THE FUTURE OF PRODUCTIVITY: MAIN BACKGROUND PAPERS

FRONTIER FIRMS, TECHNOLOGY DIFFUSION AND PUBLIC POLICY: MICRO EVIDENCE FROM OECD COUNTRIES

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BETTER POLICIES FOR BETTER LIVES

ABSTRACT/RESUMÉ

Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries

This paper analyses the characteristics of firms that operate at the global productivity frontier and their relationship with other firms in the economy, focusing on the diffusion of global productivity gains and the policies that facilitate it. Firms at the global productivity frontier – defined as the most productive firms in each two-digit industry across 23 countries – are typically larger, more profitable, younger and more likely to patent and be part of a multinational group than other firms. Despite the slowdown in aggregate productivity, productivity growth at the global frontier remained robust over the 2000s. At the same time, the rising productivity gap between the global frontier and other firms raises key questions about why seemingly non-rival technologies do not diffuse to all firms. The analysis reveals a highly uneven process of technological diffusion, which is consistent with a model whereby global frontier technologies only diffuse to laggards once they are adapted to country-specific circumstances by the most productive firms within each country (i.e. national frontier firms). This motivates an analysis of the sources of differences in the productivity and size of national frontier firms *vis-à-vis* the global frontier and the catch-up of laggard firms to the national productivity frontier. Econometric analysis suggests that well-designed framework policies can aid productivity diffusion by sharpening firms' incentives for technological adoption and by promoting a market environment that reallocates resources to the most productive firms. There is also a role for R&D tax incentives, business-university R&D collaboration and patent protection but trade-offs emerge which can inform the design of innovation-specific policies.

JEL classification: O30, O40, O43, O57, M13.

Keywords: productivity, reallocation, knowledge diffusion, firm dynamics.

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Entreprises en pointe, diffusion des technologies et politiques publiques : microdonnées des pays de l'OCDE

Ce document analyse les caractéristiques des entreprises qui se situent à la frontière mondiale en matière de productivité et leurs relations avec les autres entreprises de l'économie. Les entreprises à la frontière de la productivité mondiale – que l'on définit comme étant les entreprises les plus productives dans chaque industrie correspondant à un code à deux chiffres de la classification des activités économiques, dans 23 pays – sont en général de plus grande taille, plus rentables, plus jeunes, présentent une plus grande propension à breveter et font plus souvent partie d'un grand groupe multinational que les autres entreprises. Malgré le ralentissement de la croissance de la productivité globale, la croissance à la frontière mondiale est demeurée robuste pendant les années 2000, tandis que le creusement de l'écart de productivité entre les entreprises à la frontière et les autres soulève d'importantes questions quant aux raisons faisant que des technologies non rivales n'atteignent pas toutes les entreprises. À cet égard, l'analyse concorde avec un modèle selon lequel les technologies à la frontière mondiale ne rejoignent les entreprises retardataires que lorsqu'elles sont adaptées aux exigences propres à chaque pays des entreprises qui se situent à la frontière nationale. Ce processus très inégal de diffusion des technologies justifie une analyse des différences internationales en ce qui concerne les écarts de performances entre les entreprises à la frontière mondiale et celles qui se situent à la frontière nationale, et le rattrapage des entreprises retardataires par rapport à la frontière de productivité nationale. L'analyse économétrique donne à penser que des politiques-cadres judicieuses peuvent favoriser la diffusion de la productivité en affinant les motivations des entreprises à adopter des technologies nouvelles et en promouvant un environnement de marché qui réaffecte les ressources aux entreprises les plus productives. Les incitations fiscales à la R-D, la collaboration entreprises-universités en R-D et la protection par brevet ont un rôle à jouer, mais des arbitrages nouveaux peuvent inspirer des politiques spécifiques en faveur de l'innovation.

Classification JEL : O30, O40, O43, O57, M13.

Mots-clés : productivité, réaffectation, diffusion du savoir, dynamique des entreprises.

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FRONTIER FIRMS, TECHNOLOGY DIFFUSION AND PUBLIC POLICY: MICRO EVIDENCE FROM OECD COUNTRIES

By Dan Andrews, Chiara Criscuolo and Peter N. Gal[1]

1. Introduction

1. Aggregate productivity growth slowed in many OECD economies over the past decade. While this partly reflects cyclical factors, productivity growth slowed even before the crisis and continued to linger after the financial crisis, raising concerns that there may be structural dimensions to the slowdown. Indeed, some economists have argued that we are faced with "secular stagnation" (e.g. Summers, 2013), with accounts that focus on supply-side aspects of the slowdown in potential output growth particularly relevant. In this regard, Gordon (2012) argues that the recent productivity slowdown is a permanent phenomenon. This reflects the emergence of diminishing returns from the digital electronics revolution and more broadly, the idea that the types of innovations that took place in the first half of the 20th century (e.g. electrification) are far more significant that anything that has taken place since then (e.g. ICT), or indeed, likely to transpire in the future. By contrast, technological optimists tend to argue that the underlying rate of technological progress has not slowed and that the ICT revolution still has a long way to run (Brynjolfsson and McAfee, 2011; Mokyr, 2014).

2. While the Gordon-Brynjolfsson controversy is essentially a debate about growth at the global productivity frontier, it is remarkable how little is actually known about the characteristics of firms that operate at the global frontier. The same is true with respect to the productivity growth performance of global frontier firms over time in both absolute terms and relative to laggard firms. Interestingly, even less is known about the structural factors and policies that might help laggard firms close their productivity growth gap with the frontier. This is perhaps even more surprising given that cross-country differences in aggregate-level productivity outcomes are increasingly being linked to the widespread asymmetry and heterogeneity in firm performance within sectors (Bartelsman et al., 2013; Hsieh and Klenow, 2009). Accordingly, this firm level study aims to highlight a number of policy-relevant issues related to the performance – and implications for aggregate productivity – of frontier firms and laggards, with a view to also shed light on recent productivity developments in OECD countries. To this end, it martials cross-country firm level empirical evidence around a micro-founded framework that revolves around three key elements, which are now described in turn.

3. First, the paper defines frontier firms as those 100 firms that are the most productive in a 2-digit sector year by year. We identify this group of the globally most productive firms in each two-digit sector, in terms of labour productivity and multi-factor productivity (MFP) using a harmonised cross-country firm level database for 23 OECD countries (see Gal, 2013). The characteristics of these firms are then analysed along a number of measurable dimensions, with a view to build a profile of firms at the global productivity frontier relative to non-frontier firms in terms of productivity performance; age; size; capital intensity; ownership/global engagement and patenting activity. Global frontier firms are not only more productive than laggard firms but they are also more capital and patent-intensive, have larger sales and are more

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profitable. Global frontier firms are also more likely to be part of a multinational group, in line with new models of trade (Melitz, 2003) and the international business literature on multinationals (Dunning, 1991). Perhaps surprisingly, firms at the MFP frontier are younger, consistent with the idea that young firms possess a comparative advantage in commercialising radical innovations (Henderson, 1993; Baumol, 2002; Benner and Tushman, 2002) and not significantly larger, in terms of employment.

4. After exploring these cross-sectional differences, the evolution over time of global frontier performance and other salient characteristics, such as size and age, is explored. Productivity growth at the global frontier has remained relatively robust in the 21st century, despite the slowdown in average productivity growth, but the gap between those high productivity firms and the rest has been increasing over time. However, firms at the global frontier have become older, which may foreshadow the risk of a slowdown in the arrival of radical innovations and productivity growth.

5. Second, the rising gap in productivity growth between the global frontier and other firms raises questions about why seemingly non-rival technologies and knowledge developed at the global frontier do not diffuse to all firms. Recent cross-country evidence suggests that while adoption lags for new technologies across countries have fallen, there has been a divergence in long-run penetration rates once technologies are adopted, with important implications for cross-country income differences (Comin and Mestieri, 2013). In other words, new technologies developed at the global frontier are spreading at an increasingly fast pace across countries but spread increasingly slowly to all firms within any economy, and many existing technologies may remain unexploited by a non-trivial share of firms in an economy.[2] At the same time, the productivity growth of laggard firms within a country is more strongly related to productivity developments of the most advanced domestic firms as opposed to those (foreign firms) at the global frontier (Bartelsman et al., 2008; Van der Wiel et al., 2008; Iacovone and Crespi, 2010; Section 5.1).

6. One possible mechanism underlying these stylised facts is that new global frontier technologies do not immediately diffuse to all firms. Instead, they are first adopted by national frontier firms, and only diffuse to laggards once they are tested by the leaders and adapted to country specific circumstances. In turn, these observations motivate an analysis into the nature – and proximate drivers – of: *i*) differences in performance between global frontier and national frontier firms; and *ii*) the diffusion of existing technologies from national frontier firms to laggard.

7. To analyse differences in performance between global frontier and national frontier firms – *i.e.* the most productive firms in a given country but not globally – we isolate two sources of industry-level productivity gaps across countries: *i*) the gap originating from differences in within-firm productivity levels between national frontier firms and global frontier firms; and *ii*) the gap originating from differences in the size of national frontier firms and global frontier firms. This second term is particularly important because, all else equal, aggregate productivity will be higher when the most productive firms have a larger weight in the economy. By way of illustration, it is estimated that overall manufacturing sector labour productivity would be around 20% higher in Italy but little changed in the United States if national frontier firms were as productive and large as the global frontier benchmark. More specifically, in Italy, approximately three-quarters of this productivity gap can be explained by the fact that national frontier firms – while actually quite productive in global terms – are relatively small compared to those at the global frontier. By contrast, while national frontier firms in the United States are larger than those at the

2 Taking the examples of two well-known technologies - the telegraph and the cell phone - Comin and Mestieri (2013) estimate that while it took an average of 45 years for the former to spread across countries, the adoption lag for the cell phone technology was only 15 years and the cross-country difference in adoption lags have narrowed more than six-fold (from an interquartile range of 43 to one of 6 years). On the other hand, the cross-country differences in the level of adoption have increased significantly between the earlier telephone technology and the more recent cell phone.

global frontier, aggregate productivity could rise by around 10% if they were also as productive as those at the global frontier.

8. These stylised facts, in turn, motivate an econometric analysis of the policies that shape the respective performance gaps between national and global frontier firms. While further work is required to identify causal relationships, well-functioning product, labour and risk capital markets and bankruptcy laws that do not overly penalise failure are associated with lower size gaps between global and national frontier firms. Within-firm productivity gaps between national frontier and global frontier firms tend to be smaller in countries in which education systems are of higher quality; product market regulations are less cumbersome; businesses and universities collaborate intensively; and have more developed markets for risk capital. Important trade-offs between the policy objectives of minimizing the gaps in size and within firm productivity and heterogeneous role of policies across sectors also emerge, in particular in the innovation policy areas. While more generous R&D tax subsidies for SMEs are linked to lower within firm productivity gaps, this relationship is counterbalanced by the higher size gap between national and global frontier firms. In a similar vein, while stronger protection for patent holders are associated with a lower productivity gap between national and global frontier firms in R&D intensive sectors, the reverse is true in more dynamic sectors.

9. Third, the paper also contributes to the very small existing literature linking productivity performance of laggards with the frontier and studying the diffusion of existing technologies from national frontier firms to laggards. This literature suggests that the productivity growth of laggard firms within a country is more strongly related to productivity developments at the national frontier, as opposed to the global frontier (Bartelsman et al., 2008; Iacovone and Crespi, 2010). Given the small number of countries these findings are based on – for example, Bartelsman et al (2008) focus on five European economies[3] and the United States, while the Iacovone and Crespi (2010) and the Van der Wiel et al. (2008) study are Mexico and Netherlands-specific, respectively – it is not clear how generalizable this result is. Accordingly, Section 5.1 applies a similar methodology to a sample of 23 OECD countries over the period 2001-2009 and is able to replicate the key conclusion. The estimates suggest that a 1 per cent increase in a firms' productivity gap with the national frontier is associated with 0.3 percent faster growth rate in the following period. The distance from the global frontier also matters significantly, but its pull is less than a third as strong as that of the national frontier.

10. With this in mind, the question of how policies shape laggard firms' catch-up to the national frontier is explored. The findings suggest that the impact of policies is unlikely to be homogenous across firms and important non-linearities emerge with respect to how the impact of policies varies according to a firms' distance to the national frontier. While less stringent product market regulations facilitate the catch-up of all firms to the national frontier, pro-competition reforms are more strongly associated with the MFP growth of firms that are either very close to the national frontier or very far from it. Reducing the stringency of employment protection legislation is associated with higher MFP growth for firms closest to the national frontier, an effect that tends to diminish for firms further away from it. Finally, higher R&D collaboration is associated with a faster catch-up process of laggards firms very far from the national frontier, while firms close to this frontier keep pace with it.

11. The paper is structured as follows: following a discussion of the underlying firm level data in Section 2, Section 3 describes: *i*) cross-sectional differences in the characteristics of global frontier firms and other firms; and *ii*) differences in the evolution of productivity and other firm characteristics between frontier firms and other firms over the 2000s. Section 4 examines the performance gaps (i.e. productivity and size) between global frontier and national frontier firms and then relates these gaps to differences in public policies. Section 5 shows that productivity growth of laggard firms is more closely linked to the national frontier than the global frontier, which motivates an econometric analysis into the types of policies

3 These include: France, Finland, the Netherlands, Sweden and the United Kingdom.

that shape the catch-up of laggard firms to the national frontier. Section 6 offers some concluding thoughts and highlights the key policy messages.

2. Firm level data: sources, key definitions and challenges

12. This paper uses a harmonized firm-level productivity database, based on underlying data from the OECD-ORBIS database (see Gal 2013). The database contains several productivity measures (variants of labour productivity and multi-factor productivity, MFP) and data pertains to 23 OECD countries over the period 2001 to 2009.[4] The industry detail is at the 2-digit in NACE rev. 1.1 and comprise the nonfarm non-financial business sector (codes 15-74, excluding 65-67).

13. As discussed in Gal (2013), these data are cleaned and benchmarked using a number of common procedures, while imputations are sometimes applied in order to extend country coverage. Besides those factors discussed below, a number of issues that commonly affect productivity measurement should be kept in mind, including: *i*) differences in the quality and utilisation of inputs cannot be accounted for as the capital stock is measured in book values; *ii*) firm-level prices cannot be observed, so firm-level differences in measured productivity may also reflect differences in market power; and *iii*) measuring outputs and inputs in internationally comparable price levels remains an important challenge.[5]

2.1 Measuring the productivity frontier

14. While the existing literature is scarce, a typical approach to defining the global productivity frontier is to take the top 5% (or 10% or 25%) of firms in terms of productivity levels, within each industry and year. However, the tendency for the number of firms in ORBIS to expand over time leads to the adoption of a definition of the global frontier based on a fixed number of firms. This is particularly important in Section 3, where the performance of the global frontier over time is analysed.[6] More specifically, frontier firms are identified using an absolute number of firms: top 50 or top 100 globally most productive firms (within each industry and year), and top 10 most productive firms for the national frontier (within each country, industry and year). Moreover, this analysis is also robust to using a balanced sample of firms, so as to eliminate any effects of the changing sample.[7] Finally, as discussed below, the analysis of the global frontier in Section 3 is robust to a definition of the global productivity frontier based on labour productivity and multi-factor productivity (MFP). The latter is a simple Solow-residual based measure that applies the same industry-specific factor shares for each country and year to ensure comparability of MFP levels across countries and over time (see Gal 2013).

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4 These countries are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Italy, Japan, Korea, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Slovenia, the Slovak Republic and the United States. The country coverage is somewhat smaller in the policy analysis.

5 For manufacturing, which is traditionally viewed as more tradable internationally, nominal exchange rates are used. For typically less tradable sectors, most importantly market services (but also for construction, mining and utilities), currency conversion is done by using national purchasing power parities (PPPs).

6 One implication of the increasing coverage of ORBIS over time is that more small – and presumably less productive – firms get included in the frontier in the latter years of the sample. Thus, the evolution of the top 5%, as measured on the expanding ORBIS sample, could increasingly underestimate actual frontier growth over time.

7 As discussed below, however, the analysis is also robust to defining the global frontier in terms of a fixed proportion (top 5 or 10%) of firms.

2.2 *Representativeness issues*

15. A key drawback of ORBIS is that it is a selected sample of larger and more productive firms, which tends to result in smaller and younger firms being under-represented in some economies. Accordingly, sampling weights estimated by Gal (2013) are applied to improve representativeness in Section 4, while firms with less than 20 employees are dropped in Sections 3 and 5.[8] Even so, the analysis of the MFP growth of laggard firms in Section 5 should be interpreted with particular caution, to the extent that laggards are likely to be the least well represented firms in the sample.

16. While this issue is probably less of a concern for firms at the national and global frontier, some other issues remain. For example, the reporting unit (establishment or firm) may be different across countries. A related issue is that countries may apply different accounting requirements. For instance, US companies in ORBIS report their financial statement in a consolidated manner, while in most European countries the database contains mainly unconsolidated accounts.[9] Accordingly, the coverage of ORBIS is less satisfactory for the United States than many European countries, although its coverage of US affiliates abroad is still good. Furthermore, multinational firms may systematically shift profits across the countries in which they have affiliates, depending on the tax system of the countries of its affiliates (see OECD 2013). A priori, it is not clear in which direction these factors will bias the analyses given that the focus is only the global frontier and thus country boundaries are less relevant. However, it is reassuring that the key result of Section 3 – i.e. that global frontier firms have become relatively more productive over the 2000s compared to other firms – is robust to excluding firms that are part of a multi-national group (i.e. headquarters or subsidiaries) where profit-shifting activity may be relevant However, this comes at the cost of significantly reducing the number of observations (due to missing or inconsistent ownership information for many firms), so it is not incorporated in the baseline specification but is instead presented as a robustness test (see Figure A5 in the Appendix).

17. Another caveat is that emerging market economies are not represented in the database. While this is unlikely to significantly affect the measurement of the global productivity frontier, it may have implications for diffusion if global frontier technologies are increasingly diffusing to firms emerging markets but not those in OECD economies. However, this seems unlikely, in light of the evidence presented in Comin and Mestieri (2013) which highlights issues related to the penetration of new technologies across a sample of developed and developing economies.

18. The composition of countries in the frontier is probably still not entirely accurate, as the ORBIS database has a low coverage of US company accounts that are suitable for productivity analysis (Gal, 2013). Nevertheless, as Table A1 in the Appendix shows, firms located in the United States, and other highly developed countries, are well-represented in the global frontier grouping. Moreover, this definition of the global frontier seems to match anecdotal evidence with for example Finland and Korea having firms at the global frontier in most ICT sectors, or Italy being well represented at the global frontier in the textiles industry.

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8 In Section 4, sampling weights are applied to the extent that implications for aggregate productivity are drawn and to facilitate comparison with previous analyses (see Andrews and Cingano, 2014). In Section 5, firms with fewer than 20 employees are excluded for computational reasons.

9 Working with a mix of the two types of accounts carries the risk of double counting certain activities if a firm files both consolidated and unconsolidated accounts. However, the aim of this paper is not to aggregate economic activity but to analyse the determinants of firms' behaviour. Thus, the ideal reporting and consolidation level (i.e. group, firm or establishment) should be the one that most closely reflects managerial decisions. It is a difficult task to judge a priori which level that is, but most of the literature assumes it is either the firm or the group.

3. What is happening at the global productivity frontier?

3.1 Characteristics of frontier firms

19. Table 1 reports cross-sectional differences in average characteristics for global frontier firms relative to non-frontier firms along a number of measurable dimensions. Panel A reports these differences based on a labour productivity measure while Panel B does likewise using MFP. Firms at the global productivity frontier are on average 4 to 5 times more productive than non-frontier firms in terms of MFP, while this difference is more than 10 times in terms of labour productivity (which does not control for differences in capital intensity).[10] On average, global frontier firms are also larger, more profitable, more likely to belong to a group/conglomerate and patent more intensively than other firms.

Table 1. Mean firm characteristics: frontier firms vs other firms

2005 (unless otherwise noted)

	Global Frontier Firms			Non-Frontier Firms			Difference in means
	Mean	Std Dev	Number	Mean	Std Dev	Number	
Panel A: Labour Productivity							
Productivity	7.65	1.21	3391	4.99	1.01	299888	2.7 ***
Employment	409	4194	3391	225	4077	299888	183 **
Capital stock (Euros m)	164	867	3391	18	334	299888	147 ***
Turnover (Euros m)	708	2986	3391	53	701	299888	655 ***
Profit rate	0.83	4.00	3391	0.35	23.64	299888	0.5 ***
Age	25.1	23.0	3391	23.0	18.6	299888	2.0 ***
MNE status*							
Probability	0.42	0.49	3458	0.29	0.45	318112	0.1 ***
Patenting status							
Depreciated patent stock	11.16	277.87	3391	0.84	47.43	299888	10.3 **
Family adjusted depreciated patent stock	6.84	172.65	3391	0.48	26.33	299888	6.4 **
Panel B: Multi Factor Productivity (Solow)							
Productivity	4.06	1.04	3657	2.51	0.91	294031	1.55 ***
Employment	309	3770	3657	229	4119	294031	81
Capital stock (Euros m)	31	355	3657	19	343	294031	12 **
Turnover (Euros m)	250	1731	3657	59	754	294031	191 ***
Profit rate	0.57	0.33	3657	0.13	6.33	294031	0.45 ***
Age	21.5	20.3	3657	23.2	18.6	294031	-1.68 ***
MNE status*							
Probability	0.47	0.50	3450	0.28	0.45	310765	0.19 ***
Patenting status							
Depreciated patent stock	3.71	45.15	3657	0.90	56.17	294031	2.81 ***
Family adjusted depreciated patent stock	2.04	26.75	3657	0.53	32.26	294031	1.52 ***

Notes: * MNE status denotes multinational status, and is measured in 2008 based on ownership information from OECD-ORBIS. It equals one if a firm is part of a group where at least one group member is from a different country and zero otherwise. Productivity is measured in logs, employment is measured by the number of employees. The family adjusted depreciated patent stock refers to a distinct group of patents that are granted by different patent offices, which share the same priority application. Patent families may be a better proxy for innovative ideas, as companies generally tend to patent the same inventions to many distinct patent offices around the world.

Source: Authors' calculations based on the OECD-ORBIS productivity database (Gal, 2013).

20. While frontier firms are older on average when labour productivity is used to define the global productivity frontier, frontier firms are actually younger once the frontier is measured in terms of MFP, which controls for differences in capital intensity (older firms are more capital intensive). As discussed below, global frontier firms in services are younger on average – regardless of the productivity measure employed. At the same time, firms tend to enter the global frontier at a younger age in high-tech industries (such as manufacture of IT and medical equipment) and particularly ICT-producing services (such as computer services and telecommunications; Table 2).

10 Note that productivity is measured in logs, so relative to NF firms, GF firms are exp1.55=4.7 times more productive in terms of MFP and exp2.7=14.9 times more productive in terms of labour productivity.

Table 2. Firm age at entry into the global productivity frontier

By sector, 2002

Sector	Labour productivity frontier	MFP frontier
Manufacturing (total)	23.5	20.4
Manufacturing (ICT using)	22.8	20.9
Manufacturing (ICT producing)	18.8	16.5
Manufacturing (Hi-Tech)	20.2	18.7
Services (total)	18.5	14.5
Services (ICT using)	19.0	13.8
Services (ICT producing)	10.4	9.7
Services (Hi-Tech)	17.5	14.2

Note: The labour productivity frontier is identified using value added based labour productivity, while the MFP frontier is identified using Solow-residual based MFP. Services refer to non-financial business services (2-digit industry codes 50 to 74, excluding 65 to 67 in NACE Rev.1.1.). For the classification on ICT using and producing industries, see van Ark et al (2003). For the classification on Hi-Tech industries, see *Eurostat indicators of high-tech industry and knowledge-intensive services: High-tech aggregation by NACE Rev. 1.1 (http://ec.europa.eu/eurostat/ramon).*

Source: Authors' calculations based on the OECD-ORBIS productivity database (Gal, 2013).

21. Selection at the global frontier is harsh: only around half of the firms manage to remain at the global frontier from one year to the next, and after 5 years, less than 20% of firms are still there. Persistence is higher among frontier manufacturing firms than among business services. Frontier firms defined using MFP show less persistence than those defined by labour productivity, reflecting the fact that capital intensity changes more slowly than MFP.

Table 3. Persistence in the global frontier

Percentage of firms staying in the frontier after several years, 2001-2009

Frontier measure	Sector	Number of years: 1	2	4
Labour productivity (value added based)	**Manufacturing**	55.1%	36.3%	18.6%
	Services	53.1%	35.4%	18.8%
MFP (Solow) based	**Manufacturing**	50.3%	30.9%	14.1%
	Services	44.6%	26.1%	10.9%

Note: The labour productivity frontier is identified using value added based labour productivity, while the MFP frontier is identified using Solow-residual based MFP. Services refer to non-financial business services.

Source: Authors' calculations based on the OECD-ORBIS productivity database (Gal, 2013).

3.2 Has productivity growth at the frontier slowed over time?

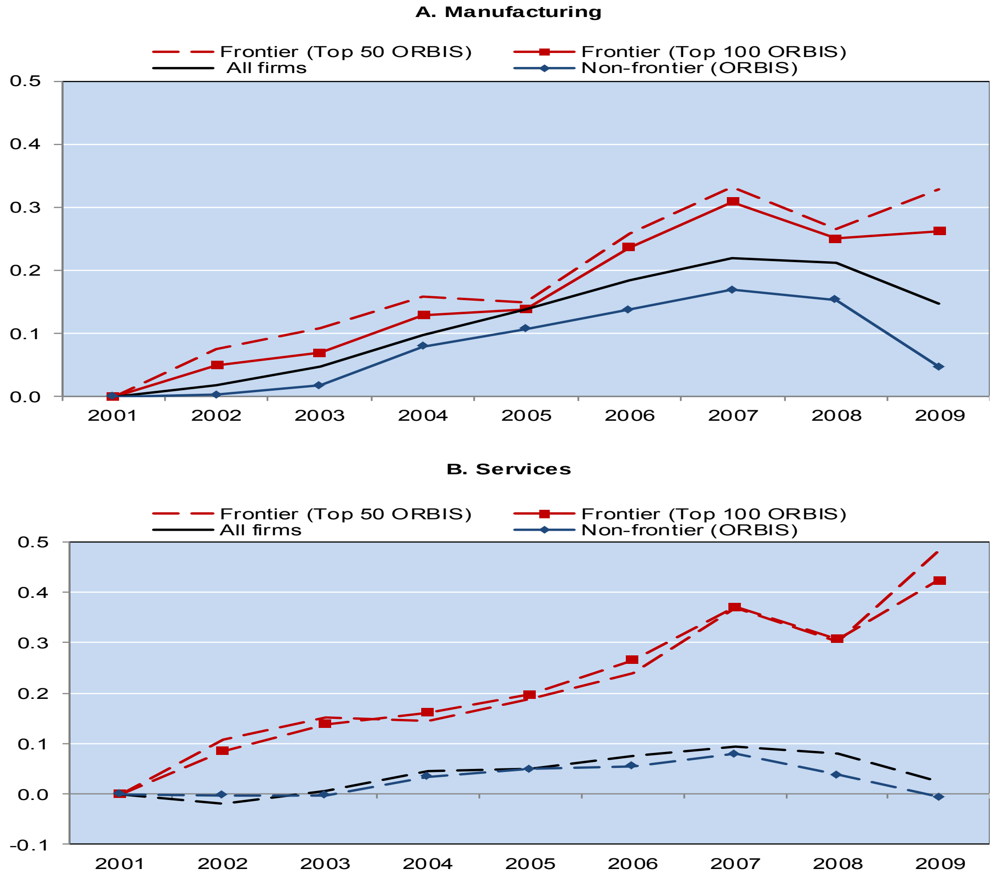
22. Figure 1 charts the evolution of labour productivity for firms at the global productivity frontier, non-frontier firms and all firms (sourced from the Structural Analysis (STAN) database of the OECD) for the years for which comparable data are available.[11] GF firms have become relatively more productive over the 2000s, expanding at an average annual rate of 3½ per cent in the manufacturing sector, compared to an average growth in labour productivity of just ½ per cent for non-frontier firms. This pattern is even more

11 Since OECD STAN is an industry level database, its evolution over time reflects not only within-firm productivity developments but also changes in allocative efficiency. As such, it is not strictly comparable with the frontier and non-frontier firms but provides a benchmark against which the ORBIS sample can be compared.

pronounced in the services sector. While data limitations make it difficult to say whether growth has slowed relative to earlier periods, it is interesting that frontier growth remained robust after 2004, when aggregate productivity in advanced economies (e.g. the United States) began to slow. More importantly, the rising gap in productivity growth between firms at the GF and other firms since the beginning of the century suggests that the capacity of other firms in the economy to learn from the frontier may have diminished. This is consistent with: *i*) longer run evidence of increasingly slower penetration rates of new technologies (e.g. Comin and Mestieri, 2013); and *ii*) winner takes all dynamics or "superstar effects" that have characterised the global economy over this period (Gabaix and Landier, 2008).

Figure 1. Firms at the global frontier have become more productive than other firms over time

Percentage difference in labour productivity levels from their 2001 values (index, 2001=0)



Notes: Labour productivity is defined using value added based labour productivity. Services refer to non-financial business services. All firms are computed from industry level data using OECD STAN and it is meant to provide a benchmark for the productivity trend obtained using the sample of firms in ORBIS (see footnote 8). The diverging pattern between the frontier and laggard firms is robust to a variety of robustness test (see Appendix).

Source: Authors' calculations based on the OECD-ORBIS productivity database (Gal, 2013).

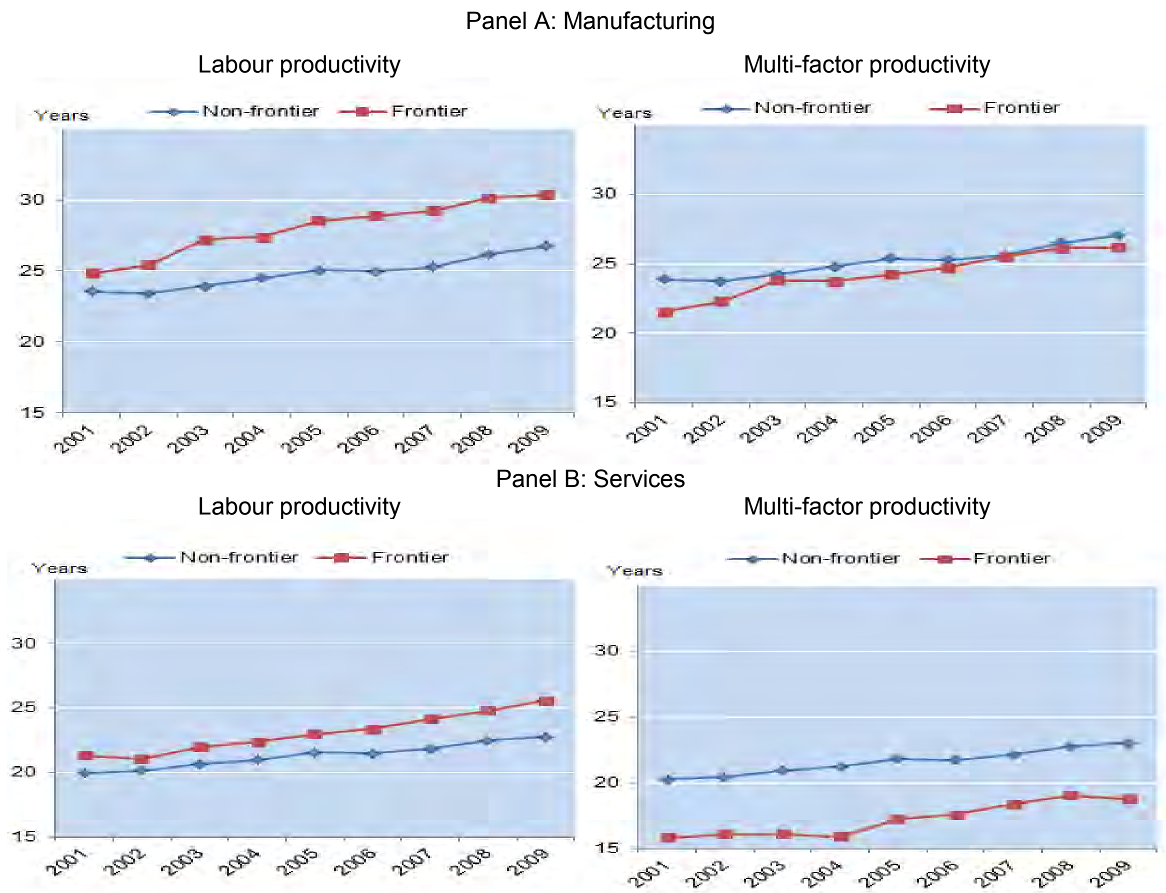
23. As illustrated in the Appendix, these broad patterns are robust to: *i*) defining the global frontier in terms of a fixed proportion of firms (Figure A1); *ii*) using different measures of productivity such as MFP (Figure A2) and turnover-based labour productivity (Figure A3); *iii*) following a fixed group of frontier

firms over time (Figure A4); and *iv*) excluding firms that are part of a multi-national group (i.e. headquarters or subsidiaries) where profit-shifting activity may be relevant (Figure A5).[12]

3.3 Changes in the characteristics of frontier firms along other dimensions

24. While it is difficult to detect a discernible trend in firm size, firms have become older over the 2000s (Figure 2) – a development that is statistically significant for frontier and non-frontier firms alike (Table A2 in the Appendix). Furthermore, frontier firms are becoming relatively older than other firms, particularly within manufacturing. Overall, these conclusions are broadly consistent with evidence of declining start-up rates in most OECD countries (Criscuolo et al., 2014) and indicate that it is increasingly more the established businesses, as opposed to young start-ups, which become the globally most productive firms.

Figure 2. Firms at the global productivity frontier have become older



Notes: The labour productivity frontier is identified using value added based labour productivity while the MFP frontier is identified using Solow-residual based MFP. Services refer to non-financial business services.

Source: Authors' calculations based on the OECD-ORBIS productivity database (Gal, 2013).

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12 Various global frontier definitions include selecting the 5% globally most productive firms (either in terms of turnover based or value added based labour productivity, Solow-residual based multi-factor productivity) within each 2-digit industry instead of the top 100 or top 50 firms. See Appendix.

25. To the extent that young firms possess a comparative advantage in commercialising radical innovations (Henderson, 1993; Baumol, 2002), the rising age of firms at the global frontier may foreshadow a slowdown in the arrival of radical innovations and productivity growth.[13]

4. Performance gaps between global frontier and national frontier firms

26. The rising gap in productivity growth between the global frontier (GF) and other firms raises questions about the ability of the most advanced firms nationally (i.e. national frontier firms; NF) to adopt new technologies and knowledge developed at the GF. At the same time, the aggregate impact of NF firms will be enhanced when they have a higher weight in the economy (i.e. they are larger). Thus, this section explores the performance gaps, in terms of productivity and size, between firms at the NF and GF and their potential links with policies.

4.1 Building blocks: a productivity decomposition

27. The starting point is the cross sectional decomposition of productivity developed by Olley and Pakes (1996). At any point in time, differences in aggregate labour productivity will reflect: *i*) the productivity distribution of firms (i.e. the fraction of 'better' relative to 'worse' firms); and *ii*) the extent to which, all else equal, it is the more productive firms that command a larger share of aggregate employment (i.e. allocative efficiency), which will be the outcome of the shift in resources across firms in previous periods. More formally, an index of productivity of industry j, defined as the weighted average of firm-level productivity $\left(P_j = \sum_{i\in j} \theta_i P_i\right)$, can be written as:

$$\sum_{i\in j} \theta_i P = \overline{P_j} + \sum_{i\in j} (\theta_i - \overline{\theta_j})(P_i - \overline{P_j}), \qquad (1)$$

where $\bar{P}_j = 1/N_j \sum_{i\in j} P_i$ is the unweighted firm productivity mean, θ_i is a measure of the relative size of each firm (e.g. the firm employment share) and $\bar{\theta}_j = 1/N_j$ is the average share at the industry level and $AE_j = \sum_{i\in j}(\theta_i - \bar{\theta}_j)(P_i - \bar{P}_j)$ is allocative efficiency. Hence, aggregate productivity (P_j) can be decomposed into a moment of the firm productivity distribution (the unweighted mean) and a joint moment with the firm size distribution reflecting the extent to which firms with higher efficiency also have a larger relative size: the "Olley-Pakes covariance" term or static allocative efficiency.

4.2 A counterfactual exercise

28. To explore the performance gaps between firms at the NF and the GF and the consequences for aggregate productivity, a counterfactual exercise that comprises three steps is performed:

- Counterfactual 1: How much higher would industry productivity be if NF firms in a given country had levels of labour *productivity* comparable to GF firms?
- Counterfactual 2: How much higher would industry productivity be if NF firms in a given country were of a comparable *size* (in terms of employment levels) to GF firms?
- Counterfactual 3: How much higher would industry productivity be if NF firms in a given country had both *productivity* and *size* comparable to GF firms?

29. In practice, this involves replacing the labour productivity (employment) of the top 10 National Frontier (NF) firms with the labour productivity (employment) of the firm at the 90th percentile of the top

13 While an attempt was also made to explore whether there was a discernible shift in the distribution of patent quality among frontier firms over the 2000s, this exercise was hindered by data limitations.

100 Global Frontier (GF) distribution (i.e. the productivity of the 10th most globally productive firms in each industry) in each two digit industry, and then recalculating weighted average labour productivity as per the decomposition in equation (1). While a definition based on the 90th percentile to identify the global frontier productivity and size benchmarks is mainly employed to ensure the estimates are not driven by extreme outlier observations, this choice is somewhat arbitrary and a number of other values are equally plausible. Given this, the dataset was reconstructed on a 95th percentile threshold and the policy conclusions are broadly robust to this choice.

30. Before proceeding, it is useful to analyse how each of the three counterfactual exercises influence aggregate productivity in the context of the decomposition outlined in equation (1), since they are employed in the policy analysis in the next Section.

31. Under Counterfactual 1, industry productivity can increase through two channels:[14]

- First, a pure within-firm effect whereby unweighted average productivity (i.e. the first term in equation 1) increases since the productivity level of NF firms is now higher than before (henceforth the unweighted P-gap).

- Second, aggregate productivity will rise if assigning the GF productivity level to NF firms increases the covariance between firm productivity and relative size (henceforth the OP P-gap). The size of this between-firm effect will be larger if the most productive firms account for a larger share of sectoral employment. This occurs because if the employment is allocated randomly across firms irrespective of their productivity levels (i.e. AE_j=0), then the aggregate productivity dividend from raising the productivity of NF firms to the GF benchmark will be proportional to the increase in the unweighted average productivity (i.e. the first term in Equation 1). By contrast, if the most productive firms have relatively larger employment weights (i.e. $AE_j > 0$) – which tends to be the case in many OECD countries – then the increase in aggregate productivity from the corresponding counterfactual scenario will be somewhat higher.[15]

32. Under Counterfactual 2, industry productivity increases purely through the OP gap term since the size of the most productive firms in each country will potentially increase. This size gap (S-Gap) is likely to be particularly strong in countries where resources are allocated less efficiently – i.e. where the OP gap is low.

33. Under Counterfactual 3 – which changes both productivity and size relative to the baseline – industry productivity will potentially increase due to both mechanisms described above plus a cross term. The latter shows the multiplicative impact on the OP gap from simultaneous changes in firm productivity and size relative to the baseline (henceforth the OP P&S gap).

4.3 Aggregate implications of improving the performance on national frontier firms

34. One way to raise aggregate productivity is to improve the performance and increase the size of national frontier firms towards the global productivity frontier. By way of illustration, Figure 3 shows that overall manufacturing sector labour productivity would be around 20% higher in Italy but virtually unchanged in the United States if national frontier firms were as productive and large as the global frontier benchmark (i.e. *Counterfactual 3*). More specifically, in Italy, approximately three-quarters of this productivity gap can be explained by the fact that national frontier firms – while actually quite productive

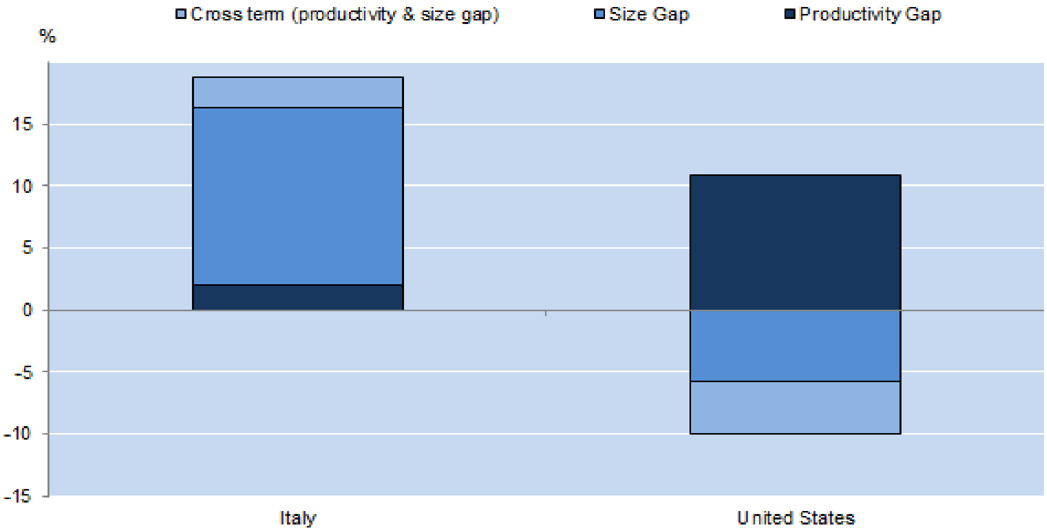
14 This discussion assumes that NF firms are both less productive and smaller than GF firms.

15 This effect could be an important driver of counterfactual productivity gaps since cross-country differences in static allocative efficiency tend to be significant (Andrews and Cingano, 2014).

in global terms – are relatively small compared to those at the global frontier (i.e. the size gap). A similar phenomenon is also observed in the auto-parts manufacturing sector in Mexico (Bolio et al., 2014). By contrast, while national frontier firms in the United States are larger than those at the global frontier, aggregate productivity could rise by around 10% if they were also as productive as those at the global frontier (i.e. *Counterfactual 1* components). This effect is particularly concentrated in the OP P-Gap term, which reflects the relatively efficient allocation of resources in the United States – i.e. the most productive firms command a high share of resources – which effectively magnifies the aggregate gains of aligning the productivity of the NF firms with the GF benchmark.

Figure 3. Performance gaps between the national and global frontier: a two-country example

How much would overall manufacturing sector productivity rise if firms at the national frontier were as productive and large as firms at the global frontier?



Notes: The productivity (size) gap shows how much higher manufacturing productivity would be relative to baseline if the national frontier firms (NF) were as productive (large) as the global frontier (GF) benchmark. The cross term shows the impact on aggregate productivity of simultaneously closing the productivity and size gaps. The estimates are constructed by taking the difference between counterfactual labour productivity and actual labour productivity. The counterfactual gaps are estimated by replacing the labour productivity (employment) of the top 10 NF firms with the labour productivity (employment) of the 10th most globally productive firm in each two-digit sector. The industry estimates are aggregated using US employment weights.

Source: Authors' calculations based on the OECD-ORBIS productivity database (Gal, 2013).

35. Overall, these differences are consistent with recent cross-country firm level[16] evidence and suggest that policy reforms in Italy could focus on improving the efficiency of its reallocation mechanisms, while in the United States, policies that can improve within-firm productivity decisions could yield a greater marginal benefit. Accordingly, the next section explores the types of policies that might be successful in closing the performance gap between NF and GF firms.

4.4 Empirical framework to explore the role of policies

36. Given that most policy indicators of interest are only available at the country level, we exploit cross-industry cross-country data and a differences-in-differences specification controlling for time

16 For example: i) the share of small firms is much higher in Italy, than in the United States and other OECD countries (Criscuolo et al., 2014); and ii) the United States is much more successful than Italy at channelling scarce resources to the most productive firms (Andrews and Cingano, 2014; Andrews et al., 2014).

invariant country-(and industry-) specific factors.[17] Specifically, we explore whether the magnitude of the impact of policies on the counterfactual productivity gaps is stronger in industries that are more likely to be exposed to the policy at hand, due to their inherent technological characteristics. This approach, popularised by Rajan and Zingales (1998), is based on the assumption that there exist industries that have 'naturally' high exposure to a given policy (*i.e.* the treatment group), and such industries – to the extent that the policy is relevant to the outcome of interest – should be disproportionally more affected than other industries (*i.e.* the control group). To see this more clearly, consider the case of an R&D tax subsidy. In this case, the baseline assumption is that there exist industries that have 'naturally' high R&D intensity, and industries where the amount of R&D conducted is almost negligible, and this pattern does not vary across countries. In this case, the marginal impact of an increase in the generosity of an R&D tax subsidy (the treatment) on the productivity gap could be expected to be larger in industries where 'natural' R&D intensity is very high, than in industries where R&D intensity is low.

37. If the presence of technological characteristics (e.g. R&D intensity) affects industry exposure to public policies, one would expect to see this effect empirically in the interaction of industry exposure and policy. Thus, abstracting from the time dimension for simplicity sake, the regressions take the following form:

$$Pgap_{s,c}^{k} = \alpha + \sum_{j} \beta_j Pol_c^j * Exp_s + \delta_c + \delta_s + \varepsilon_{s,c} \qquad (2)$$

where $Pgap_{s,c}$ measures either the aggregate productivity effect (for country *c* and industry *s*) of raising within-firm productivity of NF firms to that of GF firms (i.e. *Counterfactual 1*) or the aggregate productivity effect of aligning the size of NF firms to that of GF firms (i.e. *Counterfactual 2*). Since these variables capture how much higher industry level productivity would be if NF firms were as productive or as large as the GF benchmark, $Pgap_{s,c}$ will be larger in country*industry cells where NF firms on average perform less favourably relative to the GF benchmark. This should be kept in mind when interpreting the results below since it implies that the coefficient on the policy terms may carry the opposite sign to what is found in a typical productivity regression, even though the direction of the economic effect is the same.[18]

38. Turning to the explanatory variables, Pol_c measures the stance of various public policy measures and Exp_s is an industry-level index aiming at capturing differences in the relevance of regulation for firms operating in different industries. Interacting country-level policy variables with industry variables makes it possible to condition on country and industry fixed-effects, respectively δ_c and δ_s. For example, the coefficient β_j would measure whether increasing the generosity of a particular policy, e.g. an R&D tax incentive, would reduce the productivity gap between NF and GF firms disproportionately more in highly exposed (i.e, high R&D intensity) industries, than in other industries. The regression also controls for country and industry fixed effects. The inclusion of country fixed effects is particularly important to control for differences in country size, which could potentially result in large counterfactual size gaps for small economies. It should be noted that this approach does not provide an estimate of the country average effect of the policy of interest.

39. Details on the country-level policy and structural indicators of interest and the corresponding industry-level exposure variables used in the difference-in-differences estimations are provided in Table 4.

17 The exception is regulation impact, which captures the knock-on effects of upstream (service sector) regulations on downstream manufacturing sectors, and can be included directly (i.e. in non-interaction form) in the regression since it varies at the country*sector level.

18 For example, if more cumbersome product market regulations (PMR) are associated with a less favourable performance of NF firms relative to the GF benchmark, the coefficient on the PMR term will be positive since this implies a larger counterfactual productivity gap between NF and GF firms.

In general, industry-level indexes of exposure – *e.g.* firm turnover, job layoffs and R&D intensity – are taken from the large literature exploiting a similar framework to infer the relevance of country-level policies on a number of economic outcomes. However, knowledge intensity – proxied by the share of labour compensation of personnel with tertiary education – is also employed as an industry-level exposure variable, given recent evidence that firms which invest more in knowledge-based capital are often more sensitive to certain policy distortions (Andrews and Criscuolo, 2013). The exposure indexes are computed from US data to the extent that the United States is generally perceived to be a low regulation (*i.e.* "frictionless") country. Accordingly, the United States is excluded from the econometric analysis in both Sections 4 and 5.

Table 4. Policy and structural indicators and relevant industry characteristics in difference-in-differences estimator

Variable	Country-level variable	Industry-level exposure variable
EPL	EPL is the OECD Employment Protection Legislation (EPL) sub-index of restrictions on individual dismissal of workers with regular contracts.	Layoff rates (defined as the percentage ratio of annual layoffs to total employment) at the industry level in the United States. Sourced from Bassanini *et al.,* (2009).
PMR	PMR is the overall index of the OECD product market regulation index.	Firm turnover rate (defined as the entry rate + exit rate) at the industry level in the United States. Sourced from Bartelsman *et al.,* (2013). Knowledge intensity (defined as the share of labour compensation of personnel with tertiary education) at the industry level in the United States. Sourced from OECD (2013).
Regulation Impact Indicator	OECD indicator based on the methodology outlined in Conway and Nicoletti (2006). Indicator varies at the industry level within countries.	
Venture capital finance	Investment in seed and early stage financing as a per cent of GDP, 2005. OECD calculations, based on Pricewaterhouse Coopers/National Venture Capital Association MoneyTree™ Report.	Firm turnover rate Knowledge intensity
Bankruptcy law	The stringency of bankruptcy rules is measured by an indicator of the cost to close a business, sourced from the World Bank. Data from 2004.	Firm turnover rate. Knowledge intensity.
R&D Tax Incentives	Rate of tax subsidy rate for USD 1 of R&D sourced from the OECD Science Technology and Industry Outlook.	R&D intensity at the industry level in the United States sourced from the OECD STAN database. Firm turnover rate
Quality of Education System	The quality of education index developed by Hanushek and Woessmann (2009) is based on students' performance in cognitive skills such as mathematics and science in international tests, including PISA.	R&D intensity
Patent rights	The strength of patent protection, sourced from Ginarte and Park (2005).	R&D intensity
Higher education financed by industry	Sourced from the OECD Main Science and Technology Indicators.	R&D intensity Knowledge intensity

4.5 *Empirical links between policies and performance gaps*

40. This section analyses how policies relate to two sources of industry-level productivity gaps across countries: the gap originating from differences in within-firm productivity levels between NF firms and GF firms (*Counterfactual 1*) and the gap originating from differences in the size of NF firms and GF firms (*Counterfactual 2*). We distinguish between these two sources because the policy factors that are relevant for within-firm productivity are likely to differ from those that shape reallocation (i.e. size) effects.[19] For example, to the extent that they are effective in boosting productivity, innovation-specific policies (e.g. R&D tax incentives, IPR, Business-University R&D collaboration) are likely to affect *within-firm* productivity by improving firm's incentives to invest in costly productivity-enhancing investments. By contrast, easing the stringency of employment protection legislation (EPL) could be expected to raise aggregate productivity via the channel of more efficient resource reallocation.[20] At the same time, pro-competitive product market regulations can have pervasive effects on aggregate productivity to the extent that they affect both within-firm productivity (e.g. via higher managerial quality, sharper incentives to innovate) and resource reallocation. Of course, it is also possible that a policy may affect decisions to raise within-firm productivity via its effect on the efficiency of resource allocation. See Andrews and Criscuolo (2013) for more details on this possibility and a broader discussion of the margins through which policy reforms can influence aggregate productivity.

4.5.1 Which policies shape the productivity of national frontier firms?

41. Table 5 (panel A) explores the link between a range of policy factors and the within-firm source of aggregate productivity gaps, including one policy variable at a time. A number of results emerge which are broadly robust to including a number of policy variables simultaneously (Table 5; Panel B).

42. Column 1 shows that less cumbersome product market regulation in upstream sectors, as measured by a regulation impact indicator, is associated with a lower counterfactual productivity gap. Put differently, NF firms are more productive – and thus have a lower productivity gap with the GF – in industries where the regulatory burden impact is lower. This may reflect the tendency for product market liberalisation in upstream sectors to boost *within-firm* productivity in downstream sectors by: *i*) reducing input costs, thereby raising incentives to invest in R&D (Bourles et al., 2013); *ii*) raising the quality, variety and innovativeness of services available (Arnold et al., 2011); and through this channel, *iii*) easing access to downstream markets, thereby increasing competitive pressures on downstream firms (Bourles et al., 2013). As discussed below, however, product market regulations can also affect productivity via the reallocation channel.

43. Columns 2-6 explore the impact of a range of other policy variables typically thought to boost aggregate productivity performance via the channel of *within-firm* productivity. For example, in more R&D intensive sectors:

- Higher quality education systems are associated with a lower productivity gap, relative to other industries, reflecting the importance of an educated workforce to R&D.

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19 These analyses focus on the pure within-firm effect in Counterfactual 1 because the total counterfactual productivity gap also contains a reallocation effect (e.g. the OP productivity gap) which might be unrelated to specific policies that primarily affect within-firm productivity (e.g. business-university R&D collaboration).

20 Of course, less stringent EPL could also come at the cost of lower within-firm productivity to the extent it reduces incentives to invest in firm-specific human capital.

- More generous R&D tax subsidies for small and medium enterprises (SMEs) are associated with a lower productivity gap, relative to other industries.[21] This is consistent with research suggesting that more generous R&D tax incentives raise *within-firm* productivity by increasing the incentive to invest in R&D. All else equal, this should translate into higher aggregate productivity, although as discussed below, R&D tax incentives may also affect resource reallocation.

- Closer R&D collaboration between business and universities – as proxied by the share of higher education R&D financed by industry – is associated with a lower productivity gap, relative to other industries. This may reflect the fact that university researchers might be more connected to the global knowledge frontier, which increases the speed of technological diffusion, while financial support from industry might increase research possibilities and scope for international collaboration (by increasing the mobility of human talent), further enhancing knowledge spillovers.

Table 5. The global-national frontier unweighted average productivity gap and public policy

Dependent variable: difference between counterfactual and actual labour productivity; 2005

Panel A: One policy included at a time

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Regulation Impact	0.070* (0.042)						
Quality of Education System x R&D Intensity (US)		-0.502** (0.222)					
Tax Subsidies for R&D (SMEs) x R&D Intensity (US)			-0.414** (0.173)				
Higher education R&D financed by industry (%) x R&D Intensity (US)				-0.010* (0.006)			
Patent Rights x R&D Intensity (US)					-0.681*** (0.259)		
Patent Rights x Firm Turnover (US)						0.013** (0.006)	
Venture Capital (% of GDP) x Firm Turnover (US)							-0.017* (0.010)
Observations	697	697	697	697	697	697	697
R-squared	0.386	0.387	0.386	0.385	0.387	0.389	0.386
AdjR2	0.331	0.332	0.331	0.330	0.333	0.334	0.331
F	3.345	3.368	3.337	3.370	3.378	3.364	3.334

Panel B: Multiple policies included each time

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Regulation Impact	0.072* (0.042)	0.072* (0.042)	0.071* (0.042)	0.067 (0.042)	0.066 (0.042)	0.062 (0.042)	0.066 (0.042)	0.065 (0.042)
Quality of Education System x R&D Intensity (US)	-0.648*** (0.243)	-0.581** (0.229)	-0.599** (0.240)	-0.604** (0.238)	-0.676*** (0.245)	-0.420** (0.200)	-0.508** (0.218)	-0.605*** (0.226)
Tax Subsidies for R&D (SMEs) x R&D Intensity (US)	-0.629** (0.256)	-0.859*** (0.289)	-0.469* (0.257)	-0.560** (0.249)	-0.620** (0.250)	-0.791*** (0.265)	-0.849*** (0.281)	-0.873*** (0.284)
Higher education R&D financed by industry (%) x R&D Intensity (US)		-0.017** (0.008)				-0.037*** (0.013)	-0.022** (0.009)	-0.018** (0.008)
Patent Rights x R&D Intensity (US)			-0.495* (0.261)			-1.069** (0.421)		
Patent Rights x Firm Turnover (US)				0.011* (0.006)			0.013** (0.007)	
Venture Capital (% of GDP) x Firm Turnover (US)					-0.017* (0.010)	-0.018* (0.010)		-0.019* (0.010)
Observations	697	697	697	697	697	697	697	697
R-squared	0.391	0.392	0.392	0.394	0.392	0.399	0.396	0.394
AdjR2	0.334	0.335	0.335	0.337	0.335	0.340	0.338	0.336
F	3.244	3.154	3.229	3.221	3.196	3.254	3.158	3.128

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The sample is based on the following 19 OECD countries: AUT, BEL, CHE, DEU, DNK, ESP, FIN, FRA, GRC, HUN, ITA, JPN, KOR, NLD, NOR, POL, PRT, SVK AND SWE. The USA is excluded since it is the benchmark economy in the Rajan-Zingales model.

21 However, additional analysis suggested that this is not the case for R&D tax subsidies for large firms.

- Stronger patent protection is associated with lower productivity gap, relative to other industries. This is consistent with research showing that patents are more likely to be associated with an increase in innovation in the pharmaceutical, biotechnology and specific chemical sectors (Arora et al., 2001; Graham et al., 2009) – where the boundaries of the innovation are relatively clear, but also where the invention process is neither particularly cumulative nor highly fragmented (Hall and Harhoff, 2012).

44. However, in more entrepreneurial industries (i.e. industries with higher firm turnover rates), stronger patent rights are associated with larger productivity gaps, relative to less dynamic industries (column 7). Indeed, in some emerging KBC sectors where the innovation process is typically fragmented (e.g. software), there are concerns that the patent system may unduly favour incumbents at the expense of young firms (Cockburn et al., 2009), thus undermining productivity, innovation and growth.

45. Finally, in more entrepreneurial industries (i.e. where there is likely to be a greater demand for risk capital), a larger pool of venture capital (relative to GDP) is associated with a smaller productivity gap, relative to less dynamic industries (column 7). This may reflect the tendency for more developed financial systems to raise within-firm productivity by improving the efficiency of selection of firms at entry (Andrews and Cingano, 2014; Midrigan and Xu, 2014).

4.5.2 Which policies shape the size of national frontier firms?

46. Table 6 explores the link between a range of policy factors and the industry-level productivity gaps originating from differences in the size between NF firms and GF firms. Focusing on panel A, where only one policy is included at a time, a key result to emerge is that in industries with higher job layoff rates (where reallocation needs are likely to be more intense), less stringent employment protection legislation on regular contracts (EPLR) is associated with a lower size discrepancy – and thus productivity gap – between NF and GF firms, relative to the other industries (column 1).

47. Columns 2-5 explore the impact of policies on the relative size of NF firms in knowledge intensive industries, which tend to be particularly sensitive to rigidities in the reallocation process (see Andrews and Criscuolo, 2013). In knowledge-intensive industries relative to other industries, size discrepancy – and thus productivity gap – between NF and GF firms is lower in environments where: *i)* entry regulation is less cumbersome, as measured by lower administrative burdens on start-up firms (column 2); *ii)* bankruptcy legislation punishes business failure less severely, as measured by a lower cost to close a business (column 3); and *iii*) there is a larger pool of venture capital (column 4). Taken together, these results are consistent with recent research which highlights the relevance of such policy factors for static allocative efficiency (Andrews and Cingano, 2014) and measures of dynamic allocative efficiency (Andrews, Criscuolo and Menon, 2014).

48. Finally, in more R&D intensive industries relative to other industries, more generous R&D tax subsidies for SMEs are associated with a larger size discrepancy – and thus productivity gap – between NF and GF firms, although this effect is only statistically significant in Panel B (column 4) when multiple policies are included simultaneously. This result parallels recent research which highlights the potential for more generous R&D tax incentives to stifle efficient resource reallocation (see Bravo-Biosca et al., 2013; Acemoglu et al., 2013).

Table 6. The global-national frontier size gap and public policy

Dependent variable: difference between counterfactual and actual labour productivity; 2005

Panel A: One policy included at a time

VARIABLES	(1)	(2)	(3)	(4)	(5)
EPLR x Job Layoff Rates (US)	0.036*** (0.013)				
Administrative burdens on start-ups x Knowledge Intensity (US)		0.084** (0.040)			
Bankruptcy x Knowledge Intensity (US)			0.013** (0.006)		
Venture Capital (% of GDP) x Knowledge Intensity (US)				-0.804* (0.479)	
Tax Subsidies for R&D (SMEs) x R&D Intensity (US)					0.984 (0.599)
Observations	697	697	697	697	697
R-squared	0.337	0.330	0.331	0.328	0.328
AdjR2	0.278	0.270	0.271	0.269	0.268
F	3.953	3.781	4.001	3.888	3.997

Panel B: Multiple policies included each time

VARIABLES	(1)	(2)	(3)	(4)
EPLR x Job Layoff Rates (US)	0.035*** (0.013)	0.034** (0.013)	0.035*** (0.013)	0.037*** (0.013)
Administrative burdens on start-ups x Knowledge Intensity (US)	0.076* (0.040)			
Bankruptcy x Knowledge Intensity (US)		0.011* (0.006)		
Venture Capital (% of GDP) x Knowledge Intensity (US)			-0.637 (0.446)	
Tax Subsidies for R&D (SMEs) x R&D Intensity (US)				1.119* (0.598)
Observations	697	697	697	697
R-squared	0.340	0.340	0.338	0.339
AdjR2	0.280	0.280	0.278	0.279
F	3.948	4.069	4.058	4.191

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The sample is based on the following 19 OECD countries: AUT, BEL, CHE, DEU, DNK, ESP, FIN, FRA, GRC, HUN, ITA, JPN, KOR, NLD, NOR, POL, PRT, SVK AND SWE. The USA is excluded since it is the benchmark economy in the Rajan-Zinagles model.

49. Assuming the estimates in Table 6 are causal (and applying the most conservative coefficient estimate), Figure 4 simulates the impact on the level of industry labour productivity from reforms to key policy and structural variables that may increase the size of NF firms. Panels A, C and D consider the difference in labour productivity between a high knowledge intensity industry (e.g. manufacture of rubber and plastic products) and a low knowledge intensity industry (e.g. manufacture of textiles), as measured by the 75th percentile and 25th percentile of the industry knowledge intensity distribution respectively.[22]

- Reducing the stringency of barriers of entrepreneurship from the high level in Greece to the sample minimum implies an average gain in the above differential of over 6 percentage points (Panel A).
- Reducing the stringency of bankruptcy law – as measured by the cost to close a business – from the high level in Italy to the sample minimum implies an average gain in the above differential of 8 percentage points (Panel C).

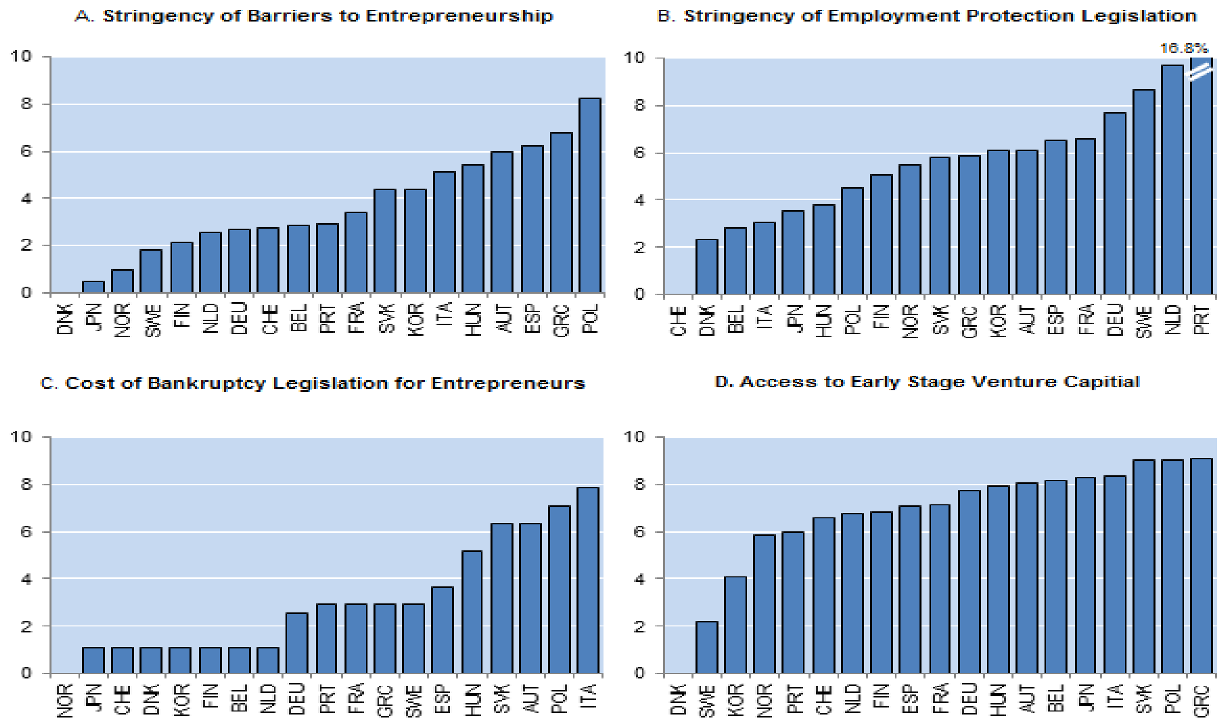
22 Note that all subsequent policy experiments use the 75th percentile and 25th percentile of the industry distribution respectively to define high and low exposed industries to the policy at hand.

- Increasing the share of seed and early stage VC in GDP from the low level in Greece to the sample maximum implies an average gain in the above differential of 9 percentage points (Panel D).

50. Figure 4 (Panel B) considers the difference in labour productivity between a high job layoff rates (e.g. manufacture of machinery and equipment), relative to an industry with low job layoff rates (e.g. Manufacture of other transport equipment). Reducing the stringency of EPL from the high level in Sweden to the sample minimum implies an average gain in the above differential of over 8 percentage points.

Figure 4. Impact on industry productivity of policy reforms that enhance the ability of national frontier firms to attract resources and grow, 2005

Impact of policy reforms to best practice level on the level of labour productivity; % difference between industries with high and low exposure to the policy



Notes: The chart estimates the cross-country gains to aggregate labour productivity from reforms to the best practice level of four policy variables that may partly explain cross-country industry differences in the size of national frontier (NF) firms, relative to global frontier (GF) benchmark.

5. Catch-up to the national productivity frontier

51. Consistent with findings from single-country studies (Van der Wiel et al, 2008, Iacovone and Crespi, 2010; Bartelsman et al., 2008), our analysis suggests that the NF exerts a stronger pull effect on laggard firms' productivity than the GF. This is consistent with the idea that new (global) frontier technologies do not immediately diffuse to all firms. At first, they are only accessible to the most productive firms in an economy (i.e. NF firms). Then, over time they can represent a source of technological diffusion to laggards, but presumably only once they have been adapted to national circumstances by national frontier firms. Accordingly, Section 5.2 explores the types of policies that may influence the speed of catch-up of laggard firms to the national frontier.

5.1 Distance to which frontier?

52. Table 7 shows regression results of the following specification of catch-up to the frontier:

$$\Delta MFP_{i,s,c,t} = \alpha + \beta^{Nat} Gap^{Nat}_{i,s,c,t-1} + \beta^{Glo} Gap^{Glo-Nat}_{s,c,t-1} + \gamma^{Nat} \Delta MFP^{Nat}_{i,s,c,t-1} + \gamma^{Glo} \Delta MFP^{Glo}_{i,s,c,t-1} + \eta X_{i,t-1} + \delta_s + \delta_{c,t} + \varepsilon_{i,s,c,t}$$

where: the dependent variable is MFP growth for firm *i*, industry *s*, country *c* and year *t*. The gap terms measure the lagged distance from the national frontier (Gap^{Nat}) and the distance of the national frontier from the global frontier ($Gap^{Glo-Nat}$). The coefficient on Gap^{Nat} provides the impact of an increase in a firms' distance to the NF on MFP growth, holding distance between the NF and GF constant ($Gap^{Glo-Nat}$). In contrast, the coefficient on $Gap^{Glo-Nat}$ shows the impact on firm MFP growth of the NF being further away from the GF, holding a firms' distance to the NF constant. This formulation of using the distance between the NF and GF rather than the distance from the GF avoids multi-collinearity between the distance to the two frontiers. The contemporaneous growth rates of the two frontiers (national and global) are also included, plus a set of firm-level control variables (firm size, capital intensity and age). The regression also controls for industry (δ_s) and country×year ($\delta_{c,t}$) fixed effects

Table 7. The national frontier exerts a stronger pull than the global frontier

Regressing MFP growth on the distance from the frontier (both national and global)

Explanatory variables	(1) Top 5%	(2) Top 10%
Distance from national frontier (t-1)	0.289*** (0.001)	0.311*** (0.002)
Distance between national and global frontier (t-1)	0.086*** (0.002)	0.054*** (0.002)
Growth at the national frontier	0.270*** (0.003)	0.399*** (0.005)
Growth at the global frontier	0.279*** (0.008)	0.296*** (0.009)
Control variables	Yes	Yes
Country * year fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Observations	2,325,842	2,325,787
R-squared	0.144	0.148

*** p<0.01, ** p<0.05, * p<0.1

Note: Robust standard errors in parentheses. Regressions are run on a sample of 23 OECD countries between 2001 and 2009. Control variables include firm size (logged number of employees), capital intensity and age. Columns 1 and 2 use a frontier definition that relates to the top 5 or top 10% most productive firms, respectively. Frontier firms are left in the sample with while setting their distance from the frontier to zero, but results are not sensitive to excluding them.

53. The positive and significant coefficient estimates for the distance to the NF term implies that the larger the productivity gap with the NF, the faster the subsequent MFP growth of laggard firms, in line with the catching-up hypothesis. Quantitatively, 1 percent larger distance is associated with 0.3 percent faster growth rate in the following period. The distance from the GF also matters significantly, but its pull is less than a third as strong as that of the NF.[23] One interpretation of these stylised facts is that new global

23 That the coefficient on the convergence term is smaller than 1 is consistent with the frontier pulling away from the rest, when there is a positive trend in frontier productivity growth. As the frontier gets more productive, the rest follows it, but only imperfectly, closing approximately 0.3 fraction (i.e. 30%) of the gap that emerges in each period. This leads to an increasing gap between the frontier and the rest, as reflected in the pattern shown by Figure 1. Note that this may contradict the long-run homogeneity

frontier technologies do not immediately diffuse to all firms. Instead, they are first adopted by national frontier firms, and only diffuse to laggards once they are tested by national frontier firms and adapted to country specific circumstances.

5.2 Empirical links between policies and catch-up to the national frontier

5.2.1 Existing evidence

54. Iacovone and Crespi (2010) shows on Mexican firm level data that carrying out more R&D helps closing the gap *vis-à-vis* the global frontier, while more external trade primarily speeds up convergence to the domestic best practice. More openness is also found to help firms that are very close to the global frontier, but firms further from the frontier tend to benefit much less from openess.

55. Using Dutch firm-level data, Van der Wiel et al (2008) find that R&D helps laggard firms to catch-up to the national frontier. However, they do not find that it can also push the frontier, i.e. contribute to genuine – not only adoptive – innovation. Their results also show that stronger competition helps to stimulate both laggards and frontier firms. They also uncover some differences between manufacturing and services firms, the former showing stronger catch-up effects from R&D than the latter, and being also more likely to innovate in the face of tough competition.

56. These results suggest that convergence of laggards toward global frontier needs to rely primarily on technology efforts rather than trade exposure, which plays a role in promoting productivity growth, but only for firms that are already close to the global frontier, pointing to the importance of innovation policies that foster adoption of frontier technologies and best practices.

5.2.2 Empirical framework

57. To identify the link between public policies and catch-up to the NF, the Rajan-Zingales methodology outlined in Section 4 is adopted, whereby the impact of national level policies (Pol_c) on MFP growth is assumed to be stronger in industries that are more likely to be exposed to the policy at hand (Exp_s), due to their inherent technological characteristics (see Table 4 for details on the relevant policy interactions). More specifically, the following equation is estimated:

$$\Delta MFP_{i,s,c} = \alpha + \beta_1^{Pol}\left(Pol_c * Exp_s\right) + \sum_{q=2}^{4}\beta_q Gap_{i,s,c,t-1}^{q} + \sum_{q=2}^{4}\beta_q^{Pol}\left(Pol_c * Exp_s\right) * Gap_{i,s,c,t-1}^{q} + \delta_s + \delta_c + \varepsilon_{i,s,c}$$

where: the dependent variable is MFP growth in 2005 for firm *i,* industry *s* and country *c*. The regression contains various Gap dummy variable terms, to denote the firm's initial position in the distribution of distance to the NF, to account for the catch-up phenomenon. Since Quartile 1 is the omitted category, β_2, β_3 and β_4 capture how much quicker firms grow on average in each quartile, relative to firms closest to the NF (Quartile 1). Similarly, β_1^{Pol} shows the impact of the $Pol_c * Exp_s$ term on MFP growth for the firms closest to the frontier (i.e. Quartile 1), while β_2^{Pol}, β_3^{Pol} and β_4^{Pol} show the additional impact of the $Pol_c * Exp_s$ term for firms in Quartiles 2, 3 and 4 respectively. The regression also controls for industry and country fixed effects.

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assumption implicit in some of the catch-up specifications, but a detailed analysis of this issue is beyond the scope of this paper.

5.2.3 Empirical results

58. Given the large number of interactions and considerable computational burden, Table 8 explores the impact of one policy at a time. Consistent with expectations, the size of the catch-up effect is stronger for firms in productivity quartiles more distant from the national frontier. The main policy results are as follows:

- Reducing the stringency of product market regulations is associated with disproportionately higher MFP growth for firms in industries with high firm turnover rates, than in other industries. The strength of this effect varies according to a firms initial distance to the national NF. While less stringent PMR would facilitate the catch-up of all firms to the NF, the reform appears to disproportionately boosts MFP growth for firms that are either close to the frontier (i.e. Quartile 1) or very far from it (i.e. Quartile 4). The former may reflect escape entry effects (e.g. Aghion and Griffith, 2005) while the latter is consistent with research showing that higher competition sharpens the incentives of low productivity firms to adopt better technologies (Bloom et al., 2011; Perla et al., 2015). By contrast, the ($Policy_c$*Exp_s) interaction terms with Quartiles 2 and 3 are positive and statistically significant, suggesting that PMR has a less negative differential impact on MFP growth for firms at intermediate levels of distance to the frontier.

- Reducing the stringency of employment protection legislation is associated with disproportionately higher MFP growth for firms in industries with high job turnover rates, than in other industries. This effect is strongest for firms closest to the NF (Quartile 1), and tends to diminish for firms further away from the NF as indicated by the positive triple interaction terms. Stringent EPL might be particularly harmful for productivity growth in firms close to the national frontier to the extent that it raises the cost of reallocation, which reduces the incentive for firms to experiment with risky technologies (Andrews and Criscuolo, 2013).

- In industries with high knowledge intensity, higher R&D collaboration between universities and firms is associated with disproportionately higher MFP growth for laggards firms further away from the NF firms, than in other industries. However, higher R&D collaboration does not accelerate the catch-up process for firms very close to the NF (i.e. Quartile 1). R&D collaboration with universities might facilitate the technological diffusion by providing smaller and less productive firms with access to sources of knowledge – e.g. advanced machinery and skilled scientists – that typically require large upfront costs. To the extent that small firms collaborate with universities to develop technologies core to their business (Santoro and Chakrabati, 2002), the benefits to productivity will be realised relatively quickly.

Table 8. Public policies and MFP convergence to the national productivity frontier

Dependent variable: MFP growth, 2005

VARIABLES	PMR x Turnover	EPL X Job Turnover	Collaboration X Knowledge intensity
Gap with Frontier (Base category: Quartile 1):			
Quartile 2_{t-1}	0.05535*** (0.01464)	0.04019** (0.01782)	0.07050*** (0.01230)
Quartile 3_{t-1}	0.07209*** (0.01594)	0.06380*** (0.02188)	0.10149*** (0.01496)
Quartile 4_{t-1}	0.18669*** (0.02761)	0.16514*** (0.03567)	0.19158*** (0.02602)
$Policy_c$ X Exp_s	-0.00297* (0.00146)	-0.00190** (0.00080)	-0.01193 (0.00914)
$Policy_c$ X Exp_s X Quartile 2_{t-1}	0.00112** (0.00051)	0.00078** (0.00031)	0.01017* (0.00517)
$Policy_c$ X Exp_s X Quartile 3_{t-1}	0.00167** (0.00059)	0.00093** (0.00038)	0.01120* (0.00644)
$Policy_c$ X Exp_s X Quartile 4_{t-1}	0.00195 (0.00124)	0.00129* (0.00069)	0.03028** (0.01425)
Observations	249,146	249,146	249,146
AdjR2	0.0557	0.0565	0.0576

Notes: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. The model includes country and industry fixed effects and lagged firm-specific controls (e.g. age, size). The sample is based on the following 20 OECD countries: AUT, BEL, CZE, DEU, DNK, ESP, FIN, FRA, GBR, GRC, HUN, ITA, JPN, KOR, NLD, NOR, POL, PRT, SVK and SWE. The United States is excluded since it is the benchmark economy in the Rajan-Zingales model.

59. Assuming the estimates from Table 8 are causal, Figure 5 simulates the impact on firm MFP growth from policy reforms to PMR, EPL and R&D collaboration. More specifically:

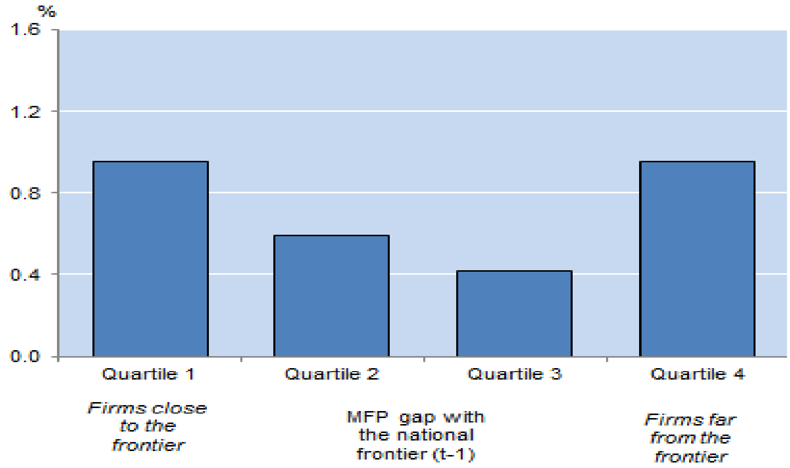
- Panel A considers the difference in MFP growth between a high firm turnover industry (e.g. retail) and a low turnover industry (e.g. manufacturing of rubber and plastic products). Reducing the stringency of PMR from the high level in Greece to the OECD average implies a gain in the above differential of almost 1 percentage points for firms close to the NF (Quartile 1) and those very far from the frontier (Quartile 4).

- Panel B considers the difference in MFP growth between a high job turnover industry (e.g. land transport; transport via pipelines) and an industry with low job industry (e.g. sale, maintenance and repair of motor vehicles and motorcycles). Reducing the stringency of EPL from the high level in the Czech Republic to the OECD average implies a gain in the above differential of around: 1½ percentage points for firms close to the NF (Quartile 1), 0.8-0.9 percentage points for firms at intermediate levels of distance to the NF (Quartiles 2 and 3) and ½ percentage points for those very far from the frontier (Quartile 4).

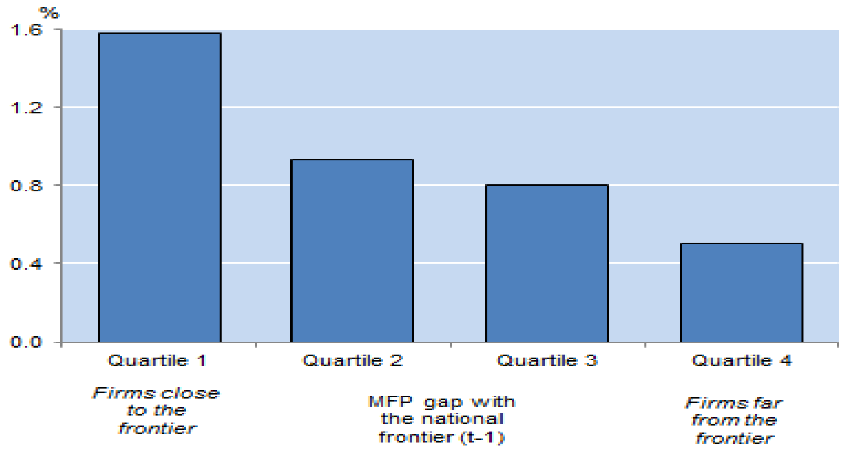
- Panel C considers the difference in MFP growth between a high knowledge intensity industry (e.g. manufacture of rubber and plastic products) and a low knowledge intensity industry (e.g. manufacture of textiles). Increasing R&D collaboration from the low level in the France to the OECD average implies a gain in the above differential of around: 1½ percentage points for firms very far from the NF (Quartile 4), ½ percentage points for firms at intermediate levels of distance to the NF (Quartiles 2 and 3) and no additional effect for firms close to the frontier (Quartile 1).

Figure 5. Impact of policy reforms on the MFP growth of laggard firms, 2005

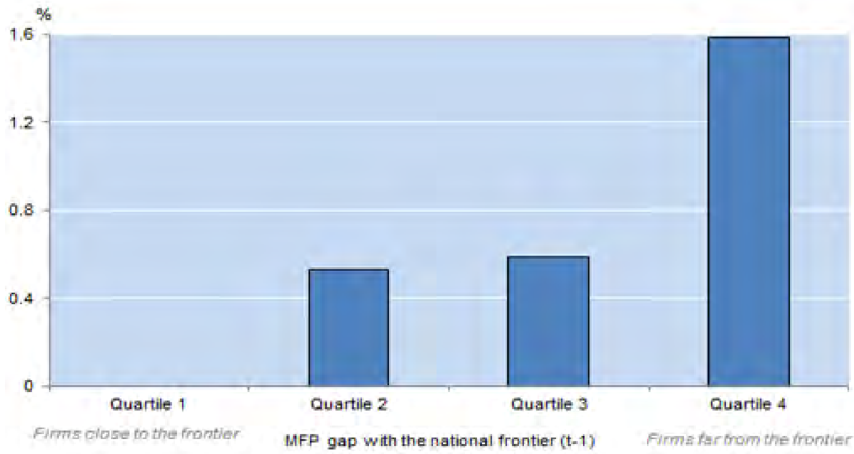
A: Reducing PMR from the high level in Greece to the OECD average; % difference between industries with high and low firm turnover



B: Reducing EPL from the high level in the Czech Republic to the OECD average % difference between industries with high and low job turnover



C: Increasing R&D Collaboration the from low level in France to the OECD average; % difference between industries with high and low knowledge intensity



6. Conclusion and policy discussion

60. This paper exploits a harmonised cross-country dataset to analyse the characteristics of firms that operate at the global productivity frontier and their relationship with other firms in the economy, focusing on the diffusion of global productivity gains and the policies that faciliate it.

61. Consistent with the widespread heterogeneity in firm performance that is observed within narrowly defined sectors (Syverson, 2004), firms at the global frontier are on average more productive, larger and more profitable, but are also younger, than other firms. Interestingly, the global productivity frontier is actually comprised of firms from different countries, reflecting varying patterns of comparative advantage and natural endowments. Moreover, they are very much "global firms" in the sense that they operate in different countries (often part of a MNE group).

62. Productivity growth of the globally most productive firms remained robust in the 21st century, despite the slowdown in aggregate productivity. At first glance, this goes against techno-pessimist accounts of recent productivity developments (i.e. Gordon, 2012) but firms at the global frontier have also become older, which may foreshadow a slowdown in the arrival of radical innovations and productivity growth.

63. Given the inherently global nature of frontier firms, assessing how policies shape frontier growth is difficult as it is not clear which countries' policies are most relevant for these firms. Nevertheless, it is likely that a policy framework that promotes more effective international co-ordination in certain areas – particularly regarding the funding of basic research, but also with respect to corporate taxation and IRP – will be important. At the same time, given that experimentation with new products and processes is a defining feature of innovation at the firm level (Kerr et al., 2014), policies that can reduce the cost of experimentation upon the entry (regulations affecting product and financial markets) and exit (EPL and bankruptcy law) will also be relevant.

64. While these policy issues warrant consideration in light of the public good characteristics of frontier innovation – which creates scope for productivity spillovers to other firms – the rising productivity gap between firms at the global frontier and other firms raises more central questions about why seemingly non-rival technologies and knowledge do not diffuse to all firms. In fact, the evidence gathered in this paper is consistent with a model whereby new global frontier technologies do not immediately diffuse to all firms but instead are first successfully adopted by national frontier firms, and only diffuse to laggards once they are tested and adapted to country-specific circumstances by national leaders. This highly uneven process of technological diffusion motivates an analysis of cross-country differences in the performance gaps between global and national frontier firms and the catch-up of laggard firms to the national productivity frontier. As it turns out, the scope for public policy to affect aggregate productivity through these three key margins is considerable.

65. First, within-firm productivity gaps between national frontier and global frontier firms tend to be smaller in countries in which education systems are of higher quality; product market regulations are less cumbersome; businesses and universities collaborate intensively; and where markets for risk capital are more developed. While stronger protection for patent holders are associated with a lower productivity gap between national and global frontier firms in R&D intensive sectors, the reverse is true in more dynamic sectors consistent with the idea that patent protection may act as a barrier to entry in these sectors.

66. Second, while this policy mix will aid the diffusion of new technologies and raise productivity *within* firms, the aggregate benefits will be magnified when the most productive firms can attract scarce resources and grow. But this process can be difficult: for example, national frontier firms in some economies have productivity levels close to the global frontier, but never grow to a sufficient scale to meaningfully affect aggregate growth in their countries. In this regard, reallocation-friendly policies –

specifically, well-functioning product, labour and risk capital markets and bankruptcy laws that do not overly penalise failure – can enhance the ability of national frontier firms to attract resources and grow. But important trade-offs also emerge. While more generous R&D tax subsidies for SMEs are linked to lower within-firm productivity gaps, this relationship is counterbalanced by the higher size gap between national and global frontier firms, which may reflect the tendency for R&D tax subsidies to favour inefficient incumbents and unduly stifle reallocation.

67. Finally, some important non-linearities emerge with respect to how policies shape laggard firms' catch-up to the national frontier. While less stringent product market regulations facilitate the catch-up of all firms to the national frontier, pro-competition reforms are more strongly associated with the MFP growth of firms that are either very close to the national frontier or very far from it. Reducing the stringency of employment protection legislation is associated with higher MFP growth for firms closest to the national frontier, and tends to diminish for firms further away from it. Finally, higher R&D collaboration is associated with a faster catch-up process of laggards firms very far from the national frontier, while firms close to this frontier keep pace with it.

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APPENDIX

Table A1. Countries that have firms at the global frontier

A: Labour Productivity definition

	Manufacturing			Business services	Total market sector
	Total	ICT producing	ICT using		
Austria		x	x	x	
Belgium	x	x	x	x	x
Czech Republic					
Germany	x	x	x	x	x
Denmark	x	x	x		
Estonia					
Spain	x	x	x	x	x
Finland		x	x		
France	x	x	x	x	x
Great Britain	x	x	x	x	x
Greece				x	
Hungary					
Italy	x	x	x	x	x
Japan	x	x	x	x	x
Korea	x	x	x	x	x
Netherlands	x	x	x	x	x
Norway					
Poland				x	
Portugal					
Sweden	x	x	x	x	x
Slovenia					
Slovakia					
United States	x	x	x	x	x
Number of countries (Total: 23)	12	14	14	14	11

B: MFP definition

	Manufacturing			Business services	Total market sector
	Total	ICT producing	ICT using		
Austria			x	x	
Belgium	x	x	x	x	x
Czech Republic					
Germany	x	x	x	x	x
Denmark	x	x	x	x	x
Estonia					
Spain	x	x	x	x	x
Finland		x			
France	x	x	x	x	x
Great Britain	x	x	x	x	x
Greece					
Hungary					
Italy	x	x	x	x	x
Japan	x	x	x	x	x
Korea		x	x		
Netherlands	x	x	x	x	x
Norway			x		
Poland				x	
Portugal					
Sweden	x	x	x	x	x
Slovenia					
Slovakia					
United States	x	x	x		x
Number of countries (Total: 23)	11	13	14	12	11

Notes: Overall, a country is classified as being at the global frontier if it has at least one frontier firm in at least 75% of 2-digit industries. The frontier is defined as the 100 most globally productive firms in each industry (in 2005), in terms of labour productivity in Panel A and (a Solow-residual based) MFP definition in Panel B.

Table A2. The difference in average age between 2001 and 2009

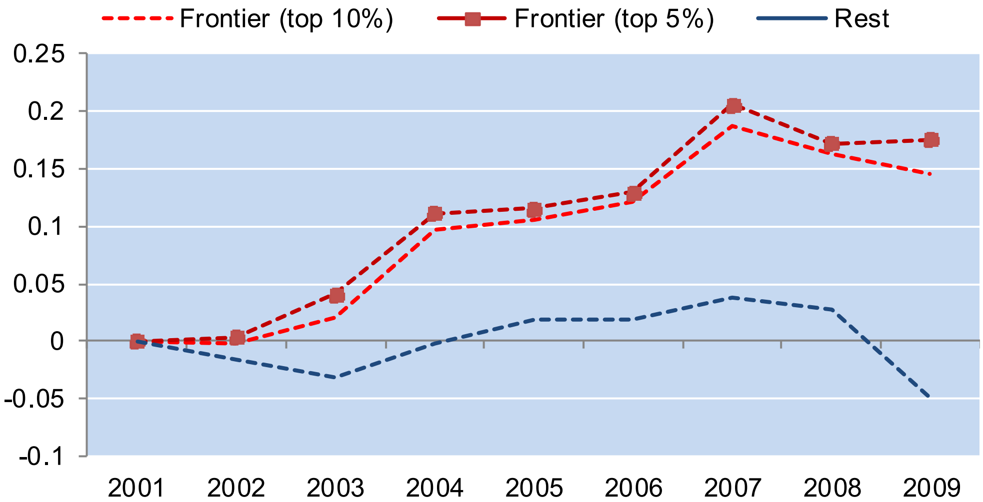
		Total business sector	*Manufacturing*	*Services*
Labour productivity (turnover-based)	Non-frontier	3.008***	3.180***	2.767***
	Frontier+	**3.007*** **	**2.883*** **	**3.348*** **
Labour productivity (value added based)	Non-frontier	3.022***	3.186***	2.786***
	Frontier+	**1.741*** **	**2.376*** **	**1.460***
MFP (Solow) based	Non-frontier	3.023***	3.191***	2.781***
	Frontier+	**0.664**	**1.437** **	**0.153**

Note: Coefficients of 2009 in a regression of average age on *year x frontier status* fixed effects where 2001 is the baseline category for age, and which includes industry fixed effects as controls.
+The coefficient in the frontier rows capture the additional age difference which is observed among frontier firms compared to non-frontier ones.
Services refer to non-financial business services.
Significance values: *** p<0.01, ** p<0.05, * p<0.1

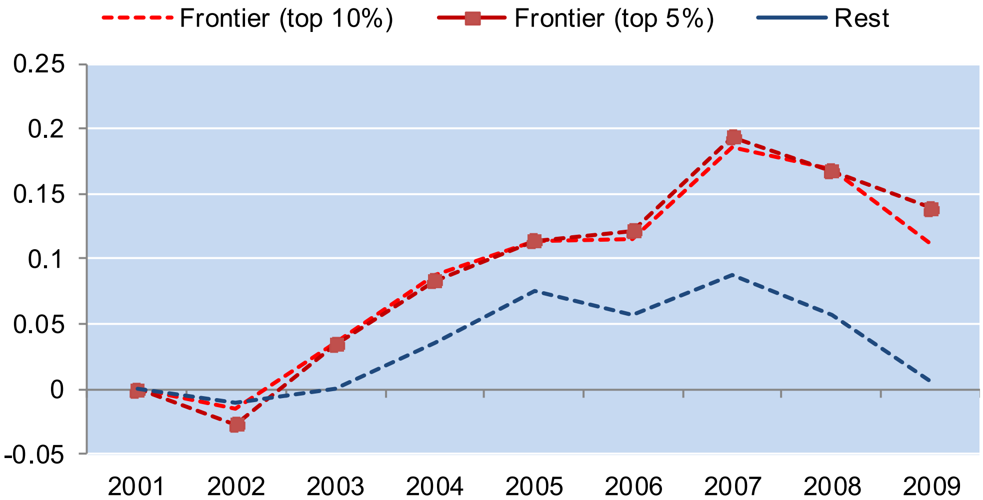
Figure A1. Robustness to defining the global frontier in terms of a fixed proportion of firms

Percentage difference in labour productivity levels from their 2001 values (index, 2001=0)

A. Manufacturing



B. Services



Note: Labour productivity is defined as real value added divided by employment. The frontier is defined as the top 5 or top 10% most productive firms per each 2-digit industry and year. Values are calculated as unweighted averages across firms within each industry and year, both for the frontier and for the rest.

Source: Authors' calculations using OECD-ORBIS.

Figure A2. Robustness to using MFP to define the global productivity frontier

Percentage difference in multi-factor productivity levels from their 2001 values (index, 2001=0)

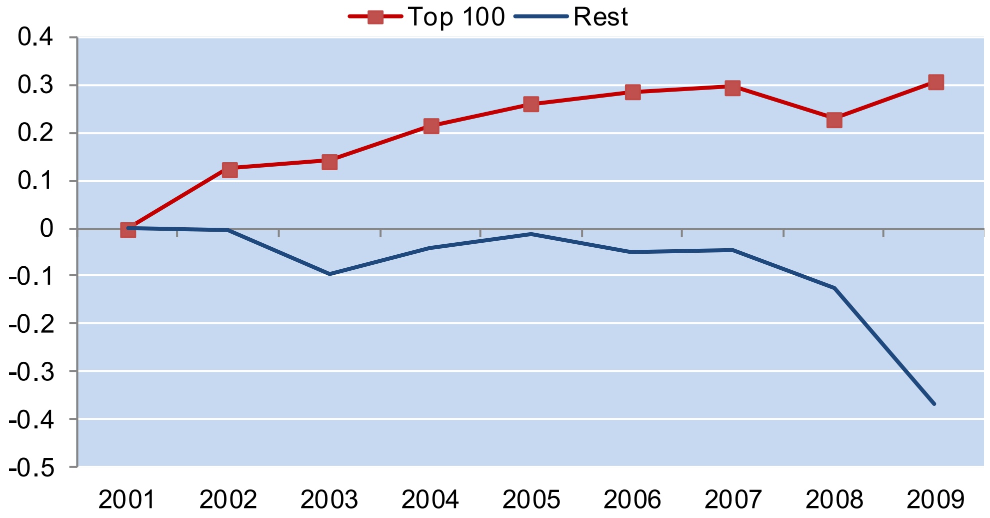
Note: Multi-factor productivity is defined as the Solow residual from a value added production function containing tangible capital and employment, using uniform factor shares across countries and over time for comparability. The frontier is defined as the top 100 most productive firms per each 2-digit industry and year. Values are calculated as unweighted averages across firms within each industry and year, both for the frontier and for the rest.

Source: Authors' calculations using OECD-ORBIS.

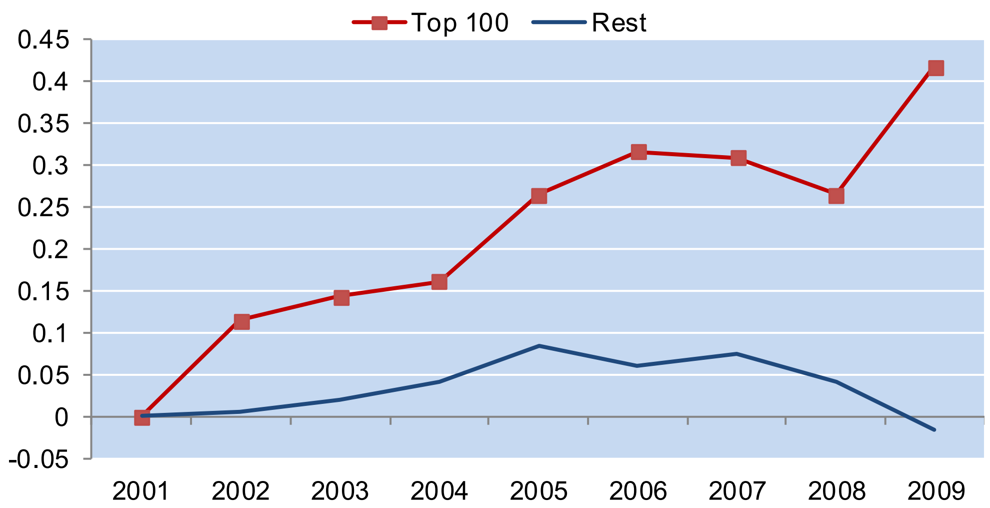
Figure A3. Robustness to using turnover-based labour productivity to define the global productivity frontier

Percentage difference in labour productivity levels from their 2001 values (index, 2001=0)

A. Manufacturing



B. Services

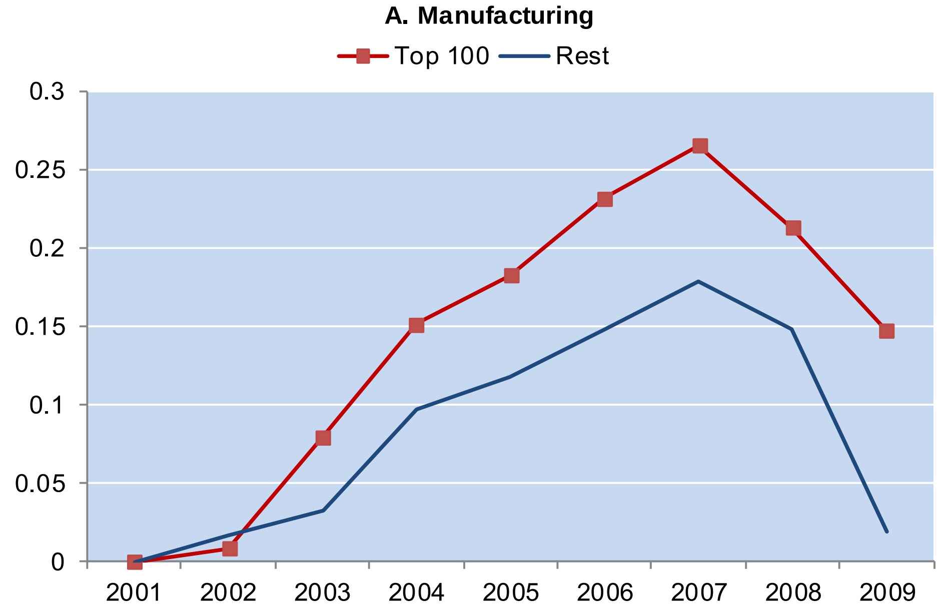


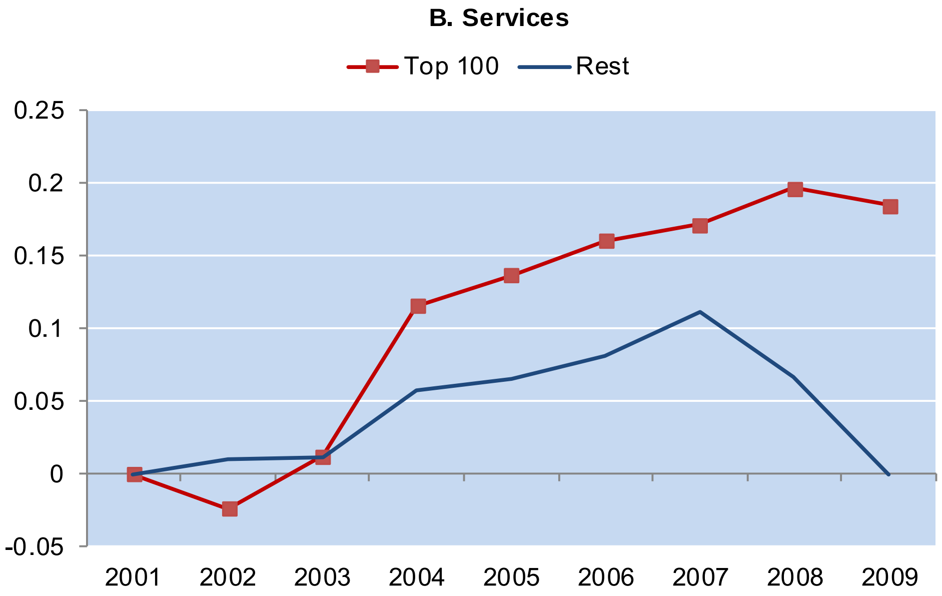
Note: Labour productivity is defined as real operating revenues divided by employment. The frontier is defined as the top 100 most productive firms per each 2-digit industry and year. Values are calculated as unweighted averages across firms within each industry and year, both for the frontier and for the rest.

Source: Authors' calculations using OECD-ORBIS.

Figure A4. Robustness of the diverging frontier to a balanced sample and to keeping the frontier group fixed over time

Percentage difference in labour productivity levels from their 2001 values (index, 2001=0)





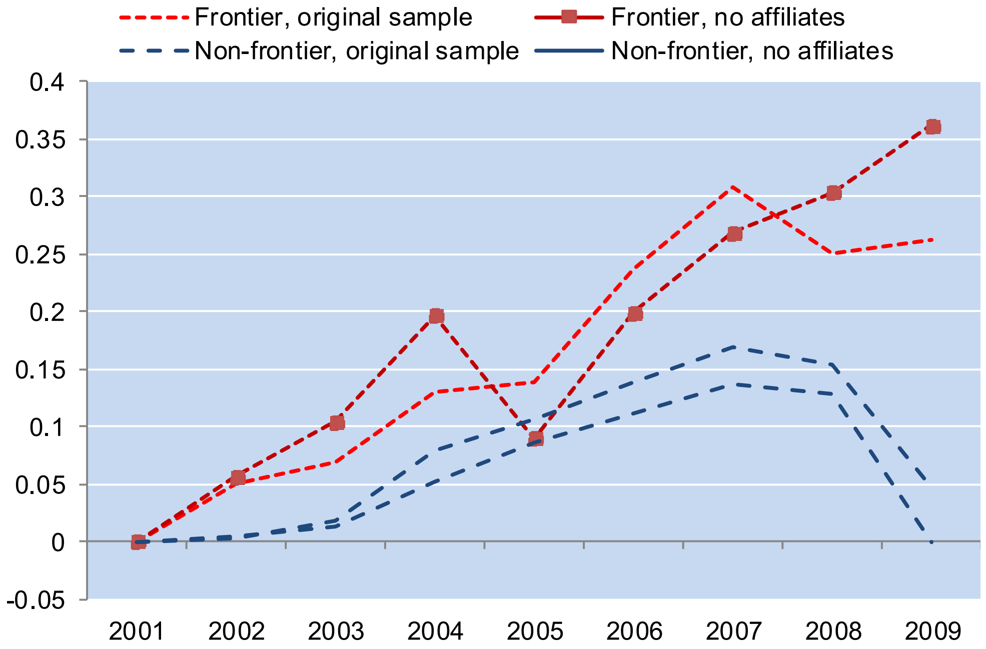
Note: Labour productivity is defined as real value added divided by employment. The frontier is defined as the top 100 most productive firms per each 2-digit industry and year. Values are calculated as unweighted averages across firms within each industry and year, both for the frontier and for the rest. The group of frontier firms is keeped fixed over time, and a balanced sample of companies are used for both the frontier group and the rest of the firms to eliminate the potential role of increasing firm coverage in ORBIS.

Source: Authors' calculations using OECD-ORBIS.

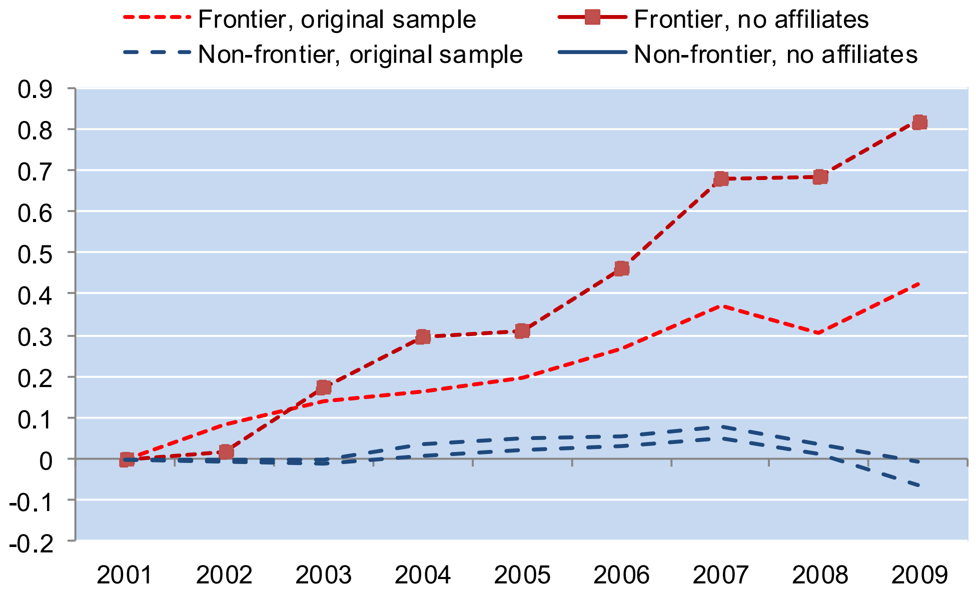
Figure A5. Robustness to leaving out non-headquarter group-affiliate firms

Percentage difference in labour productivity levels from their 2001 values (index, 2001=0)

A. Manufacturing



B. Services



Note: The dashed lines represent the full sample, while the normal lines rely on the sample that eliminates firms that are affiliates of a group but are not the headquarters. In that way, only standalone firms and group headquarter firm consolidated accounts are held in the sample. This results in a reduction of 75% of all firm-year observations, which is to a large part due to missing information on ownership links across firms. Values are calculated as unweighted averages across firms within each industry and year, both for the frontier and for the rest.

Source: Authors' calculations using OECD-ORBIS.