)	i
TD	2.10	1.94	1.05	-3.56	8.38	15.5 (mln)	i
churn rate	0.17	0.16	0.08	0.00	0.84	5711	j
entry rate	0.09	0.08	0.05	0.00	0.71	5898	j
exit rate	0.08	0.08	0.04	0.00	0.38	5724	j
Prod Mark Reg	0.12	0.09	0.10	0.01	0.60	5055	j
LabFlex Index	0.00	-0.27	1.19	-2.14	2.49	8333	c
CapFlex Index	0.00	0.00	1.61	-3.03	3.92	8333	c
Human Capital	0.40	0.40	0.073	0.20	0.54	7587	ct

Note: † The aggregation level of data is: i firm-level, j sector-level, c country-level.

Table 2: Correlation coefficients

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) TD_j^{trade}	1								
(2) TD_j	0.547	1							
(3) $\ln TFP_j$	-0.753	-0.303	1						
(4) Entry_j	0.127	0.157	-0.020	1					
(5) Exit_j	0.025	0.030	-0.013	0.495	1				
(6) Churn_j	0.098	0.119	-0.020	0.909	0.813	1			
(7) PMR_j	0.299	0.350	-0.158	0.064	-0.026	0.024	1		
(8) LabFlex_c	-0.122	-0.155	0.169	0.257	0.292	0.315	-0.157	1	
(9) CapFlex_c	-0.195	-0.017	0.321	-0.079	-0.181	-0.137	-0.044	-0.066	1
(10) HC_c	-0.291	-0.076	0.489	-0.175	-0.271	-0.245	-0.089	-0.083	0.502

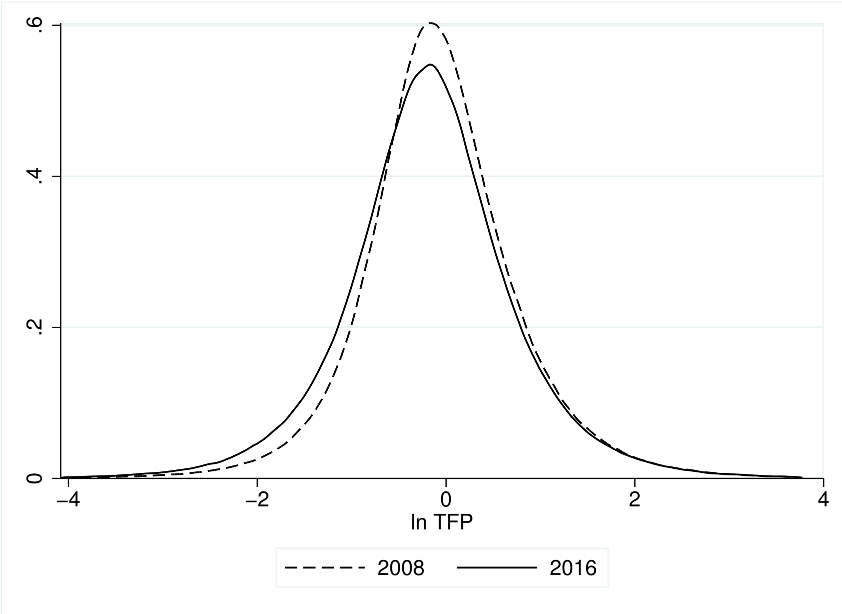

Figure 1: Kernel density estimates for $\ln TFP$

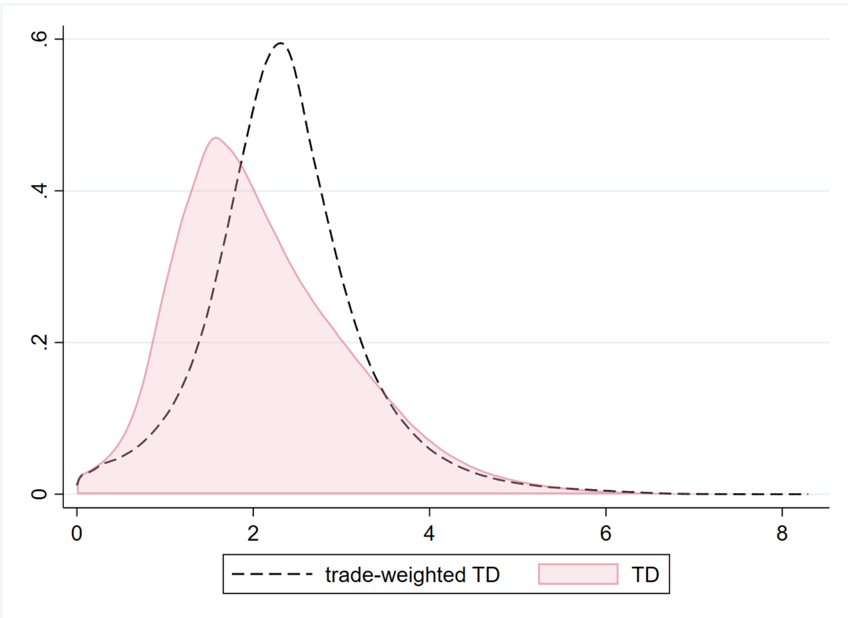

Figure 2: Distance to TFP frontier with/without intermediate input trade correction (kernel density)

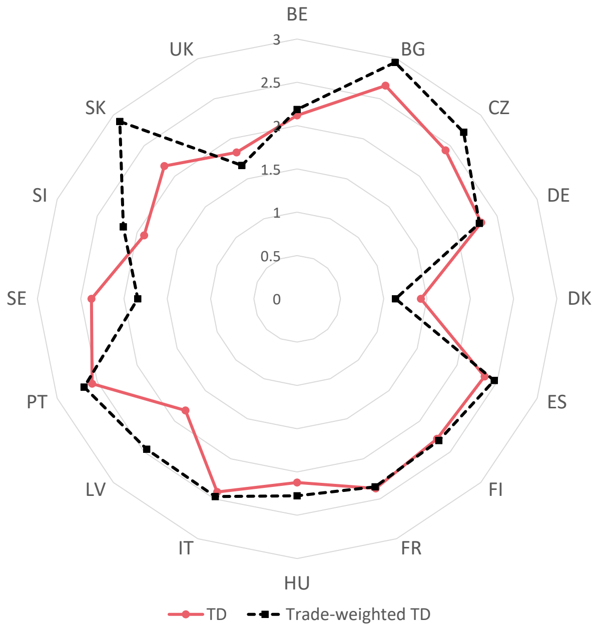

Figure 3: Differences between distances to TFP frontier (with and without trade correction)

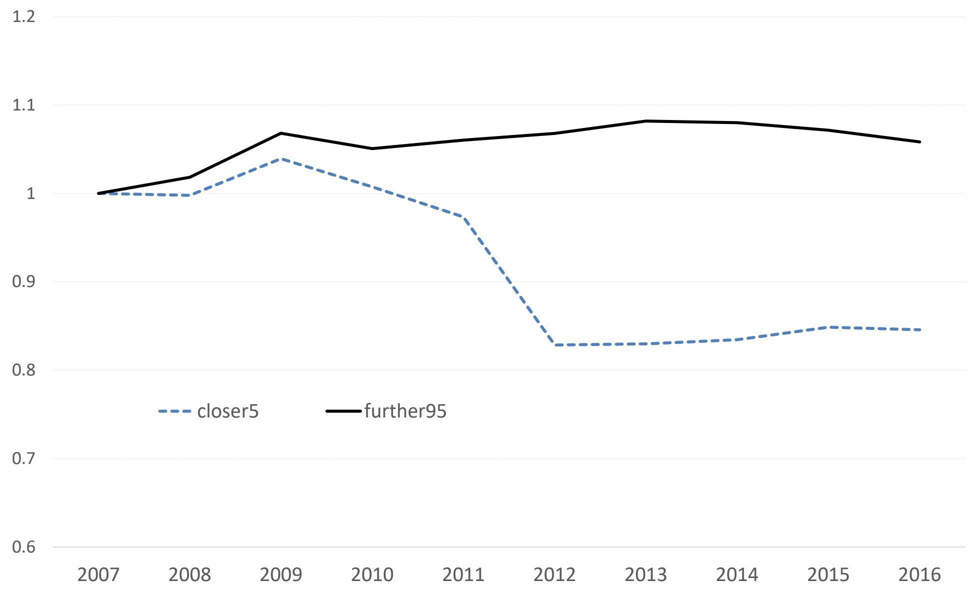

Figure 4: Trend in technology distance among top 5% (close to frontier) and bottom 95% (far from frontier) firms

Figure 5: Labour and capital market flexibility by country (bubble size = product market regulation)

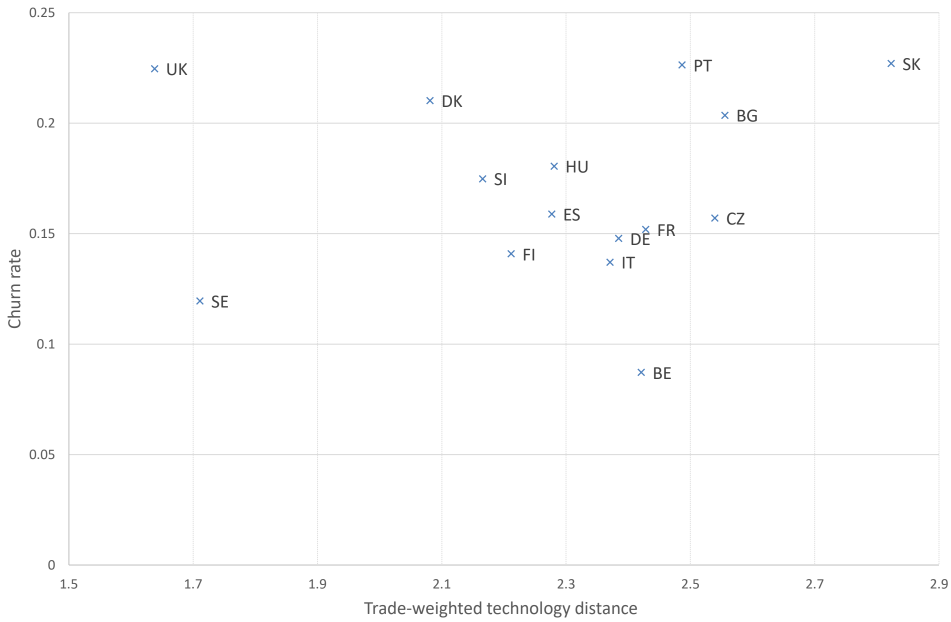

Figure 6: Churn rate and technology distance (TD^{trade}) by country

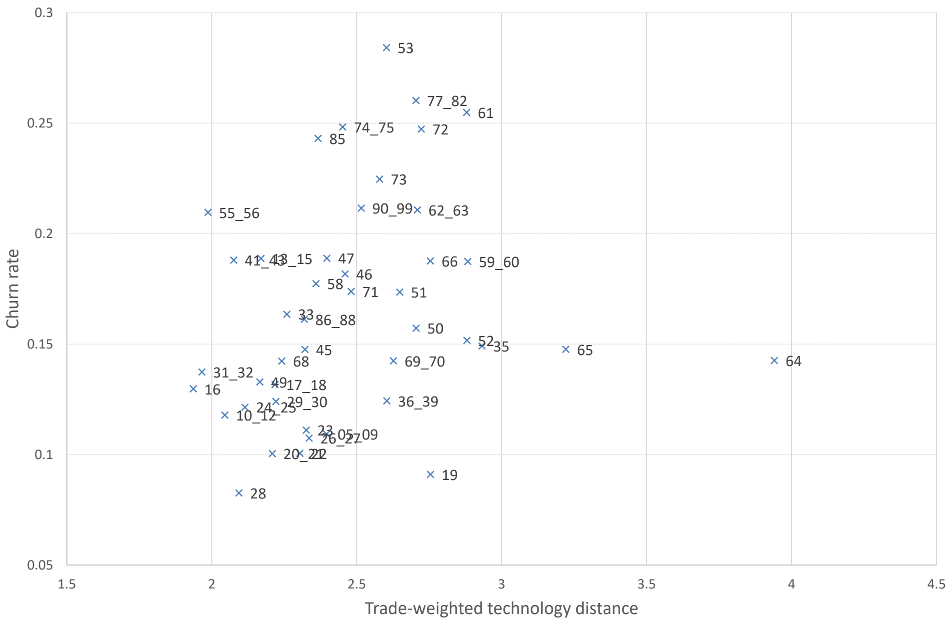

Figure 7: Churn rate and technology distance (TD^{trade}) by sector

Table 3: Estimation results (3SLS model)

Dep.var. TD_{it}^{trade}	(1)	(2)	(3)	(4)
TD_{it-1}^{trade}	0.796***	0.807***	0.817***	0.794***
	(0.010)	(0.011)	(0.011)	(0.011)
Prod Mark Reg	0.050	0.076	0.093	0.035
	(0.109)	(0.110)	(0.106)	(0.108)
LabFlex Index	0.042***	0.035***	0.039***	0.044***
	(0.013)	(0.013)	(0.013)	(0.013)
CapFlex Index	-0.051***	-0.074***	-0.070***	-0.058***
	(0.007)	(0.006)	(0.006)	(0.007)
Churn	0.635			
	(0.580)			
Entry		-0.598		-0.470**
		(0.414)		(0.205)
Exit			-0.057	0.189
			(0.405)	(0.302)
HC	-0.150***	-0.186***	-0.196***	-0.170***
	(0.028)	(0.015)	(0.015)	(0.015)
$\sigma_{TD^{trade}}$	0.379***	0.283***	0.293***	0.297***
	(0.056)	(0.022)	(0.022)	(0.022)
$\tilde{\mu}_{TD^{trade}}$	-0.185*	-0.086***	-0.079***	-0.079***
	(0.102)	(0.014)	(0.014)	(0.014)
	0.081	0.880	0.884	0.884
R-sq	0.081	0.880	0.884	0.884
N	3859	3445	3481	3365

Note: Significance codes: p<0.001 '***', p<0.01 '**', p<0.05 '*', p<0.1 '.' Robust standard errors in parentheses.
All RHS variables are lagged by one year. All econometric specifications include year, sector and country dummies.
N: Number of observations

Table 4: Estimation results 3SLS, by sector groups

Dep.var. TD_{it}^{trade}	**Churn: Low**	**Churn: High**
TD_{it-1}^{trade}	0.812***	0.786***
	(0.025)	(0.013)
Prod Mark Reg	-0.398	-0.009
	(0.485)	(0.125)
LabFlex Index	0.023	0.063***
	(0.017)	(0.019)
CapFlex Index	-0.059***	-0.069***
	(0.009)	(0.009)
Entry	-1.523 ***	-0.420
	(0.289)	(0.264)
Exit	-2.206***	0.568
	(0.815)	(0.359)
HC	-0.183***	-0.204***
	(0.021)	(0.021)
$\sigma_{TD^{trade}}$	0.591***	0.266***
	(0.035)	(0.028)
$\tilde{\mu}_{TD^{trade}}$	0.058***	-0.111***
	(0.021)	(0.020)
R-sq	0.813	0.880
N	1231	2134

Note: Significance codes: p<0.001 '***', p<0.01 '**', p<0.05 '*', p<0.1 '.' Robust standard errors in parentheses.
All RHS variables are lagged by one year. All econometric specifications include year, sector and country dummies.
N: Number of observations

Table 5: Estimation results 3SLS, by country groups

Dep.var. TD_{it}^{trade}	**Regulation: Low**	**Regulation: High**	**Labour market reg: high**	**Access to capital: high**
TD_{it-1}^{trade}	0.501***	0.791***	0.788***	0.705***
	(0.038)	(0.018)	(0.023)	(0.021)
Prod Mark Reg	0.955*	-0.001	-0.385	0.126
	(0.579)	(0.152)	(0.326)	(0.181)
LabFlex Index	0.323**	-0.009	0.133***	0.026
	(0.142)	(0.018)	(0.039)	(0.020)
CapFlex Index	0.038	-0.042***	-0.081***	-0.103***
	(0.032)	(0.008)	(0.016)	(0.015)
Entry	-0.057	0.117	-1.411***	-0.479
	(0.461)	(0.284)	(0.419)	(0.448)
Exit	6.919***	-0.570*	-2.389***	0.504
	(1.271)	(0.343)	(0.918)	(1.014)
HC	0.065	-0.125***	-0.113*	-0.200***
	(0.054)	(0.023)	(0.064)	(0.028)
$\sigma_{TD^{trade}}$	0.810***	0.084**	0.425***	0.704***
	(0.065)	(0.042)	(0.065)	(0.045)
$\tilde{\mu}_{TD^{trade}}$	-0.152***	-0.168***	-0.034	-0.108***
	(0.040)	(0.037)	(0.033)	(0.024)
R-sq	0.848	0.904	0.847	0.860
N	367	1030	731	1235

Note: Significance codes: p<0.001 '***', p<0.01 '**', p<0.05 '*', p<0.1 '.' Robust standard errors in parentheses.
All RHS variables are lagged by one year. All econometric specifications include year, sector and country dummies.
N: Number of observations

A Additional tables

Table 6: Estimation results (GLS, trade-adjusted technology distance)

Dep.var. TD_{it}^{trade}	(1)	(2)	(3)	(4)	(5)
TD_{it-1}^{trade}	0.811***	0.804***	0.805***	0.805***	0.804***
	(0.015)	(0.017)	(0.017)	(0.018)	(0.017)
Prod Mark Reg	0.031	-0.010	-0.025	-0.011	-0.006
	(0.090)	(0.109)	(0.100)	(0.110)	(0.109)
LabFlex Index	0.013	0.018*	0.015	0.019*	0.016
	(0.009)	(0.011)	(0.010)	(0.011)	(0.011)
CapFlex Index	-0.029***	-0.018***	-0.022***	-0.018***	-0.019***
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Churn		0.238**			
		(0.094)			
Entry			0.370***		0.416***
			(0.126)		(0.135)
Exit				0.160	-0.062
				(0.215)	(0.225)
HC	-0.146***	-0.170***	-0.168***	-0.172***	-0.171***
	(0.014)	(0.016)	(0.015)	(0.016)	(0.016)
$\sigma_{TD^{trade}}$	0.285***	0.315***	0.301***	0.316***	0.311***
	(0.036)	(0.043)	(0.042)	(0.044)	(0.044)
$\tilde{\mu}^3_{TD^{trade}}$	-0.055***	-0.077***	-0.076***	-0.071***	-0.077***
	(0.016)	(0.019)	(0.019)	(0.020)	(0.019)
N	4914	3919	4075	3929	3919
R-sq	0.881	0.881	0.878	0.880	0.881

Note: Significance codes: p<0.001 '***', p<0.01 '**', p<0.05 '*', p<0.1 '.' Robust standard errors in parentheses.
All RHS variables are lagged by one year. All econometric specifications include year, sector, and country dummies.
N: Number of observations
RMSE: root mean squared error

Table 7: Estimation results (GLS, standard technology distance)

Dep.var. TD_{it}	(1)	(2)	(3)	(4)	(5)
TD_{it-1}	0.580***	0.567***	0.566***	0.568***	0.567***
	(0.023)	(0.027)	(0.026)	(0.026)	(0.027)
PMR	0.322**	0.427***	0.368**	0.427***	0.427***
	(0.145)	(0.152)	(0.144)	(0.152)	(0.152)
LabFlex	-0.017*	-0.007	-0.004	-0.007	-0.007
	(0.010)	(0.013)	(0.011)	(0.013)	(0.013)
CapFlex	-0.008*	0.007	0.004	0.007	0.007
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Churn		0.025			
		(0.131)			
Entry			0.035		0.023
			(0.168)		(0.167)
Exit				0.031	0.030
				(0.263)	(0.265)
HC	-0.003	-0.017	-0.012	-0.017	-0.017
	(0.010)	(0.012)	(0.011)	(0.012)	(0.012)
σ_{TD}	0.748***	0.775***	0.783***	0.776***	0.775***
	(0.058)	(0.067)	(0.067)	(0.067)	(0.067)
$\tilde{\mu}_{TD}$	-0.329***	-0.379***	-0.376***	-0.379***	-0.379***
	(0.029)	(0.035)	(0.034)	(0.035)	(0.035)
N	4914	3919	4075	3929	3919
R-sq	0.866	0.866	0.863	0.866	0.866

Note: Significance codes: p<0.001 '***', p<0.01 '**', p<0.05 '*', p<0.1 '.' Robust standard errors in parentheses.
All RHS variables are lagged by one year. All econometric specifications include year, sector and country dummies.
N: Number of observations

Table 8: Sectors description

Code	Industry Description
1	Crop and animal production, hunting and related service activities
2	Forestry and logging
3	Fishing and aquaculture
05-09	Mining and quarrying
10-12	Manufacture of food products, beverages and tobacco products
13-15	Manufacture of textiles, wearing apparel and leather products
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
17	Manufacture of paper and paper products
18	Printing and reproduction of recorded media
19	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
22	Manufacture of rubber and plastic products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment
26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
28	Manufacture of machinery and equipment n.e.c.
29	Manufacture of motor vehicles, trailers and semi-trailers
30	Manufacture of other transport equipment
31-32	Manufacture of furniture; other manufacturing
33	Repair and installation of machinery and equipment
35	Electricity, gas, steam and air conditioning supply
36-39	Water and waste management services
41-43	Construction
45	Wholesale and retail trade and repair of motor vehicles and motorcycles
46	Wholesale trade, except of motor vehicles and motorcycles
47	Retail trade, except of motor vehicles and motorcycles
49	Land transport and transport via pipelines
50	Water transport
51	Air transport
52	Warehousing and support activities for transportation
53	Postal and courier activities
55-56	Accommodation and food service activities
58	Publishing activities
59-60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities
61	Telecommunications
62-63	Computer programming, consultancy and related activities; information service activities
64	Financial service activities, except insurance and pension funding
65	Insurance, reinsurance and pension funding, except compulsory social security
66	Activities auxiliary to financial services and insurance activities
68	Real estate activities
69-70	Legal and accounting activities; activities of head offices; management consultancy activities
71	Architectural and engineering activities; technical testing and analysis
72	Scientific research and development
73	Advertising and market research
74-75	Other professional, scientific and technical activities; veterinary activities
77-82	Administrative and support service activities
84	Public administration and defence; compulsory social security
85	Education
86-88	Human health and social work activities
90-99	Other service activities

B Sample selection

To construct our final sample, we use the online version of Orbis and we restricted our sample selection to firms that reported balance sheet information on turnover, value added, capital, and employees for at least 3 consecutive years. Table 9 reports the number of observations (firms) per year and country. While between the 13-year period 2005–2017 the sample contains approximately 1.7 million firms, in 2004 and 2005 only less than 70 thousands firms have more than 3 years of balance sheet information. Therefore, to construct a more balanced panel data, we focus on the period 2007–2017.

Similar to the approach of Kalemli-Ozcan et al. (2015), we examine the coverage of our sample compared to the population official statistics from Eurostat. In Tables 9 to 13 we show how much of total turnover, value added and employment are accounted for by the firms in our sample. Moreover, similar to Kalemli-Ozcan et al. (2015), we examine the coverage in terms of number of firms per country, year, sector of activity and size class. To increase the representativeness of our data, we keep only those countries for which our sample accounts either for at least 50% of total employment or 50% of total gross output. Doing so, we are left with a sample covering 18 countries that is reasonably representative of macroeconomic values as reported in Eurostat. The countries included in the final sample are BE, BG, CZ, DE, DK, EE, ES, FI, FR, GB, HR, HU, IT, LV, PT, SE, SI and SK. To be noted that we decided to drop Romanian companies even though they respect the selection criteria, since RO resulted to be over-represented in the sample, notably due known characteristics of our data source.

Table 9: Number of firms providing financial information for >3 years

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
AT			20	227	431	1396	1558	1650	1724	1794	1895	1882	1705	14282
BE	47	217	12094	13682	13911	14223	14538	14823	15037	15325	15527	15386	7251	152061
BG	78	178	832	21351	22534	27229	31514	33943	36090	37861	38424	37935	35268	323237
CY	4	27	63	63	63	63	63	63	63	63	59	36		630
CZ	1485	6932	25437	31210	32620	33870	35114	36130	37456	38284	37211	30153	13312	359214
DE	139	2407	8650	12027	12555	13159	13837	14565	15312	16131	16268	14070	4011	143131
DK			9	61	61	61	61	63	1020	1231	1294	1299	1280	6440
EE	155	663	13488	13863	13863	13863	13864	13864	13864	13864	13709	13201	375	138636
ES	6566	22828	232552	302182	316767	330503	345968	362664	383743	401303	407081	383022	148994	3644173
FI	30	411	4774	8808	9352	9648	9923	10168	10487	10797	11000	10433	6432	102263
FR	2479	6141	17284	45137	47297	48937	50545	52160	53569	54684	52747	47023	33784	511787
GB	30	260	17217	21798	23516	23945	24347	24825	25306	25830	26346	26175	12852	252447
GR	151	2739	7795	7898	7898	7898	7898	7898	7898	7898	7747	5159	103	78980
HR	255	816	27554	27577	27578	27579	27579	27579	27581	27574	27326	26765	27	275790
HU		8	8873	9910	10054	10133	10239	10337	10414	10480	10504	10483	2914	104349
IE	3	71	1813	2063	2102	2139	2167	2206	2254	2351	2433	2360	696	22658
IT	314	2497	73295	204965	219981	235752	252424	269577	288479	307630	320210	312349	255868	2743341
LT		13	1298	1338	1338	1338	1338	1338	1338	1338	1338	1325	40	13380
LU				195	220	271	289	308	327	356	370	330	280	2946
LV	3	26	1798	2269	2260	2685	2791	2840	2880	2910	2924	2883	1084	27353
NL	13	56	412	458	459	459	460	461	461	461	448	405	47	4600
PL	6	42	190	420	435	443	466	543	644	678	705	630	476	5678
PT	1317	8256	170337	183375	190650	197926	206478	214884	226101	237927	247358	239271	71055	2194935
RO	2613	7029	246167	250617	252943	255338	258365	261208	263620	265020	262840	258311	48448	2632519
SE	397	1165	67169	119789	121703	122845	124653	126870	129042	131323	132844	132408	71038	1281246
SI	41	122	5302	5643	5743	7934	8201	8468	8768	9028	9173	9074	5011	82508
SK	113	329	11994	12107	12294	12410	12509	12582	12640	12670	12557	12177	163	124545
Total	16239	63233	956417	1299033	1348628	1402047	1457189	1512017	1576118	1634811	1660338	1594545	722514	15243129

Table 10: Coverage in total economy based on gross output

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016
AT	0.14	0.16	0.37	0.43	0.47	0.47	0.47	0.45	0.44
BE	0.71	0.70	0.71	0.73	0.74	0.74	0.74	0.75	0.75
BG	0.57	0.55	0.59	0.62	0.64	0.65	0.66	0.67	0.67
CY	0.04	0.04	0.04	0.05	0.06	0.06	0.05	0.04	0.02
CZ	0.51	0.55	0.58	0.57	0.61	0.60	0.65	0.68	0.64
DE	0.59	0.60	0.60	0.60	0.62	0.63	0.62	0.61	0.55
DK	0.24	0.14	0.14	0.15	0.15	0.33	0.34	0.35	0.35
EE	0.42	0.44	0.44	0.44	0.45	0.44	0.44	0.43	0.42
ES	0.74	0.78	0.85	0.89	0.94	0.97	0.96	0.94	0.91
FI	0.67	0.67	0.69	0.69	0.68	0.66	0.65	0.66	0.69
FR	0.46	0.48	0.48	0.49	0.50	0.50	0.52	0.52	0.50
GB	0.91	1.01	1.07	1.14	1.05	1.04	1.04	0.95	0.94
GR	0.27		0.27	0.28	0.27	0.28	0.28	0.29	0.26
HR	0.59	0.60	0.61	0.64	0.66	0.66	0.67	0.65	0.64
HU	0.44	0.49	0.49	0.47	0.53	0.55	0.55	0.59	0.57
IE		0.35	0.43	0.45	0.47		0.46	0.35	0.32
IT	0.66	0.71	0.71	0.76	0.77	0.78	0.80	0.80	0.81
LT	0.33	0.35	0.34	0.34	0.34	0.34	0.34	0.34	0.34
LU	0.10	0.15	0.14	0.14	0.16	0.18	0.19	0.25	0.26
LV	0.45	0.49	0.48	0.49	0.47	0.45	0.46	0.46	0.44
NL	0.23	0.22	0.24	0.24	0.24	0.24	0.25	0.25	0.25
PL	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
PT	0.75	0.76	0.83	0.84	0.87	0.88	0.88	0.90	0.87
RO	0.65	0.73	0.74	0.76	0.79	0.80	0.81	0.81	0.82
SE	0.92	1.06	1.10	1.07	1.05	1.02	1.04	1.12	1.07
SI	0.51	0.53	0.57	0.59	0.60	0.61	0.61	0.63	0.62
SK	0.61	0.63	0.53	0.54	0.54	0.54	0.52	0.52	0.50

Note: Tables 10 and 11 report the ratios between the aggregated gross output (or employment) of firms in our sample and figures reported by the SBS from Eurostat for the period 2008-2016 (tables "Turnover by NACE Rev. 2 (tin00149)" and "Persons employed by NACE Rev. 2 (tin00151) "; details on data availability and country codes are found here). Eurostat SBS data represent total business economy except financial and insurance activities, while Orbis reports firm-level information for all sectors.

Table 11: Coverage in total economy based on employment

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016
AT	0.09	0.08	0.08	0.10	0.21	0.26	0.28	0.29	0.29
BE	0.60	0.63	0.57	0.58	0.59	0.59	0.59	0.59	0.61
BG	0.39	0.39	0.40	0.44	0.52	0.53	0.54	0.56	0.55
CY	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CZ	0.38	0.44	0.46	0.49	0.49	0.51	0.51	0.52	0.47
DE	0.37	0.37	0.37	0.36	0.38	0.39	0.38	0.38	0.34
DK	0.62	0.43	0.47	0.46	0.46	0.55	0.55	0.53	0.53
EE	0.43	0.44	0.44	0.44	0.43	0.43	0.42	0.41	0.40
ES	0.51	0.54	0.56	0.59	0.60	0.62	0.64	0.64	0.62
FI	0.64	0.56	0.58	0.62	0.58	0.57	0.57	0.59	0.61
FR			0.38	0.37	0.36	0.39	0.42	0.48	0.44
GB	0.68	0.70	0.72	0.73	0.74	0.74	0.74	0.72	0.71
GR	0.11		0.15	0.15	0.15	0.16	0.16	0.16	0.12
HR	0.44	0.43	0.46	0.48	0.49	0.50	0.49	0.50	0.50
HU	0.29	0.32	0.33	0.35	0.35	0.36	0.37	0.37	0.37
IE		0.24	0.24	0.26	0.29		0.30	0.29	0.27
IT	0.35	0.33	0.34	0.41	0.44	0.46	0.49	0.51	0.51
LT	0.16	0.18	0.22	0.23	0.23	0.22	0.22	0.22	0.21
LU	0.04	0.07	0.09	0.10	0.11	0.11	0.12	0.13	0.13
LV	0.27	0.30	0.30	0.30	0.29	0.29	0.28	0.27	0.27
NL	0.18	0.23	0.24	0.18	0.18	0.18	0.18	0.17	0.19
PL	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PT	0.50	0.53	0.56	0.59	0.62	0.64	0.66	0.67	0.65
RO	0.67	0.74	0.73	0.71	0.72	0.71	0.72	0.72	0.71
SE	0.85	0.86	0.86	0.88	0.90	0.92	0.94	0.94	0.94
SI	0.38	0.38	0.41	0.42	0.43	0.43	0.43	0.44	0.45
SK	0.52	0.53	0.37	0.34	0.36	0.37	0.36	0.35	0.34

Note: See notes in Table 10.

Table 12: Firm size distribution in total economy (based on number of firms)

	GE250		50-249		20-49		10-19		0-9	
Country	Eurostat	BvD	Eurostat	BvD	Eurostat	BvD	Eurostat	BvD	Eurostat	BvD
AT	0.3	34.3	1.6	45.6	3.8	11.8	7.2	3.6	87.0	4.6
BE	0.1	7.3	0.7	24.4	1.6	24.3	2.9	14.8	94.7	29.3
BG	0.2	1.6	1.3	8.9	2.6	15.7	4.2	20.2	91.7	53.6
CY	0.1	2.8	0.9	30.6		25.0		16.7		25.0
CZ	0.2	4.4	0.7	14.6	1.2	17.5	1.9	17.1	96.1	46.3
DE	0.5	36.6	2.5	38.6	5.0	10.7	10.1	4.1	81.9	10.0
DK	0.3	17.4	1.7	34.9	3.6	18.2	5.6	10.9	88.8	18.6
EE	0.2	0.6	1.5	4.2	2.9	8.0	4.8	12.1	90.6	75.1
ES	0.1	0.8	0.6	3.5	1.6	7.9	3.1	12.6	94.6	75.2
FI	0.3	4.7	1.2	10.9	2.7	15.4	4.6	16.9	91.2	52.1
FR	0.1	5.2	0.6	17.2	1.5	20.2	2.6	16.8	95.1	40.6
GB	0.3	23.4	1.3	44.2	2.8	15.7	5.5	7.3	90.1	9.4
GR		3.9		17.8		26.4	2.1	23.3	96.5	28.6
HR	0.3	1.1	1.2	4.8	2.5	8.6	4.9	12.9	91.2	72.7
HU	0.2	6.3	0.8	22.7	1.7	23.3	3.2	18.4	94.1	29.4
IE		11.6		24.9	2.4	18.5		15.7	91.9	29.3
IT	0.1	1.1	0.5	5.3	1.3	10.3	3.3	17.7	94.8	65.5
LT	0.2	14.0	1.2	44.6	2.3	23.2	3.7	12.1	92.7	6.0
LU	0.5	10.9	2.0	41.8	3.9	18.2	6.7	10.9	86.9	18.2
LV	0.2	5.7	1.2	19.4	2.4	16.9	4.0	13.2	92.1	44.8
NL	0.1	29.4	0.7	46.9	1.4	11.6	2.2	4.4	95.6	7.7
PL	0.2	18.6	0.9	38.3	1.4	20.8	1.9	7.9	95.6	14.4
PT	0.1	0.3	0.6	2.1	1.4	4.6	2.6	8.2	95.3	84.8
RO	0.4	0.6	1.8	2.7	3.5	5.1	5.9	7.5	88.5	84.1
SE	0.1	0.9	0.8	3.6	1.7	6.6	2.8	10.2	94.5	78.6
SI	0.2	2.0	0.8	7.8	1.4	11.2	2.9	15.5	94.8	63.5
SK	0.1	2.9	0.5	11.0	0.9	13.6	1.4	15.4	97.0	57.0

Table 13: Firm size distribution in total economy (based on gross output)

	GE250		50-249		20-49		10-19		0-9	
Country	Eurostat	BvD	Eurostat	BvD	Eurostat	BvD	Eurostat	BvD	Eurostat	BvD
AT	34.8	70.9	26.9	20.8	12.3	5.4	8.4	1.4	17.6	1.6
BE	34.3	58.5	19.3	22.6	12.8	10.4	9.3	4.2	24.2	4.3
BG	29.8	41.1	24.6	28.2	14.0	14.3	9.0	7.8	22.5	8.6
CY	21.7		23.0	21.3		26.3		8.8		43.6
CZ	43.8	56.8	21.8	26.9	9.7	7.5	7.2	5.6	17.5	3.2
DE	51.9	85.1	20.5	11.0	9.3	2.1	6.9	0.8	11.4	1.0
DK		75.6		16.2		4.5		1.3	17.9	2.4
EE	22.0	30.3	24.1	28.7	13.7	16.5	10.7	11.2	29.4	13.3
ES	37.2	55.4	19.8	19.1	11.5	10.0	8.5	6.4	23.0	9.1
FI	42.8	69.9	22.7	18.2	11.2	6.9	7.3	2.6	15.9	2.4
FR	45.3	74.6	16.5	14.3	11.2	7.1	6.5	2.3	20.5	1.7
GB	55.3	84.3	14.9	11.3	8.2	2.4	5.8	1.6	15.9	0.5
GR		39.2		37.1		15.0	8.2	5.5	29.9	3.1
HR	37.8	44.0	21.0	24.8	12.0	13.0	9.2	9.0	19.9	9.2
HU	42.4	57.2	20.5	27.0	10.2	8.7	7.6	3.7	19.3	3.3
IE		69.9		20.2	10.8	6.7		1.9	17.2	1.2
IT	31.9	52.0	20.8	20.2	11.9	11.1	10.8	8.1	24.5	8.5
LT	31.3	46.3	26.0	40.0	14.2	9.9	9.4	2.5	19.1	1.3
LU	33.4	37.1	32.4	42.8	12.1	12.3	6.9	3.7	15.2	4.1
LV	22.5	41.3	25.7	38.4	17.4	11.0	9.9	4.9	24.4	4.4
NL	37.4	85.4	28.9	11.6	11.6	1.9	6.4	0.4	15.6	0.6
PL	44.0	82.6	19.9	12.7	8.9	3.3	5.2	0.7	22.1	0.7
PT		30.7		26.6	13.9	14.6	8.9	9.1	24.1	19.1
RO	41.4	44.8	22.9	25.3	11.7	12.0	8.6	7.0	15.4	10.9
SE	42.7	61.8	20.7	17.6	10.9	8.4	7.1	5.1	18.7	7.1
SI	32.0	37.3	25.1	32.0	12.2	13.9	9.0	7.2	21.7	9.7
SK	42.3	61.4	18.8	21.5	10.6	8.5	6.0	4.2	22.4	4.4

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