BACKGROUND PAPER

THE GLOBAL PRODUCTIVITY SLOWDOWN, TECHNOLOGY DIVERGENCE AND PUBLIC POLICY: A FIRM LEVEL PERSPECTIVE

DAN ANDREWS, CHIARA CRISCUOLO AND PETER GAL

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Dan Andrews, Chiara Criscuolo and Peter N. Gal

1. Introduction and main findings

1. Aggregate productivity growth has slowed in many OECD countries over the past decade, igniting a spirited debate on the future of productivity. Some argue that the low-hanging fruit has already been picked: the IT revolution has run its course and other new technologies like biotech have yet to make a major impact on our lives (Gordon, 2012). Others see the IT revolution continuing apace, fuelling disruptive new business models and enabling a new wave of productivity growth across the economy (Brynjolfsson and McAfee, 2011; Mokyr, 2014). Either technological progress is slowing down, or it's speeding up. Which view is right?

2. This paper martials firm level evidence to shed new light on the factors behind the global slowdown in productivity growth – a debate which has by and large been conducted from a macroeconomic perspective. While the Gordon-Brynjolfsson controversy is essentially a debate about prospects 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 both in absolute terms and relative to laggard firms. Interestingly, even less is known about the policies that might help laggard firms close their productivity growth gap with the frontier. This is even more surprising given that cross-country differences in aggregate-level productivity are increasingly being linked to the widespread heterogeneity in firm performance within sectors (Bartelsman et al., 2013; Hsieh and Klenow, 2009).

3. Accordingly, we highlight a number of policy-relevant issues related to the performance of frontier firms and laggards, with a view to also shed light on recent aggregate productivity developments in OECD countries. Using a harmonised cross-country firm-level database for 23 countries, we essentially define global frontier firms as the top 5% of firms in terms of labour productivity or multi-factor productivity (MFP) levels within each two-digit industry in each year since the early 2000s. The characteristics of these firms are then analysed along a number of observable dimensions, with a view to build a profile of firms at the global frontier. Global frontier firms are not only more productive than laggards but they are also more capital intensive, have larger sales, more patents and are more profitable. They are also more likely to be part of a multinational group, in line with new models of trade (Melitz, 2003) and literature on multinationals (Dunning, 1991).

4. After examining these cross-sectional differences, we explore the evolution over time of productivity performance at the global frontier. This analysis suggests that the most striking feature of the productivity slowdown is not so much a slowing in the rate of innovation at the global frontier, but rather rising productivity at the global frontier coupled with an increasing productivity divergence between the global frontier and laggard firms. In fact, slow productivity growth of the "average" firm masks the fact that a small cadre of firms are experiencing robust gains. Between 2001 and 2013, for example, average labour productivity at the global productivity frontier grew at an average annual rate of 2.8% in the manufacturing sector and 3.6% in the market services sector, while the corresponding growth rate of all other firms was around 0.5% in both sectors. This pattern of productivity divergence – especially in the services sector – suggests that some firms clearly "get it" and others don't.

5. Building on our previous research (see Andrews, Criscuolo and Gal, 2015), we show that this rising labour productivity gap between global frontier and laggard firms largely reflects

divergence in revenue MFP (MFPR), as opposed to capital deepening. Moreover, we explore the role of market power and tentatively conclude that divergence in MFPR does not simply reflect the increasing ability of frontier firms to charge higher mark-ups. This leads us to the conclusion that the rising MFPR gap between global frontier and laggard firms may in fact reflect technological divergence.

6. To the extent that these developments reflect structural changes in the global economy – underpinned by digitalisation, globalisation and the rising importance of tacit knowledge – MFP divergence could arise from two possible factors: winner takes all dynamics or stalling technological diffusion. Of course, it is difficult to distinguish with the data at hand the relative importance of these two factors, but a number of smoking guns emerge to suggest that both may be important.

7. MFP divergence may partly reflect the increasing potential for digital technologies to unleash winner take all dynamics in the global market (Brynjolfsson and McAfee, 2011), which allows the technological leaders to increase their MFP gap with laggard firms. Three findings emerge to suggest that winner takes all dynamic may be relevant: *i*) MFP divergence has been accompanied by a divergence in sales, whereby global frontier firms claim an increasing share of the market; *ii*) MFP divergence is most pronounced in ICT-intensive services where one would expect these patterns to be more relevant; and *iii*) within the global frontier grouping, an even smaller group of the most elite firms (top 2%) became more productive relative to other frontier firms in ICT-intensive services while this pattern is not particularly evident elsewhere in the economy.

8. MFP divergence could also be symptomatic of stalling technological diffusion. According to this view, the strength of global frontier firms lies in their capacity to technologically innovate, but also to optimally combine technological, organisational and human capital in production processes. Moreover, the ever increasing complexity of technologies might have spurred a related surge in the amount and sophistication of complementary investments required for technological adoption. This surge, coupled with the rising importance of tacit knowledge, especially in services, may act as a barrier to the catch-up of laggard firms. Consistent with this hypothesis, we present firm level econometric evidence to suggest that the pace of productivity convergence has slowed over time. Furthermore, in services sectors – where tacit knowledge is likely to be more important – persistence at the global frontier has risen and it has become increasingly less likely that firms from outside the top 20% of the MFP distribution subsequently enter the global frontier. These findings further illustrate the increasing obstacles to the catch-up of laggard firms.

9. This evidence is significant in light of recent aggregate level analysis suggesting that while adoption lags for new technologies across countries have fallen over time, 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.

10. While rising MFP divergence was somewhat inevitable due to the aforementioned structural changes in the global economy, as it turns out there was scope for public policy to lean against these headwinds. Crucially, we find that these patterns of MFP divergence were much more extreme in sectors where pro-competitive product market reforms were least extensive. In light of existing evidence linking product market reforms to productivity via improved incentives for technological adoption, it is likely that part of the observed rise in MFP divergence is due to policy weakness stifling productivity diffusion in OECD economies. A simple counterfactual exercise suggests that had the pace of product market reforms in retail trade and professional services – where market regulations remained relatively stringent in OECD countries – been equivalent to that observed in the best practice

service sector (i.e. telecommunications), then the average increase in the MFP gap may have been roughly 40% lower than what was actually observed. To the extent that most of the outputs produced by these heavily regulated sectors are used as inputs in production elsewhere in the economy (see Bourles et al., 2013), this may in fact provide a lower bound of the total impact of inappropriate service regulation on technology divergence.

11. The paper proceeds as follows. The next section places our research in the context of the existing literature on the productivity slowdown. Section 3 discusses the firm level data set and a number of productivity measurement issues, before identifying and describing the characteristics of firms at the global productivity frontier. Section 4 presents new evidence on labour productivity divergence between global frontier and laggard firms in OECD countries, before exploring the relative roles of capital, MFP, market power, winner takes all dynamics and technology diffusion. In Section 5, we explore the link between product market reforms and the MFP gap, with a particular focus on technology diffusion in the services sector. The final section provides a qualitative discussion of other factors that may potentially explain MFP divergence and identifies some areas for future research.

2. The productivity slowdown

12. The recent productivity slowdown and the highly uncertain outlook for MFP growth have fuelled a lively debate amongst economists on the causes, the prospects and the duration of the slowdown. In this section, we review some of the competing explanations for the productivity slowdown and place our research in the context of the existing literature.

2.1 Techno-pessimists and techno-optimists

13. The debate on the productivity slowdown has focused on expectations about future growth of the technology frontier and on the pace and economic potential of innovations at the frontier. Indeed, there are strongly contrasting views on the potential of ICT to continue to propel growth.

14. Techno-pessimists, such as Gordon, Jones, Cowen or Fernald, argue that the slowdown is just a reflection of a "return to normal" effect after nearly a decade of exceptional IT-fuelled gains; given that the slowdown is driven by industries that produce information technology (IT) or use IT intensively (Fernald, 2014). This pessimistic view holds that the recent slowdown is a permanent phenomenon and that the types of innovations that took place in the first half of the 20th century (e.g. electrification etc.) are far more significant than anything that has taken place since then (e.g. ICT), or indeed, likely to transpire in the future (Gordon, 2012; Cowen, 2011). These arguments are reinforced by the slowdown in business dynamism observed in frontier economies such as the United States (Decker et al., 2013; Decker et al., 2016). Focusing on the US economy, Gordon also argues that several headwinds will further slowdown future growth, including ageing population, deterioration of education, growing inequality, globalization, sustainability, and the overhang of consumer and government debt. At the same time, Jones (2012) – focusing on the global prospects for innovation – argues that the more technology advances and ideas cumulate, the more costly it becomes for researchers to innovate.

15. Against this, techno-optimists – such as Brynjolfsson, Mokyr and Jovanovic – argue that stagnation might be a reflection of the difficult transition from an economy based on tangible production to one based on ideas, but that the underlying rate of technological progress has not slowed and that the IT revolution will continue to dramatically transform frontier economies. According to Brynjolfsson and McAfee (2011), the increasing digitalization of economic activities has unleashed four main innovative trends: *i*) improved real-time measurement of business activities; *ii*) faster and cheaper business experimentation; *iii*) more widespread and easier sharing of ideas; and *iv*) the ability

to replicate innovations with greater speed and fidelity (scaling-up). While each of these trends are important in isolation, their impacts are amplified when applied in unison. For example, measurement is far more useful when coupled with active experimentation and knowledge sharing, while the value of experimentation is proportionately greater if the benefits, in the event of success, can be leveraged through rapid scaling-up. However, significant changes to organisational structures are required to fully realise the productivity benefits of new technologies and to share the resulting prosperity more broadly.

16. Similarly, Joel Mokyr argues that economic history shows no evidence of diminishing returns with respect to technological progress. In fact, science and technology's main function in history is to make taller and taller ladders to get to the higher-hanging fruits (and to plant new and possibly improved trees). With respect to future developments, Mokyr emphasises three key factors: *i*) artificial revelation – whereby technological progress provides the tools that facilitate scientific advances, which then feed back into new technologies in a virtuous cycle (e.g. advances in ICT technologies raises the productivity of R&D); *ii*) access costs; and *iii*) a good institutional set-up for intellectual innovation. For instance, advances in computing power and information and communication technologies have the potential to fuel future productivity growth by making advances in basic science more likely (i.e. via artificial revelation) and reducing access costs. However, Mokyr warns of the potential for bad institutions and policies to act as obstacles to this virtuous cycle, with potential barriers coming from: *i*) outright resistance by entrenched interests which could lead to excess regulation and lack of entrepreneurial finance; *ii*) a poor institutional set up of research funding which favours incremental as opposed to radical innovation; and *iii*) new forms of crime and insecurity (e.g. cyber insecurity).

17. One interesting angle in the techno-optimist argument is that we might not have seen the full benefits of the "digital economy" based on ideas because we are still in a transition phase characterised by staggered adoption of the new technology and transition costs. These transition dynamics are very much in line with the idea that ICT is a General Purpose Technology (GPT) whose adoption and diffusion is characterised by an S-curve (Griliches, 1957; David, 1991; Jovanovic and Rousseau, 2005). In particular, GPT adoption and diffusion is complicated by a high cost of learning on how to use it effectively; large adjustment costs and slow introduction of complementary inputs, especially knowledge based capital (KBC). In fact, the productivity slowdown may reflect the dynamics associated with this complementary investment (Fernald and Basu, 2006).

2.2 Macroeconomic factors

18. The debate however has also focused on non-technology macro factors that might have driven the recent slowdown, namely on the role of demand, savings and monetary policy. As recently summarized by Larry Summers (2016), the key mechanisms to understand the link between demand and the slowdown rely on the "secular stagnation" idea that there is an imbalance between savings and investment caused by an increased propensity to save and a decreasing propensity to invest which in turn leads to excessive savings dragging down demand; lower real interest rates and a reduction in growth and inflation. Significant growth, such as that characterizing the 2003-2007 boom, was achieved thanks to excessive levels of borrowing and unsustainable investment levels.

19. Recent models have analysed the role of macro shocks during the crisis as triggers of the slowdown. These models, however, generally take the slowdown in MFP as exogenous and cannot explain the pre-crisis slowdown. For example, Christiano et al. (2015) focus on key features of the Great Recession, such as the "financial wedge", motivated by the sharp increase in credit spreads, and resulting from e.g. changes in bankruptcy costs and other costs of financial intermediations; the "consumption wedge", motivated by the flight to safe assets during the crisis and a reduction in

consumption as a trigger to the lower zero bound; and the changing behaviour of the government consumption alongside a neutral technology shock that captures the observed decline, relative to trend, in MFP.

20. More interestingly for our framework is the link between monetary policy, real interest rates on one side and reallocation, innovation and diffusion on the other. A recent paper by Anzoategui, Comin, Gertler and Martinez (2016) proposes a theoretical model whereby the increase in demand for liquidity, as observed during the crisis, increases the spread between cost of capital and the risk -free rate of liquid assets. This leads to a decline in investment in R&D and technological adoption, which in turn yields lower output and lower MFP. According to the model, the spread of technology adoption varies over the business cycle, with the cyclicality mainly driven by fluctuation in the adoption rate which depends also on fiscal and monetary policies. The model, however, has to rely on exogenous medium term factors to explain the pre-recession slowdown.

2.3 Rising resource misallocation

21. Gopinath et al. (2015) explore the implications for sectoral MFP of the decline in real interest rate, observed in Southern Europe during the euro-convergence process. They find evidence that the associated capital inflow was increasingly misallocated towards firms that had higher net worth but were not necessarily more productive, which could explain why MFP slowed in Southern Europe – especially Spain – even before the crisis. This misallocation-driven slowdown was further exacerbated by the additional uncertainty generated by the crisis and more generally is likely to be related to weakening market selection, declining business dynamism and deteriorating business investment.

2.4 Measurement issues

22. Finally, the debate had also raised the possibility that the productivity slowdown might have just been a reflection of a problem of mismeasurement of the gains from innovation in IT-related goods and services. However recent analysis (Byrne, Fernald and Reinsdorf 2016; and Syverson, 2016) suggests that this is highly unlikely. Given that IT producing sectors have seen rising import penetration and most of the IT production is now done outside the US, the effect (either way) would be small and in no way large enough to explain the observed slowdown observed in the US. In fact, "improving" measurement would, if anything, make the slowdown more pronounced to the extent domestic production of these products has fallen, since the 1995-2004 period. Furthermore, mismeasurement of IT hardware is significant prior to the slowdown. Finally, the largest benefits of recent innovation in ICT go to consumers in non-market production activities. In fact Syverson (2016) shows that the slowdown is not correlated with IT production or use.

2.5 Our contribution

23. In this paper, we aim to bring the debate on the global productivity slowdown – which has by and large been conducted from a macroeconomic perspective – back to a more micro-level. While the Gordon-Brynjolfsson controversy is essentially a debate about prospects at the global productivity frontier, it is remarkable how little is actually known about the performance of firms that operate at the global frontier. In this regard, we provide new evidence that highlights the importance of separately considering what happens to innovation at the frontier as well as the diffusion of new and unexploited existing technologies to laggards firms. This micro evidence is both key to a motivating new theoretical work and to shifting the debate to areas where there may be more traction for policy reforms to revive productivity performance in OECD countries.

3. Data and identification of the global productivity frontier

24. This paper uses a harmonized firm-level productivity database, based on underlying data from the recently updated OECD-Orbis database (see Gal, 2013). The database contains several productivity measures (variants of labour productivity and multi-factor productivity, MFP) and pertains to 24 OECD countries over the period 1997 to 2014.[1] The industry detail is at the 2-digit in NACE rev. 2 and comprise the nonfarm non-financial business sector excluding mining (i.e. codes 10-82, excluding 64-66).

25. As discussed in Gal (2013), these data are cleaned and benchmarked using a number of common procedures. Despite substantial efforts on data preparation steps, and also following suggestions by Kalemli-Ozcan et al (2015), a number of issues that commonly affect productivity measurement should be kept in mind. Amongst these, it is worth mentioning that differences in the quality and utilisation of capital and labour inputs cannot be accounted for as the capital stock is measured in book values and labour input by the number of employees. Secondly, measuring outputs and inputs in internationally comparable price levels remains an important challenge.[2] Finally, similar to most firm-level datasets, Orbis contains variables on outputs and inputs in nominal values and no additional separate information on firm-specific prices and quantities (i.e. we observe total sales of steel bars, but no information on tonnes of steel bars sold and price per ton), thus output is proxied by a firm total revenues. Hence, differences in measured (revenue) productivity across firms may reflect both differences in technology as well as differences in market power[3]. As described below, we attempt to correct our productivity measures for differences in market power by deriving firm- and time- specific mark-ups following De Loecker and Warzynski (2012).

3.1 Productivity measurement

26. As a starting point, we focus on labour productivity, which is calculated by dividing real value added (in US industry level PPP) by the number of employees. This has the advantage that it retains the largest set of observations, as it does not require the availability of measures for fixed assets or intermediate inputs potentially used for deriving multi-factor productivity (MFP). Our baseline MFP relies on a value added based production function estimation with the number of employees and real capital as inputs.[4] We employ the IV estimation method proposed by Wooldridge (2009), which

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1 These countries are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Ireland, 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.

2 We use the country-industry level purchasing power parity database of Inklaar and Timmer (2014), see details therein for tradeoffs involved in deriving their PPP measures.

3 Thus in the example above, one would not know whether revenue based productivity is higher because the firm is producing more steel bars, or whether the firm's higher observed productivity is driven by higher prices reflecting high mark-ups, which the firm can charge for example because of a lack of competition.

4 The capital stock is derived from the book value of fixed assets using the perpetual inventory method on gross investments - deflated by 2-digit country-specific investment deflators – and the initially observed fixed assets. Firm-specific depreciation rates are derived using the book value of depreciation and fixed assets. Before running the production function estimations, a number of additional cleaning rules were applied. In particular, within each 2-digit industry, those observations are excluded where log(value added/employment), log(capital/employment) and log (materials/employment) are outside the top or bottom 0.5% of their distribution. The resulting productivity measures as well as the mark-up and capital intensity measures discussed below are then also filtered by following a similar procedure: the top and bottom 0.5% of their annual growth rates are used to identify the

mitigates the endogeneity problem of input choices by using intermediate inputs as proxy variables for productivity and (twice) lagged values of labour as instruments.[5] The production function is estimated separately for each 2-digit industry, controlling for country and year fixed effects. This allows for inherent technological differences across industries, while at the same time ensures comparability of MFP levels across countries and over time by having a uniform labour and capital coefficient along these dimensions.[6]

3.2 Correcting for mark-ups

27. In order to mitigate the limitations from not observing firm-level prices, the mark-up estimation methodology of De Loecker and Warzynski (2012) is applied to correct the revenue MFP measure.

28. We introduce a notation for the MFP estimates as MFPR (denoting revenue based productivity) and the mark-up corrected MFP estimates as MFPQ (physical or quantity based productivity), and we define it as follows for each firm *i* and year *t:*

$$MFPQ_{it} = MFPR_{it} - \log(\mu_{it}),$$

where the MFP values are also measured in logs and μ_{it} denotes the estimated mark-up. The MFPQ measure provides an estimate for productivity that is purged from mark-up variations and hence is not influenced by market power changes.[7]

29. The mark-up is derived from the supply-side approach originally proposed by Hall (1986) and more recently re-explored by De Loecker and Warzynski (2012). As described in De Loecker and Warzynski (2012), the approach computes mark-ups without needing assumptions about the demand function, but only relying on available information on output and inputs, making the assumption that at least one input is fully flexible and that plants minimize costs. Thus, the mark-up is derived from the first order condition of the plant's cost minimization problem with respect to the flexible input *k* as:

$$\mu_{it} = \frac{P_{it}}{MC_{it}} = Output\ Elasticity_{ikt}/Output\ Share_{ikt}\ ,$$

top and bottom 0.5% separately for each country, to avoid the influence of extreme outliers in terms of productivity (and mark-up or capital-intensity) growth.

5 This approach builds on Levinsohn and Petrin (2003) but addresses the critique of Ackerberg et al (2015) on the identification of the labour coefficient, and also makes estimations more efficient and robust since it avoids using a two-step approach. To avoid limiting sample size unnecessarily, the MFP measures are also calculated for those firms where intermediate inputs are not observed. With the actual implementation of Wooldridge (2009) in software code (in Stata) we follow the program codes provided by Petrin and Levinsohn (2012).

6 The estimated coefficients are statistically significant and economically meaningful in that the labour coefficients tend to be higher in services than in manufacturing and overall they range between 0.6 and 0.85. The production function estimation results are available upon request. In order to maximize coverage for our MFP measures, they are also calculated – as a residual from the estimated production function – for those firms where materials (our measure of intermediate inputs) are not available. However, the first step of the mark-up estimation also relies on materials, hence the sample size reduction in the mark-up correctedMFP measures MFPQ.

7 A further step would be a separation of market power and quality and/or demand. See Foster et al. (2008), and also Forlani et al (2016) on a related discussion about the role of different business strategies and their impact on measured productivity through the example of Nissan (high number of produced cars into the cheaper segment) and Mercedes (lower number of cars produced into the premium segment).

i.e. the mark-up of plant i at time t can be computed as the ratio between the elasticity of output[8] with respect to the flexible input *k* (estimated in a first step) and flexible input k shares of sales (observed in the data). In our baseline specification, we use as flexible input labour to ensure the largest coverage of countries, thus mark-ups are calculated as the ratio between the estimated production function parameter for labour $\hat{\beta}_L^j$ for the particular industry *j* where firm *i* belongs to and the "corrected" wage share $ws_{it} = \frac{\mathrm{WL_{it}}}{\widehat{\mathrm{VA}}_{\mathrm{it}}}$:

$$\mu_{it} = \hat{\beta}_L^j / ws_{it}$$

30. The correction of the wage share is achieved by predicting the value added using a rich polynomial function of observable inputs – what is called "first stage" in De Loecker and Warzynski (2012)[9]. Given potential criticisms that labour input may not be fully flexible – especially in countries with rigid labour markets – we also calculated for a subset of 18 countries for which data are available mark-ups using materials as the fully flexible input. As shown in Appendix A, the main results are robust to these different choices.

31. As Biesebroeck and De Loecker (2016: 25) note, the intuition behind this mark-up measure is as follows:

> "Holding other inputs constant, a competitive firm will expand its use of [the flexible input, i.e. labour] until the revenue share equals the output elasticity [hence the markup measure would be 1]. […] If a firm does not increase [its flexible input use] all the way until equality holds, but prefers to produce a lower quantity and raise the output price instead, it indicates the firm is able to exercise market power and charge a price above marginal cost."

32. As noted in the De Loecker and Warzynski (2012), the low demand in terms of additional assumptions of their approach and the lack of information on firm level prices bear some costs. Given that we do not observe firms' physical output, the approach is only informative on the way mark-ups change over time (not their level) and in relative terms, i.e. on the correlation with firm characteristics (e.g. productivity, size, export status) rather than in absolute levels. In what follows therefore, we will look at relative trends in mark-ups for frontier and laggard firms.

3.3 Measuring the productivity frontier

33. 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. As there is a tendency in Orbis for the number of firms (with available data to calculate productivity) to expand over time, we slightly deviate from this practice in our preferred definition of frontier firms.[10] One implication of the increasing coverage of Orbis over time is that

8 Note that for simplicity we have assumed that the firm only produces one product. In the case of multiproduct firms one should calculate mark-ups for each of the products sold by the firm.

9 One of the potential caveats with this methodology, as mentioned by De Loecker and Warzynski, is that the level of mark-ups can be biased. However, since our analysis is focused on within-industry differences over time (double-differencing), any bias affecting the levels is eliminated.

10 In a previous version of the paper (Andrews et al, 2015), we adopted a definition based on a fixed number of firms across time as well as across industries (top 100 or top 50). By allowing the frontier size to vary across industries, we better tailor the frontier definition to each industry. As Figure A3 in Appendix A shows, the choice among these alternatives does not affect the main finding of a growing productivity gap between the frontier and the rest.

smaller – and presumably less productive – firms get included in the frontier in the latter years of the sample. Thus, the evolution of the top 5% on the expanding Orbis sample could artificially underestimate average productivity at the frontier over time just as a reflection of the expanding sample. To avoid this, we calculate the 5% of firms per industry using a fixed number of firms across time. This circumvents the expanding coverage problem but still allows for differences across industries in terms of their firm population, which is important given vastly heterogeneous sizes across industries. More specifically, frontier firms are identified using the top 5% of the median number of firms (across years), separately by each industry. This approach aims to capture as close as possible capture the top 5% of the typical population of firms.

34. Importantly, however, while the *number* of frontier firms is fixed, the *set* of frontier firms is allowed to change over time. This choice is necessary to ensure that when assessing the evolution of the frontier, we account for the phenomenon of turbulence at the top: some firms can become highly productive and push the frontier, while others, previously productive businesses can lose their advantages. As discussed in Section 4.4, while there is churning at the frontier, this is largely concentrated amongst the top quintile of the productivity distribution.

3.4 Representativeness issues

35. 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, we exclude firms with less than 20 employees. 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.

36. 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.[11] 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 analysis given that the focus is only on the global frontier and the gap relative to "all laggard firms" and thus country boundaries are less relevant. However, it is reassuring that the key result of Section 4 – 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, so it is not incorporated in the baseline specification but is instead presented as a robustness test (Appendix A).

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11 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. For these reasons, we give priority to consolidated accounts by removing the unconsolidated ones for companies where both types of accounts are present in the data.

37. Another caveat is that emerging market economies are not well represented in the database hence they are not included in our analysis. 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 in 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 impediments related to the penetration of new technologies across a sample of developed and developing economies alike.

38. 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 discussed in Andrews, Criscuolo and Gal (2015), 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.

3.5 Characteristics of frontier firms

39. 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 MFPR and Panel C using MFPQ.

40. A few interesting facts emerge from the tables: *i*) firms at the global productivity frontier are on average 3 to 4 times more productive than non-frontier firms;[12] *ii*) on average, global frontier firms have larger sales, are more capital intensive – and as expected, more so for labour productivity –, and pay higher wages; *iii*) however, they do not employ a significantly larger number of employees in services for any of the productivity measures analysed; *iv*) in manufacturing, firms at the frontier in terms of MFP (MFPR and MFPQ) have significantly higher employment size than laggards, in line with existing evidence that productivity is positively correlated with size; and *v*) frontier firms are also shown to charge higher mark-ups in the case of labour productivity and MFPR, even more so in services. This could reflect weaker competition in the less tradable and more regulated services sector, which allows for larger market power differences across firms. However, when the frontier is defined based on MFPQ, frontier firms are found to charge lower mark-ups. This is consistent with the idea that the most (physically) productive firms can afford to charge lower prices and thus attract more demand. Finally global frontier firms are also more likely to belong to a group/conglomerate and patent more intensively than other firms (Andrews et al, 2015).[13]

12 Note that productivity is measured in logs, so relative to NF firms, GF firms are exp1.3=3.6 times more productive.

13 These results are based on our previous analysis for 2005, when information of patenting and available the firm's multinational status was available. The OECD is currently in the process of updating this information for the new vintage of Orbis.

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

A: Labour productivity

	Sector: manufacturing							Sector: services						
	Non-frontier firms			Frontier-firms			Difference	Non-frontier firms			Frontier-firms			Difference
Variables	Mean	St.dev.	N	Mean	St.dev.	N		Mean	St.dev.	N	Mean	St.dev.	N	
Productivity	10.7	0.6	21191	12.0	0.4	825	1.3 ***	10.4	0.7	22053	11.9	0.7	627	1.5 ***
Employees	49.3	52.1	21191	45.1	33.8	825	-4.2 ***	59.5	156.6	22053	38.0	24.8	627	-21.6 ***
Capital-labour ratio*	0.1	0.1	21191	0.3	0.4	825	0.2 ***	0.0	0.0	22053	0.0	0.2	627	0.0 ***
Revenues *	11.8	21.6	21191	39.0	58.8	825	27.2 ***	1.1	2.2	22053	3.8	9.2	627	2.7 ***
Markup (log)	0.1	0.4	21191	0.1	0.4	825	0.0 ***	0.1	0.4	22053	0.3	0.5	627	0.2 ***
Wages**	31.0	15.1	21191	49.4	18.2	825	18.4 ***	12.3	20.0	22053	27.1	37.9	627	14.8 ***

B: MFPR

	Sector: manufacturing							Sector: services						
	Non-frontier firms			Frontier-firms			Difference	Non-frontier firms			Frontier-firms			Difference
Variables	Mean	St.dev.	N	Mean	St.dev.	N		Mean	St.dev.	N	Mean	St.dev.	N	
Productivity	10.4	0.6	21317	11.6	0.4	706	1.3 ***	10.3	0.7	22147	11.7	0.7	538	1.4 ***
Employees	48.3	46.8	21317	73.7	126.0	706	25.4 ***	59.1	155.3	22147	53.4	115.6	538	-5.6
Capital-labour ratio*	0.1	0.1	21317	0.2	0.4	706	0.1 ***	0.0	0.0	22147	0.0	0.1	538	0.0 ***
Revenues *	11.5	19.9	21317	50.5	74.1	706	39.0 ***	1.1	2.2	22147	5.1	13.1	538	4.0 ***
Markup (log)	0.1	0.4	21317	0.0	0.4	706	0.0	0.1	0.4	22147	0.2	0.5	538	0.1 ***
Wages**	31.0	15.1	21317	51.0	17.1	706	20.0 ***	12.3	20.0	22147	27.6	37.7	538	15.3 ***

C: MFPQ

	Sector: manufacturing							Sector: services						
	Non-frontier firms			Frontier-firms			Difference	Non-frontier firms			Frontier-firms			Difference
Variables	Mean	St.dev.	N	Mean	St.dev.	N		Mean	St.dev.	N	Mean	St.dev.	N	
Productivity	10.3	0.8	19844	11.7	0.4	887	1.4 ***	10.2	0.9	21823	11.6	0.7	776	1.4 ***
Employees	48.6	46.9	19844	79.1	119.1	887	30.5 ***	58.9	156.8	21823	58.5	73.0	776	-0.4
Capital-labour ratio*	0.1	0.1	19844	0.1	0.3	887	0.0 **	0.0	0.0	21823	0.0	0.0	776	0.0 **
Revenues *	12.0	22.5	19844	34.7	51.4	887	22.7 ***	1.1	2.2	21823	3.9	9.6	776	2.8 ***
Markup (log)	0.1	0.4	19844	-0.2	0.2	887	-0.3 ***	0.1	0.4	21823	-0.2	0.3	776	-0.2 ***
Wages**	31.2	14.9	19844	54.8	14.3	887	23.6 ***	12.2	19.9	21823	34.7	41.4	776	22.5 ***

Note: All statistics refer to 2013.
*:- in millions of 2005 USD; **: in thousands of 2005 USD

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013).

4. Productivity divergence between the global frontier and laggard firms

4.1 Labour productivity divergence

41. Figure 1 describes the evolution of labour productivity for firms at the global productivity frontier and non-frontier firms for the broadest possible sample of firms and years for which comparable data are available. In this exercise, the global frontier is defined as the top 5% of firms in terms of labour productivity levels within each two digit industry and year, while laggard firms refer to all other firms. In turn, the chart then shows how the unweighted average of log labour productivity across firms in these two groupings evolved over time, which the initial year – 2001 – indexed to 0 and separately for two broad sectors: manufacturing and business services.[14]

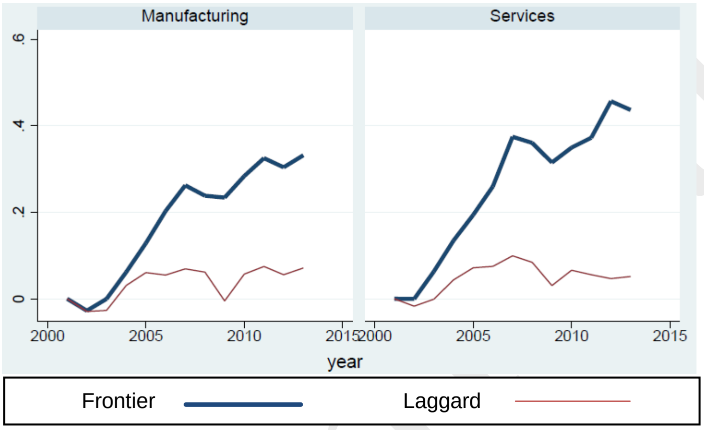
42. Between 2001 and 2013, firms at the global frontier have become relatively more productive, with their productivity increasing at an average annual rate of 2.8% in the manufacturing sector, compared to an improvement in the evolution of labour productivity of just 0.6% for non-frontier firms. This pattern of divergence is even more pronounced in the market services sector, with the

14 We restrict the time horizon of the figures between 2001 and 2013 because the years before the 2000s and the latest year (2014) is less well captured in Orbis. In the regressions below we control for a rich set of fixed effects capturing potential changes in coverage, hence we are able to utilize a longer span of data (1997-2014).

labour productivity at the global frontier growing at an average annual rate of 3.6%, compared to an average of just 0.4% for the group of non-frontier firms. Given the concerns discussed above of sampling variation in Orbis, Figure A1 of Appendix A also reports figures for the industry average. These statistics will represent an underestimate of the true gap between frontiers and laggards as the performance of frontier firms will also affect (i.e. raise) the average industry level productivity and the more so the larger they are, but sectoral level figures will not be affected by the sampling change problems of Orbis.[15] Reassuringly industry level trends look very much in line with the picture obtained with information from Orbis.

Figure 1. A widening labour productivity gap between global frontier firms and other firms

Labour productivity: value added per worker (2001-2013)



Notes: the global frontier is measured by the average of log labour productivity for the top 5% of companies with the highest productivity levels within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. Services refer to non-financial business services. See details in Section 3.3.

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

43. Digging deeper, two distinct time periods emerge, which are essentially punctuated by the global financial crisis. Between 2001 and 2007, labour productivity at the global frontier grew at a rapid rate of 4-5% per annum, significantly eclipsing the growth of non-frontier productivity which averaged roughly 1% per annum.[16] From 2008 onwards, labour productivity growth at the global frontier slowed to around 1% per annum, while the growth of non-frontier labour productivity ground to a halt. Reflecting these patterns, around three-quarters of the labour productivity gap between frontier and other firms that had accumulated by 2013 had been realised by 2007.

15 Since the detailed OECD National Accounts 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.

16 Note that "growth" here does not refer to the average growth of firms within the productivity frontier (laggard firms) but rather to the change over time of the average log productivity in the group of firms that are at the frontier (are laggards), with this group of firms allowed to vary over time. Besides, the aggregate labour productivity measures from the industry data also reflect developments among the smallest companies (below 20 employees) as well as the self employed.

44. As illustrated in Appendix A, these broad patterns are robust to: *i)* using turnover-based labour productivity (Figure A2); *ii*) defining the global frontier in terms of top 100 firms or top 10% of firms (Figure A3); *iii)* taking median labour productivity in the frontier and non-frontier firms groupings as opposed to average productivity; and i*v)* excluding from the sample firms that are part of a multi-national group (i.e. headquarters or subsidiaries) where profit-shifting activity may be relevant (Figure A4).

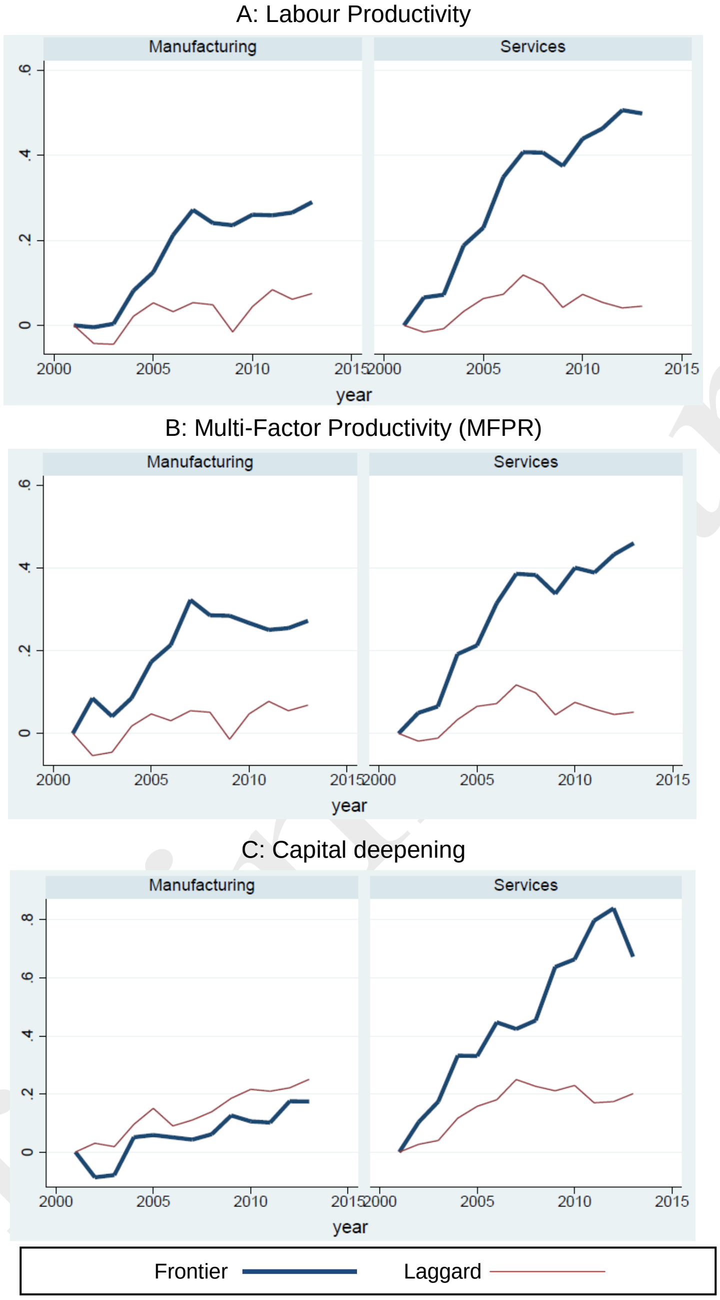
4.2 Labour productivity divergence: capital deepening or MFP?

45. Since gains in labour productivity at the firm level can be achieved through either higher capital deepening or multi-factor productivity (MFP), Figure 2 plots the evolution of these two components for global frontier and non-frontier firms, using the same definition of the global frontier as in Figure 1. Given that the sample of firms for which reliable capital stock is available is smaller than the baseline sample in Section 4.1, Figure 2, Panel A reproduces the evolution of labour productivity for global frontier and non-frontier firms in this smaller sample of firms, which broadly confirms the story of labour productivity divergence illustrated in Figure 1.

46. From a comparison of Panels B and C in Figure 2, it is evident that the rising labour productivity gap between global frontier and non-frontier firms in the manufacturing sector entirely reflects divergence in revenue-based MFP (MFPR), while capital deepening of non-frontier firms slightly outpaces that of global frontier firms over the sample period.[17] For the market services sector, there is evidence of divergence of both MFPR and capital deepening between global frontier and non-frontier firms, although labour productivity divergence in the pre-crisis period appears to be more strongly related to MFP-R than capital deepening.

[17] In fact, in manufacturing the divergence in MFP is larger than the divergence in labour productivity, given the faster capital deepening of non-frontier firms.

Figure 2. The widening labour productivity gap is mainly driven by MFP divergence



Notes: the global frontier group of firms is defined by the top 5% of companies with the highest productivity levels within each 2-digit industry. Laggards capture the all the other firms. Unweighted averages across 2-digit industries are shown for log labour productivity, the Wooldridge (2009) type production-function based log MFPR measure and the log of real capital stock over employment for Panels A, B and C, respectively, separately for manufacturing and services, normalized to 0 in the starting year. Time period is 2001-2013. Services refer to non-financial business services. See details in Section 3.3. The sample is restricted to those companies that have data available so as to measure capital stock and MFP. MFP (Panel B) and capital deepening (Panel C) do not sum to labour productivity (Panel A) in a simple way. That is because $VA\,/\,L = MFP\ (K^a L^b)\,/\,L = MFP\ \left(\frac{K}{L}\right)^a L^{a+b-1}$, where the capital coefficient (*a*) and the labour coefficient (*b*) allowed to vary by industry.

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

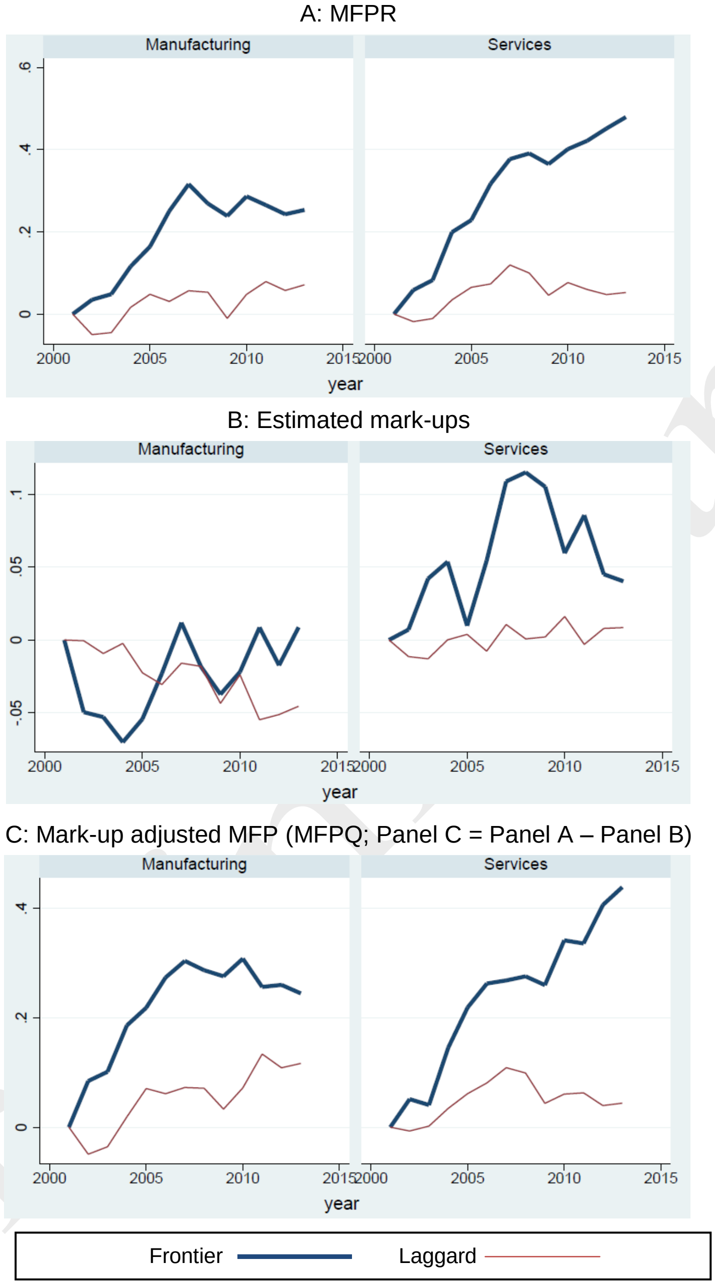
4.3 MFP divergence: mark-ups or technology?

47. While evidence of divergence in MFP points towards a technological explanation of the rising labour productivity gap between global frontier and other firms, it might also reflect the increasing market power of frontier firms, given that our measure of multifactor productivity MFPR is based on information on revenues as discussed in section 3. If the increasing differences in MFPR between frontier and laggards reflect unobserved differences in firm level prices, the rising gap between global frontier and other firms in MFPR may simply reflect the increasing ability of frontier firms to charge higher mark-ups, as opposed to differences in technical efficiency. Accordingly, we attempt to assess the contribution of mark-up behaviour to MFPR divergence, using the methodology developed by De Loecker and Warzynski (2012) outlined in Section 3.

48. Given the focus on MFPR, the global frontier in Figure 3 is redefined in terms of the top 5% of firms in terms of MFPR levels within each two digit industry and year. Using such a definition, the divergence of MFPR in Figure 3, Panel A is very similar to that in Figure 2, Panel B, which defines the global frontier in terms of labour productivity. As illustrated in Appendix A, these patterns are robust to using alternative definitions of MFPR, such as a Solow or Wooldridge gross-output approach (Figure A6) and to using intermediates as the fully flexible input in De Loecker and Warzynski (2012) methodology for a subset of 18 countries for which data are available (Figure A8).

49. Figure 3, Panel B plots the evolution of the unweighted average of the estimated mark-ups for global frontier and non-frontier firms. While estimates are quite volatile, the pre-crisis divergence in MFPR in the manufacturing sector does not appear to be driven by frontier firms charging higher mark-ups, relative to non-frontier firms. If anything, frontier firms charged significantly lower mark-ups relative to laggards (Table 1) suggesting that they could charge lower prices given their superior technological efficiency: in fact accounting for mark-up behaviour in the pre-crisis period exacerbates the divergence in MFP in the manufacturing sector, as reflected in Figure 3, Panel C, which provides a crude measure of the mark-up corrected MFP by subtracting the estimated mark-up (Panel B) from MFPR (Panel A) and which therefore should capture technology driven differences across firms. Turning to the services sector, there is evidence that frontier firms charged higher mark-ups relative to non-frontier firms in the pre-crisis period, and increasingly so after 2005, but this divergence in mark-up behaviour is significantly unwound in the post-crisis period. Once we correct MFPR for these patterns in mark-ups, the divergence in MFP between frontier and non-frontier firms in the pre-crisis is reduced by a factor of about one-third, while the divergence becomes somewhat larger in recent years (Figure 3, Panel C).

Figure 3. The widening MFP gap remains after controlling for mark-ups



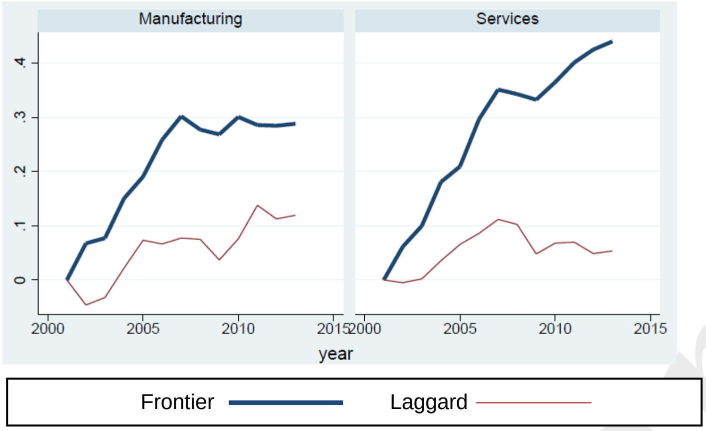
Notes: the global frontier group of firms is defined by the top 5% of companies with the highest MFPR levels within each 2-digit industry. Laggards capture the all the other firms. Unweighted averages across 2-digit industries are shown for MFPR, estimated markups and MFPQ for Panels A, B and C, respectively, separately for manufacturing and services, normalized to 0 in the starting year. Time period is 2001-2013. Services refer to non-financial business services. See details in Section 3.3.

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

50. For completeness, Figure 4 chart the evolution of mark-up corrected MFP where the global frontier is now defined as the top 5% of firms in terms of mark-up corrected MFP levels within each two digit industry and year. Taken together, the evidence in Figures 3 and 4 implies that MFP divergence in the manufacturing sector is a technology story, while the MFP divergence in services is largely a technology story but with some contribution from rising mark-ups.

Figure 4. A widening gap in mark-up corrected MFP

Global frontier defined in terms of mark-up corrected MFP (MFPQ)



Notes: the global frontier group of firms is defined by the top 5% of companies with the highest MFPQ levels within each 2-digit industry. Laggards capture the all the other firms. Unweighted averages across 2-digit industries are shown for MFPQ, separately for manufacturing and services, normalized to 0 in the starting year. Time period is 2001-2013. Services refer to non-financial business services. See details in Section 3.3.

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

4.4 MFP divergence: winner takes all dynamics vs stalling diffusion?

51. The evidence presented so far suggests that the MFP gap between the global frontier and other firms has risen significantly over time and that this pattern has emerged even before the crisis. To the extent that these developments reflect structural changes in the global economy driven by digitalisation, globalisation and the rising importance of tacit knowledge, MFP divergence could arise from two factors: winner takes all dynamics or stalling technological diffusion. In practice, it is difficult to distinguish with the data at hand the relative importance of these two factors, but a number of smoking guns emerge to suggest that both factors may be relevant.

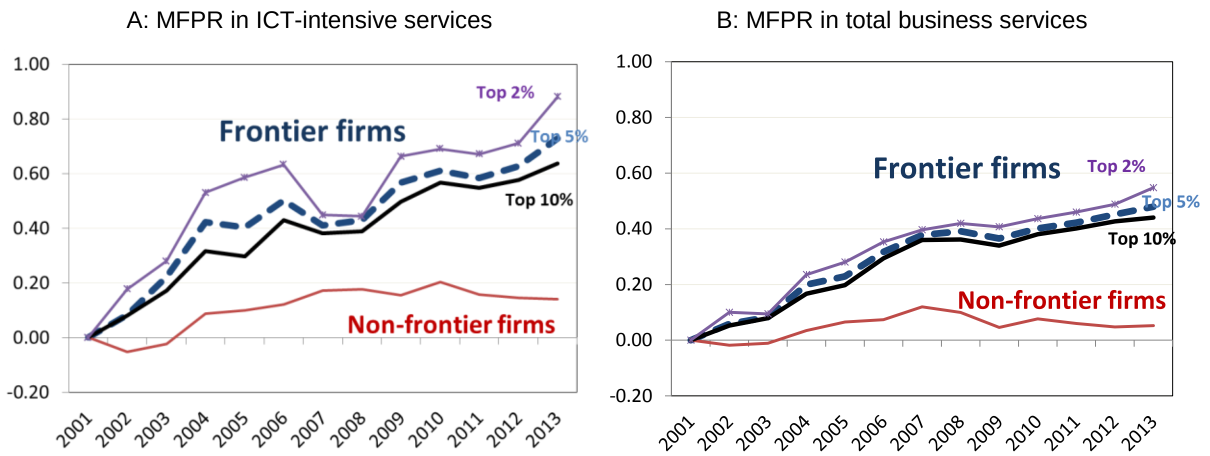
4.4.1 Winner takes all dynamics

52. First, it may partly reflect the increasing potential for digital technologies to unleash winner take all dynamics (Brynjolfsson and McAfee, 2011), which allows the technological leaders to increase their MFP gap with laggard firms. More specifically, digital technologies – which allow the replication of informational goods and business processes at near zero marginal cost – enables the top-quality provider to capture most, or all, of their market, while only a tiny fraction of that revenue may accrue to the next-best (even if they are almost as good as the best provider). At the same time, given the global nature of frontier firms (Section 3.5), these patterns are likely to be reinforced by globalisation, which increases the returns to investing in non-rival technologies via expanded market size (Acemoglu and Linn, 2004).

53. If these factors are relevant, than we would expect to observe: *i*) that divergence in MFPR is accompanied by divergence in sales – a pattern confirmed by Figure A5; *ii*) a more pronounced MFP divergence in ICT-intensive sectors and within the global frontier grouping in sectors ICT intensive sectors; *iii*) a stronger increase in mark-ups in ICT intensive sectors and within the global frontier

grouping in sectors ICT intensive sectors[18]; and *iv*) notwithstanding developments in the mark-up, a divergence in MFPQ.

Figure 5. Developments within the global frontier: the emergence of a global elite



Notes: the global frontier group of firms is defined by the top 5% of companies with the highest MFPQ levels within each 2-digit industry. Laggards capture the all the other firms. Unweighted averages across 2-digit industries are shown for MFPQ, separately for manufacturing and services, normalized to 0 in the starting year. Time period is 2001-2013. Services refer to non-financial business services. ICT-intensive services refer to the information and communication sector (industry code J in NACE Rev. 2) and postal and courier activities (53). See details in Sections 3.3 and 4.4.

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

54. As it turns out, we find support for some of these propositions. First, Figure A5, Panel A shows that the divergence in sales has been growing over time: global frontier firms have gained significant market share relative to laggards in manufacturing and to a larger extent in services, while the average size of frontier firms and laggards in terms of employment show similar trends over time (Panel B). This might reflect winner takes all dynamics where firms that make it to the top might gain too large of a market share, which could make entry into the frontier more difficult for newcomers and more generally lead to lower competition in the market (see Section 4.4).[19]

55. Second, the rise in the MFPR gap was most pronounced in ICT-intensive services (Figure A7).[20] Third, within the global frontier grouping, we see that a small cadre of the most elite firms (top 2%) become more productive relative to other frontier firms in ICT-intensive services (Figure 5, Panel A), while this pattern is not particularly evident within the services sector on average (Figure 5, Panel

18 We are currently exploring this issue in more detail.

19 Finally, given the ongoing debate on jobless growth, it is interesting to understand what is happening to employment at the frontier and whether frontier firms are shedding labour at a faster rate than laggards.

20 We rely on UK data since data for the United States is unavailable. ICT intensive sectors are defined as those where the ICT capital in total capital compensation from EU-KLEMS (on average over 2001-2009) is among the highest 25% across all 2-digit industries. These industries are the information and communication sector (industry code J [58-63] in NACE Rev. 2) and postal and courier activities (code 53). Due to the lack of information on purchases of ICT services and other digital technologies, we rely on a measure of ICT capital based on the sum of software, computing and communications equipment as a proxy for digital intensity of sectors.

B).[21] One limitation in the data at hand is that we do not have firm level information on ICT capital so we are obliged to abstract from differences in ICT capital across firms within ICT intensive sectors.

4.4.2 Stalling technological diffusion

56. Second, a rising gap in MFPR might be symptomatic of stalling technological diffusion. According to this view, the strength of global frontier firms not only reflects their capacity to technologically innovate but also to optimally combine technological, organisational and human capital in production processes. Indeed, the importance of tacit knowledge as a source of competitive advantage for frontier firms may have risen if increases in the complexity of technologies over time have increased the amount and sophistication of complementary investments required for technological adoption.[22] This rising importance of tacit knowledge could act as a barrier to the catch-up of laggard firms, and cause the technological diffusion machine – which sustained productivity growth in the OECD 1950-1995 (OECD, 2015) – to break down.

57. Again, it is difficult with the data at hand to say for sure that technological diffusion has stalled, but some progress can be made by exploring the nature of churning at the frontier. One reflection of the increasing challenges to diffusion could be if there is increasing persistence at the frontier or that churning increasingly comes from firms close to the frontier (i.e. within the top 10% or 20% of the MFP distribution). We might also expect these patterns to be especially evident in the services sector where tacit knowledge is becoming ever more important.

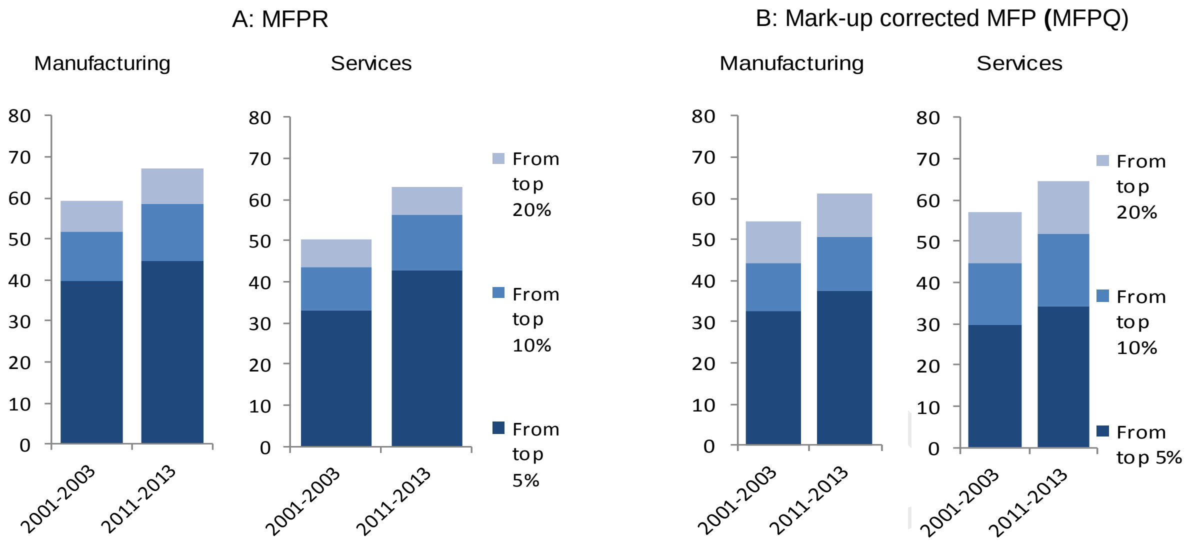
58. Figure 6 presents some evident to support these hypothesis. On average over 2001-2003, for example, over 50% of firms at the global frontier in terms of MFPR in the services sector (Figure 6 Panel A) where either classified two years earlier as frontier firms (i.e. 33% of firms where in the top 5%), or resided outside the frontier grouping but were in the top 10% (10% of firms) or top 20% (7% of firms). By 2011-2013, however, this figure had risen to 63%, driven by a significant increase in the proportion of incumbent firms retaining their position in the frontier (43%) and a more modest increase in entry to the frontier from firms residing just outside the frontier but in the top 10% (13%) some two years early. These patterns – which are also evident for MFPQ (Figure 6, Panel B) and are consistent with the broader decline in business dynamism (Haltiwanger et al., 2013; Criscuolo et al., 2014) – suggest that it has become more difficult for laggard firms outside the top 20% of the MFP distribution to enter the global productivity frontier over time, implying that technological diffusion may have stalled.

21 These patterns are robust to alternative productivity measures, such as labour productivity or mark-up corrected MFP. For sake of brevity, these results are available at request.

22 We attribute this idea to Chad Syverson's comments at the *OECD-NBER Conference on Productivity and Innovation in the Long-Run*.

Figure 6. Entry into the global frontier has become more entrenched amongst top quintile firms

Proportion of frontier firms in time *t* according to their frontier status in *t-2*

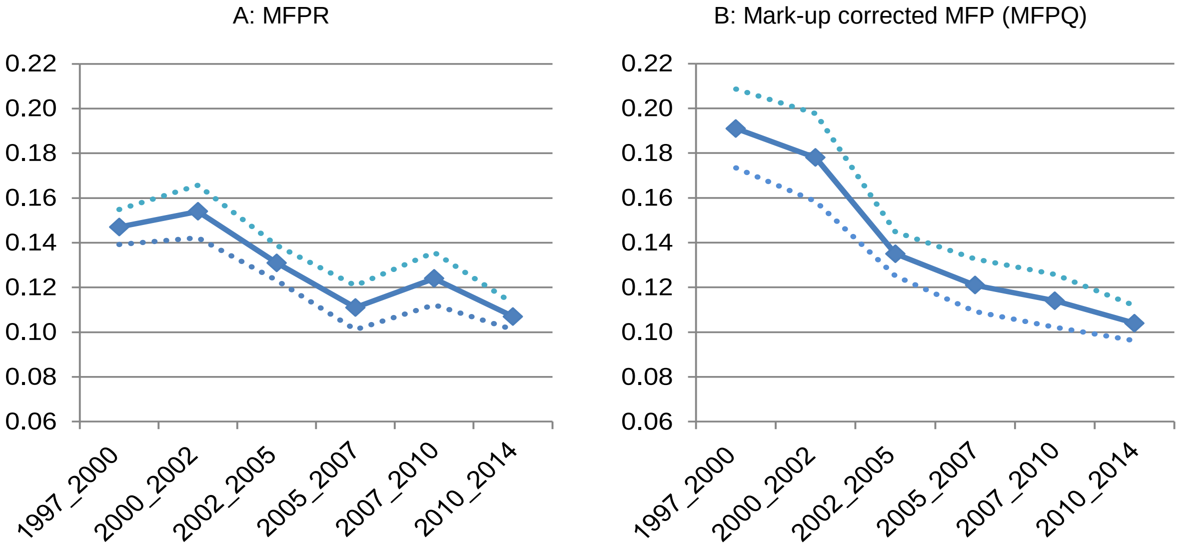


Notes: The figure shows the proportion of firms classified as global frontier firms at time *t* – i.e. in the top 5% of the industry MFPR or MFPQ distribution – according to their status two years earlier (*t-2*). Estimates are averaged over each three year time period. For example, Panel A shows that on average over the period 2011-2013 in services, 43% of frontier firms (i.e. top 5%) were present in the frontier grouping two years earlier, while amongst the firms that entered the frontier grouping, 13% had MFPR levels in the top 5-10% (top 10%) and 7% had MFP levels in the top 10-20% (top 20%)

59. To more robustly test whether the pace of technological convergence has slowed over time, our analysis shifts to the firm level. As outlined in Appendix B, we estimate a neo-Schumpeterian model where firm level MFP growth depends on a firm's lagged MFP gap with the global frontier. The results suggest that on average across time, firms further behind the technological frontier have higher MFP growth, reflecting their ability to catch-up based on the adoption of a larger stock of unexploited technologies. As Figure 7 demonstrates, however, the pace of technological convergence via this mechanism has declined significantly over time. For example, the estimated coefficient on the lagged MFPR gap term declined by almost 30% from the late 1990s to the most recent period, with most of this decline realised by 2007 (Panel A). This pattern of slowing productivity convergence is even more pronounced when the model is estimated using mark-up corrected MFP (Panel B).

Figure 7. The pace of convergence slowed, even before the crisis

Estimated convergence parameter from neo-Schumpeterian model and 95% confidence intervals



Notes: The marker line shows the evolution over time of the estimated $GAP_{i,t-1}$ coefficient from the firm level MFP growth regression in Table B1 Appendix B (Column 1, Panel A), while the dashed line provides the 95% confidence interval around this coefficient estimate.

60. To the extent that these developments reflect structural changes in the global economy driven by digitalisation, globalisation and the increasing importance of tacit knowledge, then it is likely that some increase in MFP divergence was inevitable. Yet, as we have seen, the increase in the MFP gap was not uniform across sectors, with the rise much more apparent in services than manufacturing. Given that services are typically more sheltered from competitive pressures – due to lower exposure to international competition and more stringent product market regulations – this provides a "smoking gun" to suggest that there might be more to the story than just the structural factors outlined above. In the next section, we present evidence to suggest that the rise in the MFPR gap was less pronounced in sectors where the pace of product market reform was more intense, suggesting scope for public policy to lean against the wind of rising MFP divergence.

5. Productivity divergence: the role of product market regulation

5.1 Technological diffusion and product market regulation

61. At the margin, there are number of channels through which pro-competitive product market reforms can strengthen the incentives for laggard firms to adopt frontier technologies, thereby moderating – but not necessarily reversing – the pressures towards higher MFP divergence induced by technological change. Indeed, a range of firm-level evidence generally supports the idea that competitive pressures are a driver of productivity-enhancing innovation and adoption.[23] More specifically, pro-competition reforms in product markets could be expected to promote the catch-up of laggard firms to the global frontier for a number of reasons:

[23] See, for instance: Geroski (1995a, 1995b); Nickell (1996); Nickell, Nicolitsas and Dryden (1997); Blundell, Griffith and Van Reenen, (1999); Griffith, Redding and Simpson (2002); Aghion et al (2004); Haskel, Pereira and Slaughter (2007).

- First, higher competition sharpens the incentives for incumbent laggard firms to adopt better technologies (Bloom et al., 2015; Perla et al., 2015).
- Second, stronger product market competition can improve managerial quality (Bloom and Van Reenen, 2010), which is complementary to technological adoption (Bloom et al., 2012).
- Third, reductions in administrative entry barriers can spur entry, which promotes technological diffusion to the extent that young firms possess a comparative advantage in commercialising cutting-edge technologies (Henderson, 1993; Baumol, 2002).
- Fourth, pro-competitive reforms to market regulations in upstream services sectors may increase the rents expected by firms in downstream manufacturing sectors from adopting best-practice techniques (Bourles et at., 2013).
- Finally, product market reforms can promote productivity-enhancing reallocation (Andrews and Cingano, 2014), thereby enhancing the ability of firms to attract inputs complementary to technological adoption and achieve sufficient scale to enter global markets and learn from global frontier firms.

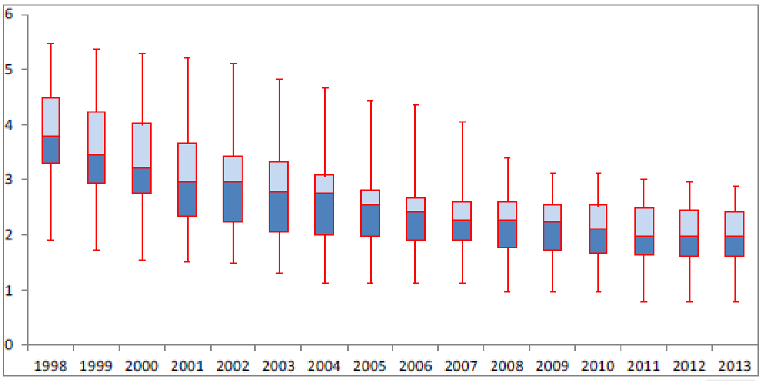
5.2 Product market reforms in OECD countries

62. As it turns out, there is considerable scope for further product market reform in many OECD countries, particularly in market services where the increase in MFP divergence has been most striking.[24] Within non-manufacturing industries, most reform activity over the past 15 years has been concentrated in network industries (i.e. energy, transport and communication), and this is reflected in both a decline in the median level and dispersion of market regulation across countries (Figure 8, Panel A). Even so, there remains some scope for further reform action in specific network industries and countries, while the imperative for large-scale reforms in retail trade and professional services has become increasingly urgent. Between 1998 and 2013, the median restrictiveness of product market regulations only fell modestly in retail (Panel B) and was little changed in professional services (Panel C), while the dispersion in the restrictiveness of market regulations across countries in these sectors remains high. If product market regulations affect the incentives for laggard firms to adopt leading technologies and best practices, to what extent is the rising MFP gap between frontier and laggard firm in services a product of the slow pace of market reforms in these industries?

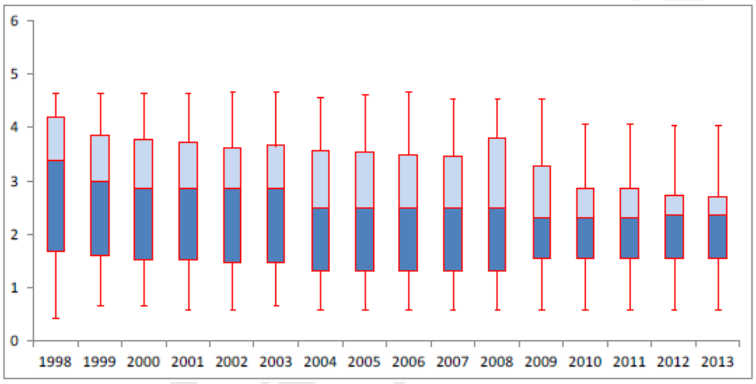
24 As outlined in Nicoletti et al. (2000), restrictions to competition were defined either as barriers to access in markets that are inherently competitive or as government interferences with market mechanisms in areas in which there are no obvious reasons why such mechanisms should not be operating freely (e.g. price controls imposed in competitive industries as road freight or retail distribution). Moreover, the construction of the indicators assumes that regulatory patterns do not reflect cross-country differences in the level of public concern for the market failures that motivate regulations, but rather reflect regulatory failure or policies adverse to competition.

Figure 8. The restrictiveness of product market regulations over time, 1998-2013

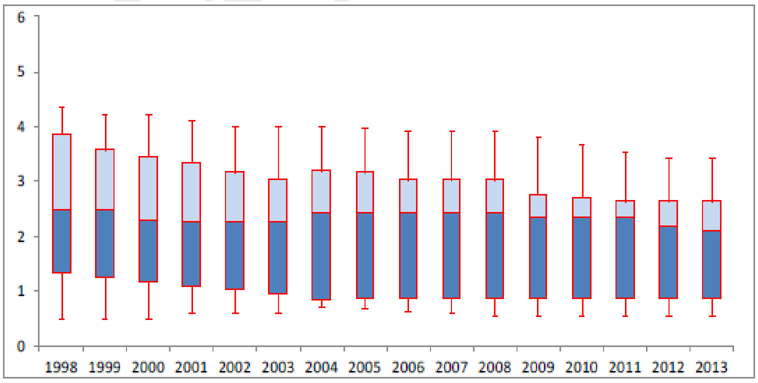
A: Network industries



B: Retail



C: Professional services



Note: The PMR indicator varies between 0 and 6, and higher values indicate more stringent and less competition-friendly regulation. The horizontal line in the boxes represents the median, the upper and lower edges of each boxes reflect the 25th and 75th percentiles and the markers on the extremes denote the maximum and the minimum across countries. As discussed in Gal and Hijzen (2016), regulation in: *i*) network industries is largely about the organisation of network access to potential service providers; *ii*) retail trade typically takes the form of entry barriers, specific restrictions for large firms and the flexibility of shops in terms of opening hours and prices; *iii*) professional services concerns to barriers to entry and the way services are delivered and includes, amongst others, rules governing the recognition of qualifications and the determination of fees and prices.

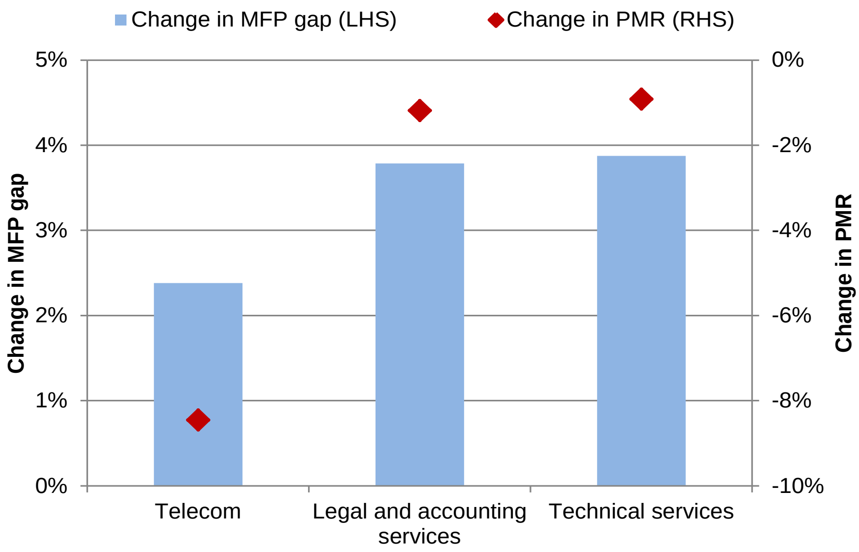
Source: calculations by Gal and Hijzen (2016) based on OECD indicators on product market regulation (Koske, et al. 2015) and additional information on the timing of reforms for retail and professional services (Duval et al., 2016).

63. By way of introduction and purely for illustrative purposes, Figure 9 provides some preliminary evidence on the link between the pace of market reforms and the evolution of the MFP

gap between global frontier and laggard firms in three selected services industries. As it turns out, the MFP gap increased more quickly in professional service industries such as legal, accounting and technical services (engineering and architecture) where the pace of reform lagged, compared to network industries such as telecommunications where the pace of market reform has been much more intensive. While these patterns are consistent with the idea that pro-competitive market reforms in services can sharpen the incentives for technological adoption, it is important to control for a number of potentially omitted country, industry and time factors to establish a more robust link between PMR and the MFP gap. Herein lies the aim of the next section.

Figure 9. Slower product market reform, a larger increase in the MFP gap

Selected industries; annual average change over time and across countries



Note: The figure shows the annual change in the (log) MFPR gap between the frontier and laggard firms and the change in the (log) PMR indicator. Technical services refer to architecture and engineering. Percentages are approximated by log-point differences.

5.3 Empirical strategy

64. To more rigorously explore the link between product markets regulations and the MFP gap between global frontier firms and other firms over time, we estimate two complementary econometric specifications.

65. First, for 10 market services sectors for which regulatory indicators are available over the period 1998-2013, we estimate the following long difference specification:

$$\Delta^{ld} MFPgap_{s,c,t} = \beta_0 + \beta_1 \Delta^{ld} PMR_{s,c,t} + \beta_2 \Delta^{ld} E_{s,c,t} + \delta_c + \delta_s + \delta_t + \varepsilon_{s,c,t} \qquad [2]$$

where: Δ^{ld} denotes the long difference operator, corresponding to five years in the baseline specification;[25] $MFPgap_{s,c,t}$ refers to the difference between the average MFP (MFPR or mark-up corrected MFP) of global frontier firms and the average MFP of laggard firms in country *c*, industry *s*

25 As discussed below, the results are not particularly sensitive to the choice of the length of the long difference window.

and year *t; $PMR_{s,c,t}$* refers to the overall restrictiveness of product market regulation in key service industries (expressed in log terms)[26], which is increasing in the degree of regulation. If $\beta_1>0$, then it implies that a slowdown in the pace of pro-competitive product market reforms (i.e. a less negative $\Delta^{ld} PMR_{s,c,t}$ term) is associated with a rising MFP gap between the global frontier and non-frontier firms.

66. The regression also includes the growth of sectoral employment (E) to control for time-varying shocks within country*industry pairings and for changes in the coverage of the dataset over time.[27] The baseline model includes separate country, industry and year fixed effects to control for omitted time-invariant country (δ_c) or industry (δ_s) factors and global shocks (δ_t), but as an extension, we include interacted country-year fixed effects (δ_{ct}) to control for time-varying country-specific shocks. We maximize the use of the data we rely on overlapping five-year differences (e.g. 2013-2008, 2012-2007 etc.) but given that we cluster at the country-industry pair level this is innocuous (Bloom et al., 2015). Finally, country-industry-year cells that contain less than 10 firms are excluded in order to reduce the influence of highly idiosyncratic firm-level developments on the evolution of the productivity gap.

67. Second, we estimate a dynamic ordinary least squares (see Stock and Watson, 1993; DOLS) equation in [3], which relates the level of the MFP gap to the (log) level of PMR and lags and leads changes (i.e. first differences) of the explanatory variables (ΔX) – the latter are included to control for serial correlation and endogeneity.[28]

$$MFPgap_{s,c,t} = \beta_0 + \beta_1 PMR_{s,c,t} + \beta_2 \Delta E_{s,c,t} + \sum_{t+k,t-k} \Delta X^{j}_{c,s,t} + \delta_{ct} + \delta_{st} + \delta_{cs} + \varepsilon_{s,c,t} \qquad [3]$$

68. We estimate the DOLS equation in [3] on the same sample of 10 market services sectors over the period 1998-2013. If these baseline estimates are robust, then one might also expect there to be a relationship between the MFP gap in manufacturing sectors and the extent of regulation in upstream service sectors in those instances where input-output connections are more intense. Accordingly, as an extension, we estimate a variant of equation [3] for 22 industries in the manufacturing sector over the period 1998-2013 using the OECD regulatory impact indicator, which captures the knock-on or indirect effect of product market regulations in upstream services sectors (Bourlès et al., 2013; Conway and Nicoletti, 2006) on the MFP gap in downstream manufacturing industries. This is done by crossing the upstream regulatory indicators with the intensity of use of intermediate inputs calculated from input-output matrices since the impact of upstream regulations on downstream productivity is an increasing function of the intensity of use of intermediate inputs from the regulated upstream industries.

26 For retail and professional services industries, where the indicators are updated only every 5 years (1998, 2003, 2008, 2013), additional information was used on the timing of reforms following the calculations of Gal and Hijzen (2016) and Duval et al (2016). Taking the log of PMR is a useful transformation to the extent that it allows for reforms to be evaluated in relative terms, in relation to the pre-reform policy stance. This is particularly relevant as in many industries the level of regulation – as expressed by the PMR indicator – is already at low levels, and there is limited scope for further reforms that lead to a similar reduction in absolute terms in the indicator than in the past.

27 The employment variable is based on information from the Orbis database, and is calculated as the average of log employment levels across firms.

28 DOLS estimates are presented based on both one and two lags and leads.

5.4 Empirical results

5.4.1 Market services

69. Table 2, Panel A shows the baseline estimates for the 5-year long difference specification (Equation 2) for the MFP gap based on MFPR and mark-up corrected MFP for the services sector. The odd numbered columns include separate country, industry and year fixed effects, while the even numbered columns include country-year fixed effects – which control for time varying country-specific shocks – and separate industry fixed effects. In each case, the change in the MFP gap is positively related to the change in PMR and the coefficient is statistically significant at the 1% level. Similarly, the DOLS estimates (Table 2, Panel B) – which provide an alternative estimate of the long-run relationship – suggest that higher PMR is associated with a larger MFP gap, with levels of statistical significance varying between 5 and 10%.

Table 2. MFP divergence and product market regulation in services

A: Estimation method – five-year long differences

	Y: Δ MFP gap		Y: Δ Mark-up corrected MFP gap	
	(1)	(2)	(3)	(4)
Δ Product Market Regulation$_{s,c,t}$	0.205*** (0.065)	0.231*** (0.083)	0.332*** (0.103)	0.311** (0.132)
Country fixed effects	YES	NO	YES	NO
Industry fixed effects	YES	YES	YES	YES
Year fixed effects	YES	NO	YES	NO
Country X year fixed effects	NO	YES	NO	YES
Observations	458	458	376	376
R-squared	0.201	0.323	0.327	0.463

B: Estimation method – dynamic OLS

	Y: MFP gap		Y: Mark-up corrected MFP gap	
	(1)	(2)	(3)	(4)
Product Market Regulation$_{s,c,t}$	0.181* (0.098)	0.292** (0.139)	0.281** (0.134)	0.395* (0.216)
Country X year fixed effects	YES	YES	YES	YES
Country X industry fixed effects	YES	YES	YES	YES
Industry X year fixed effects	YES	YES	YES	YES
Lag and lead length	1	2	1	2
Observations	564	429	471	358
R-squared	0.983	0.988	0.954	0.963

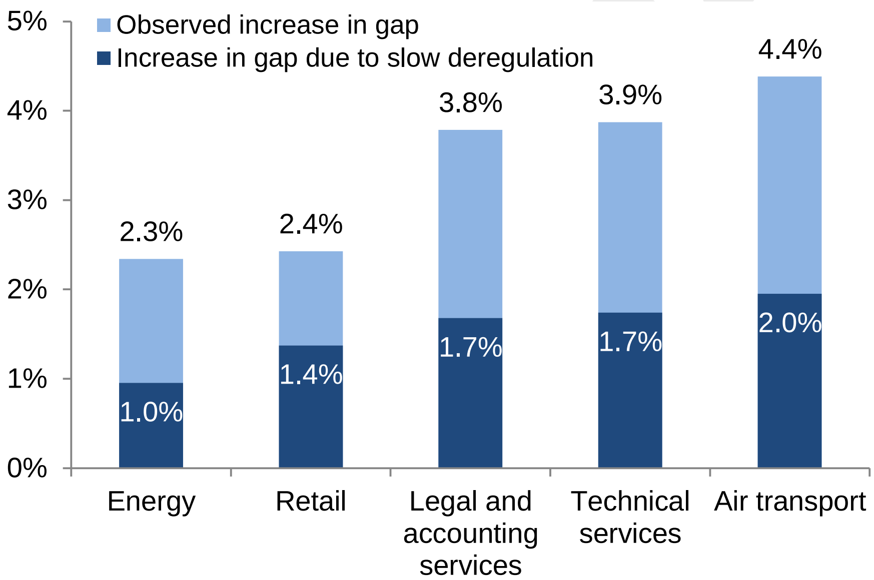
Notes: Cluster robust standard errors (at the industry-year level) in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Both the MFP gap and the PMR indicator are measured in log terms. The MFP gap is calculated at the country-industry-year level, by taking the difference between the global frontier and the average of log productivity of non-frontier firms. The time period is 1998-2013.

70. One possible interpretation is that the rising MFP gap between frontier and non-frontier firms in market services could be related to a slowdown in the pace of pro-competitive reforms in product markets. That is, while the MFP gap between the global frontier and laggard firms increased over the sample period due to technological factors, this pattern of MFP divergence was much less pronounced in services sectors where the pro-competitive product market reform was more intensive.

71. To illustrate the economic magnitude of the effects, Figure 10 performs a counterfactual simulation to estimate how much the MFP gap would have risen if market reforms in five key services sectors had proceeded at the same pace of that observed in telecommunications, where reform was most extensive. For example, the MFP gap increased at an annual average rate of 3.8% in legal and accounting services over the sample period, but 1.7% of this increase may have been avoided if market liberalisation in this sector accelerated more rapidly. On average, these estimates imply that up to [40]% of the increase in MFP divergence may have been avoided if countries had engaged in extensive market liberalisation in services.

Figure 10. MFP divergence and market reforms in services

Contribution to the annual change in the MFP gap of the slower pace of reform relative to the best practice industry



Notes: The figure shows the annual change in the MFPR gap between the frontier and laggard firms, and the part that is explained by slower deregulation than that observed in the fastest deregulating industry (telecom), based on the coefficient estimates in Column 2 of Table 2, Panel A. The estimates are averaged over countries and years and are measured in first-differences of log-points.

5.4.2 Extensions and robustness

72. The econometric results presented in this section are robust to using: *i*) an MFP gap that corrects for mark-ups (Table 2, columns 3-4); *ii*) alternative lengths of the long difference operator (Table C of Appendix C 2); *iii*) the median productivity of the laggard groupings to construct the MFP gap (Table C3); and *iv*) alternative lag and lead lengths in the DOLS estimator (Table 2, Panel B).

73. Finally, if these baseline estimates are robust, then one might also expect there to be a relationship between the MFP gap in manufacturing sectors and the extent of regulation in upstream service sectors in those instances where input-output connections are more intense. Accordingly, the

DOLS estimates in Table C4 of Appendix C imply that higher PMR in upstream sectors is associated with a larger MFP gap in manufacturing, and this effect is statistically significant at the 1% level. These results raise the prospect that aggregate impact of services regulation of the MFP gap is likely to be somewhat larger than the direct estimates reported in Figure 10.

6. Conclusion and future research

74. In this paper, we aim to reorient the debate on the global productivity slowdown – which has by and large been conducted from a macroeconomic perspective – towards a more micro-level. We provide new firm level evidence that highlights the importance of separately considering what happens to innovation at the frontier as well as the diffusion of technologies to laggards firms. This micro evidence is both key to a motivating new theoretical work and to identifying areas where there may be more traction for policy reforms to revive productivity growth in OECD countries.

75. The most striking feature of the productivity slowdown is not so much a slowing in the rate of innovation at the global frontier, but rather rising productivity at the global frontier coupled with an increasing productivity divergence between the global frontier and laggard firms. We show that this rising labour productivity gap between firms at the global frontier and laggard firms largely reflects divergence in revenue MFP (MFPR), as opposed to capital deepening. Moreover, after exploring the role of market power, we tentatively conclude that divergence in MFPR does not simply reflect the increasing ability of frontier firms to charge higher mark-ups. This leads us to suspect that the rising MFPR gap between global frontier and laggard firms may in fact reflect technological divergence. A number of smoking guns emerge which suggest that technological divergence could be a product of structural changes in the global economy – i.e. digitalisation, globalisation and the rising importance of tacit knowledge – which unleashed winner takes all dynamics and made technological adoption by laggard firms more difficult.

76. These structural changes imply that technological divergence was to some extent inevitable, but there was scope for public policy to lean against these headwinds. In this regard, MFP divergence was much more extreme in sectors where pro-competitive product market reforms were least extensive, suggesting that the observed rise in MFP divergence is at least partly due to policy weakness stifling diffusion in OECD economies. A simple counterfactual exercise suggests that had the pace of product market reforms in retail trade and professional services been equivalent to that observed in the best practice service sector (i.e. telecommunications), then the extent of MFP divergence may have been up to 40% less than what was actually observed. Put differently, technological catch-up to the global productivity frontier became more difficult for the typical firm over the 2000s, but these difficulties were compounded by policy weakness. From this perspective, the opportunity cost of poorly designed product market regulations may have risen over time.

77. This research raises a number of issues for future research. First, it would be interesting to explore the impact of the crisis and macroeconomic policies on global frontier and laggard firms, via the channels identified in Anzoategui et al (2016) and Gopinath et al (2015). Second, a logical next step is to connect these findings with other cross-country productivity-related research at the OECD, which reveals declining business dynamism (Criscuolo et al., 2014), rising resource misallocation (Berlingieri et al., 2016) and weakening market selection, particularly the rise of "zombie" firms (Adalet McGowan, Andrews and Millot, 2016). Third, policies that can contain MFP divergence may carry a double-dividend for inclusiveness to the extent that the observed rise in wage inequality is closely related to the rising dispersion in average wages paid across firms (Card et al., 2013; Song et al., 2016).

78. The results of this analysis also suggest scope for policy relevant research in other areas. For example, to the extent that technological adoption is complementary to investments in organisational capital (Bloom et al., 2012), it would be interesting to explore the link between managerial quality and technological divergence. The same is true for IPR regimes given their intuitive link with winner take all dynamics and opportunities for technological diffusion, although nuanced cross-country policy indicators of IPRs are currently lacking. Finally, given the increasing potential for entrenchment at the frontier, concerns about non-technological barriers to entry – such as lobbying activity by incumbents to prevent the proliferation of new business models and regulatory incumbency more generally– represent a fruitful area for future research.

REFERENCES

Ackerberg, D., Caves, K., and Frazer, G. (2015), "Identification properties of recent production function estimators", *Econometrica*, Forthcoming.

Aghion, Philippe, Richard Blundell, Rachel Griffith, Peter Howitt, and Susanne Prantl (2004), ''Entry and Productivity Growth: Evidence from Micro level Panel Data,'' Journal of the European Economic Association 2 (2004), 265–276.

Adalet McGowan, M., D. Andrews and V. Millot (2016), "The Walking Dead? Zombie Firms and Productivity Performance in OECD countries", OECD Economics Department Working Paper forthcoming.

Aghion, P. and P. Howitt. (1998), *Endogenous Growth Theory*, MIT Press

Andrews, D. and F. Cingano (2014), "Public Policy and Resource Allocation: Evidence from firms in OECD countries" *Economic Policy*, Issue 74 April.

Andrews, D. C. Criscuolo and P. Gal (2015), "Frontier firms, technology diffusion and public policy: micro evidence from OECD countries", OECD Productivity Working Papers No. 2.

Anzoategui, Diego, Diego Comin, Mark Gertler, and Joseba Martinez (2015), "Endogenous Technology Adoption and R&D as Sources of Business Cycle Persistence". NBER Working Paper No. 22005.

Bartelsman, E., J. Haltiwanger and S. Scarpetta (2013). "Cross-Country Differences in Productivity: The Role of Allocation and Selection," *American Economic Review*, 103(1): 305-34.

Baumol, W.J. (2002), The Free-Market Innovation Machine: Analyzing the Growth Miracle of Capitalism Princeton University Press.

Berlingieri, G, P. Blanchaney and C. Criscuolo (2016), "The Great Divergence" OECD Science, Technology and Innovation Working Paper forthcoming.

Bertrand, M., E. Duflo and S. Mullainathan (2004), "How Much Should We Trust Differences in Differences Estimates", *Quarterly Journal of Economics*, Vol. 119(1), pp. 249-275.

Bourlès, R., et al. (2013), "Do Product Market Regulations in Upstream Sectors Curb Productivity Growth?: Panel Data Evidence for OECD Countries", Review of Economics and Statistics, 95(5), pp. 1750-1768.

Bloom, N. and J. Van Reenen (2007), "Measuring and Explaining Management Practices Across Firms and Countries", *Quarterly Journal of Economics*, 122 (4), pp. 1351-1408.

Bloom, N., M. Draca and J. Van Reenen (2015), "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity", *Review of Economic Studies*, 83(1), pages 87-117.

Bloom, N., R. Sadun and J. Van Reenen (2012a), "Americans Do IT Better: US Multinationals and the Productivity Miracle", *American Economic Review*, 102(1): 167–201.

Blundell, Richard, Rachel Griffith, and John Van Reenen (1999), ''Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms,'' *Review of Economic Studies* 66, pp. 529–554.

Bourlès, R., et al. (2013), “Do Product Market Regulations in Upstream Sectors Curb Productivity Growth?: Panel Data Evidence for OECD Countries”, *The Review of Economics and Statistics*, Vol. 95(5), pp. 1750-1768.

Brynjolfsson, E, and A. McAfee (2011), Race Against The Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy, Digital Frontier Press.

Byrne, D., J. Fernald and M. Reinsdorf (2016), “Does the United States have a productivity slowdown or a measurement problem?” Brookings Papers on Economic Activity Conference Draft, March 10-11, 2016

Card, D., J. Heining and P. Kline (2013), “Workplace Heterogeneity and the Rise of West German Wage Inequality”, *Quarterly Journal of Economics*, 128(3), pp. 967-1015.

Christiano, L.J., M.S. Eichenbaum and M. Trabandt (2015), “Understanding the Great Recession”, *American Economic Journal: Macroeconomics* 7(1): 110–167

Conway, P. and G. Nicoletti, 2006, "Product Market Regulation in the Non-Manufacturing Sectors of OECD Countries: Measurement and Highlights", OECD Economics Department Working Papers, No. 530, OECD Publishing, Paris.

Comin, D and M. Mestieri (2013), “If Technology Has Arrived Everywhere, Why Has Income Diverged?” NBER Working Paper Series, No. 19010.

Cowen, T. (2011), The Great Stagnation: How America Ate All the Low-Hanging Fruit of Modern History, Got Sick, and Will (Eventually) Feel Better.

Criscuolo, C, P. Gal, C. Menon (2014), “The Dynamics of Employment Growth: New Evidence from 17 Countries” OECD STI Policy Papers No. 14.

David, P. A. (1991), "Computer and Dynamo: The Modern Productivity Paradox in a Not-Too-Distant Mirror," in Technology and Productivity: The Challenge for Economic Policy, Organization for Economic Co-operation and Development, Paris, pp. 315-48.

Dunning, J.H. (1981), *International Production and the Multinational Enterprise* George, Allen, and Unwin, London.

Decker, R., J. Haltiwanger, R.S. Jarmin, and J. Miranda (2014), “The role of entrepreneurship in U.S. job creation and economic dynamism”, *Journal of Economic Perspectives* (28), pp. 3-24.

Decker, R., J. Haltiwanger, R.S. Jarmin, and J. Miranda (2016), “Where Has All the Skewness Gone? The Decline in High-Growth (Young) Firms in the U.S”, *European Economic Review* 86 (July): 4-23.

De Loecker, J. and J. v. Biesebroeck, 2016, “Effect of International Competition on Firm Productivity and Market Power”, NBER Working Paper No. 21994.

De Loecker, J. and F. Warzynski, 2012. “Markups and Firm-Level Export Status”, *American Economic Review* Vol. 102, No. 6, October 2012 (pp. 2437-71)

Duval, R., D. Furceri, J. Jalles, and H. Nguyen, 2016, “A New Narrative Database of Product and Labour Market Reforms in Advanced Economies.” IMF Working Paper, forthcoming.

Fernald, J. (2014), “Productivity and Potential Output Before, During, and After the Great Recession”, in: NBER Macroeconomics Annual 2014, Volume 29.

Forlani, E., R. Martin, G. Mion and M. Muûls (2016), “Unraveling Firms: Demand, Productivity and Markups Heterogeneity”, EP Discussion Paper No 1402.

Foster, F, J. Haltiwanger and C. Syverson (2008), “Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?,” *American Economic Review* 98(1), pages 394-42.

Gal, P. (2013), “Measuring Total Factor Productivity at the Firm Level using OECD-ORBIS”, OECD Economics Department Working Papers No. 1049, OECD, Paris.

Gal, P. and A. Hijzen (2016), “The short-term impact of product market reforms: A cross-country firm-level analysis”, OECD Economics Department Working Paper No. 1311.

Geroski, P (1995a), ‘‘What Do We Know about Entry?’’ *International Journal of Industrial Organization* 13, 421–440.

Geroski, P (1995b), *Market Structure, Corporate Performance and Innovative Activity* (Oxford: Oxford University Press).

Gopinath, G., S. Kalemli-Ozcan, L. Karabarbounis and C. Villegas-Sanchez (2015), “Capital Allocation and Productivity in South Europe”, NBER Working Paper No. 21453Forlani, E., R. Martin, G. Mion and M. Muuls. 2016 “Unraveling Firms: Demand, Productivity and Markups Heterogeneity” CEP Discussion Paper No 1402

Gordon, R. (2012), “Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds”, NBER Working Papers, No. 18315.

Griffith, Rachel, Stephen Redding, and Helen Simpson (2002), ‘‘Productivity Convergence and Foreign Ownership at the Establishment level,’’ CEPR discussion paper 3765 (2002).

Griffith, R., S. Redding and H. Simpson (2006), "Technological Catch-Up and the Role of Multinationals", Revised Version of CEPR Discussion Paper No. 3765.

Griliches, Z. (1957) “Hybrid Corn: An Exploration in the Economics of Technological Change” *Econometrica* vol. 25 (October).

Hall, R. E. 1986. “Market structure and macroeconomic fluctuations”, Brookings Papers on Economic Activity, 2:285–338.

Haskel, Jonathan, Sonia Pereira, and Matthew Slaughter (2007), ‘‘Does Inward Foreign Direct Investment Boost the Productivity of Domestic Firms?’’ *The Review of Economics and Statistics* 89:3, 482–496.

Henderson, R. (1993), “Underinvestment and Incompetence as Responses to Radical Innovation: Evidence from the Photolithographic Alignment Equipment Industry”, *RAND Journal of Economics* 24(2), pp. 248–270.

Hsieh, C-T. and P. Klenow (2009), "Misallocation and Manufacturing Productivity in China and India," *Quarterly Journal of Economics*, 124(4), pp. 1403-1448.

Inklaar, R and M.P. Timmer, 2014. "The Relative Price of Services," Review of Income and Wealth, International Association for Research in Income and Wealth, vol. 60(4), pages 727-746, December.

Jones, B. F. (2012), "The Burden of Knowledge and the 'Death of the Renaissance Man': Is Innovation Getting Harder?", *Review of Economic Studies*, Vol. 76, pp. 283-317.

Jovanovic, Boyan & Rousseau, Peter L., 2005. "General Purpose Technologies," Handbook of Economic Growth, in: Philippe Aghion & Steven Durlauf (ed.), *Handbook of Economic Growth*, edition 1, volume 1, chapter 18, pages 1181-1224 Elsevier.

Kalemli-Ozcan, S., B. Sorensen, C. Villegas-Sanchez, V. Volosovych and S. Yesiltas, 2015, "How to Construct Nationally Representative Firm Level data from the Orbis Global Database," NBER Working Papers 21558, National Bureau of Economic Research, Inc.

Koske, I., I. Wanner, R. Bitetti and O. Barbiero, 2015, "The 2013 update of the OECD's database on product market regulation: Policy insights for OECD and non-OECD countries", OECD Economics Department Working Papers, No. 1200, OECD Publishing.

Levinsohn, James and Amil Petrin (2003) "Estimating Production Functions Using Inputs to Control for Unobservables," *Review of Economic Studies*, Vol. 70, No. 2, pp. 317–341.

Melitz, M. (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity", *Econometrica*, Vol. 71, pp. 1695-1725.

Mokyr, J (2014), "The Next Age of Invention: Technology's future is brighter than pessimists allow", in Brian C. Anderson ed., City Journal, Manhattan Institute, Winter 2014, pp. 14-20.

Moulton, B.R. (1991), "An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables on Micro Units", *Review of Economics and Statistics*, Vol. 72, pp. 334-338.

Nickell, Stephen, ''Competition and Corporate Performance,'' *Journal of Political Economy* 104 (1996), 724–746.

Nickell, S., Daphne´ Nicolitsas, and Neil Dryden, ''What Makes Firms Perform Well?'' *European Economic Review* 41 (1997), 783–796.

OECD (2015), *The Future of Productivity*, OECD Publishing, Paris.

Perla, J., C. Tonetti and M. Waugh (2015), "Equilibrium Technology Diffusion, Trade and Growth", NBER Working Papers, No. 20881.

Petrin, A. and J. Levinsohn, 2012 "Measuring aggregate productivity growth using plant-level data" *The RAND Journal of Economics*, Volume 43, Issue 4, pages 705–725, Winter 2012

Song, J., D. J. Price, F. Guvenen, N. Bloom and T. von Wachter (2015), "Firming up Inequality", NBER Working Papers, No. 21199.

Stock, J., & Watson, M. (1993), "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems", *Econometrica*, 61(4), 783-820.

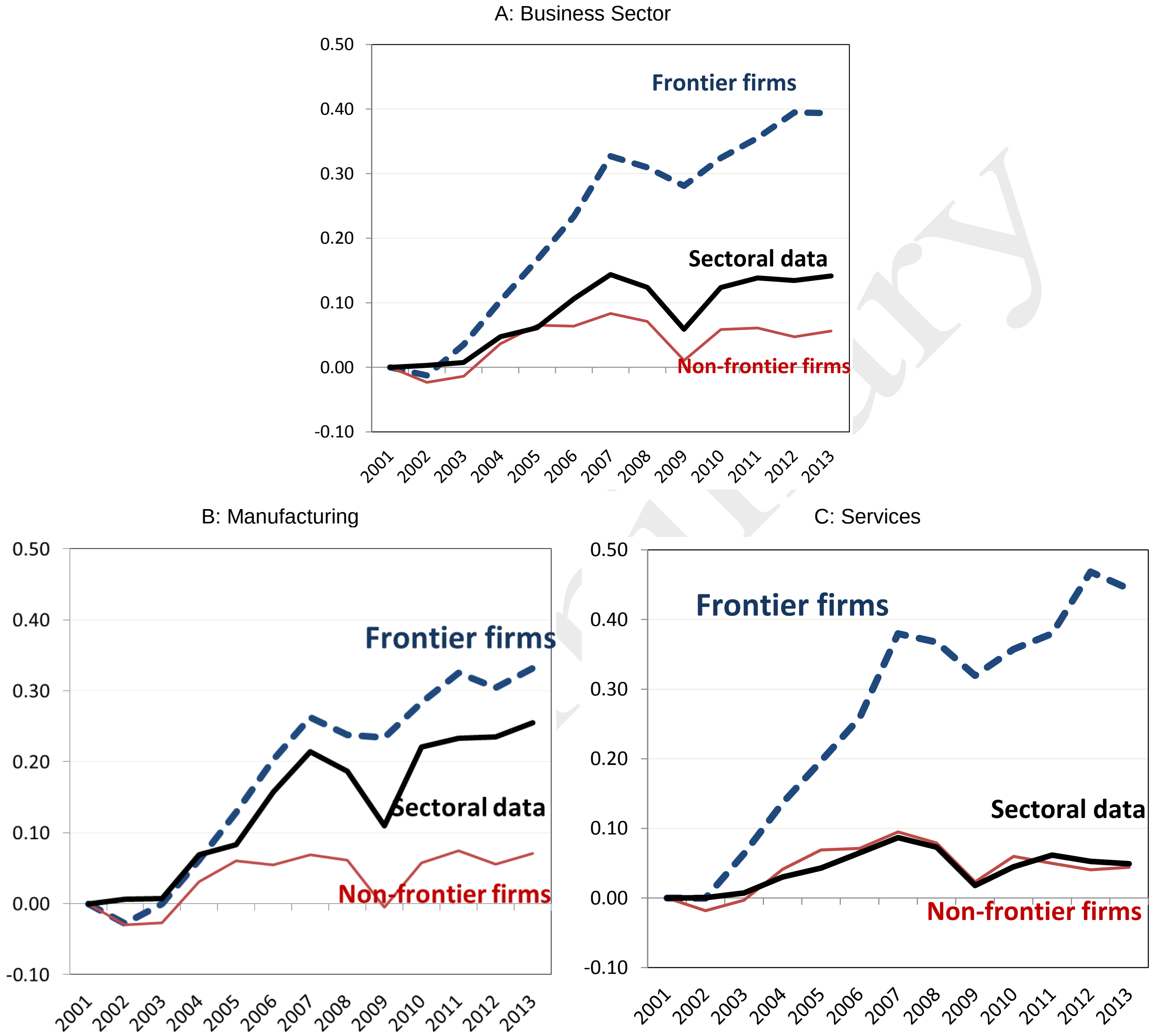
Summers, L (2016), "The Age of Secular Stagnation: What It Is and What to Do About It," Foreign Affairs March/April issue.

Syverson, C (2016), "Challenges to Mismeasurement Explanations for the U.S. Productivity Slowdown", NBER Working Paper No. 21974.

Wooldridge, J. M., 2009,"On estimating firm-level production functions using proxy variables to control for unobservables," *Economics Letters*, Vol. 104.

APPENDIX A: DIVERGENCE INDICATORS

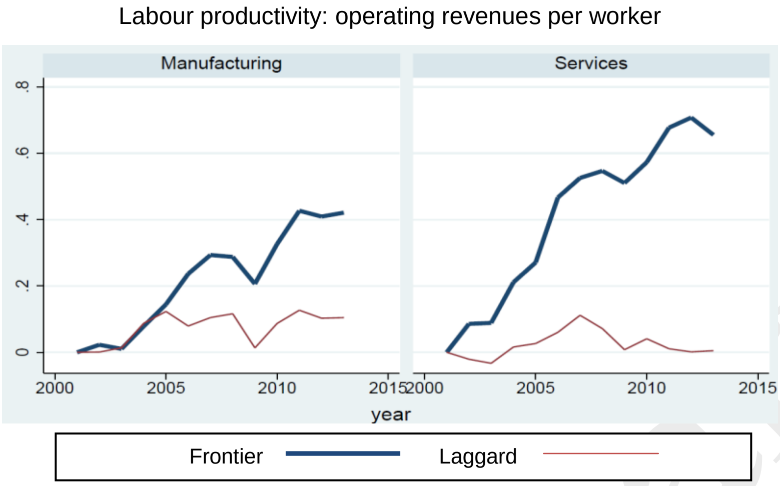
Figure A1. Divergence: firm-level patterns vs average industry level productivity



Notes: The global frontier is measured by the average of log labour productivity (value added over employees) for the top 5% of companies with the highest productivity levels within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. Services refer to non-financial, non-real estate business services (industry codes 45-82, excluding 64-68, in NACE Rev.2.). The business sector denotes manufacturing and services. The sectoral data refers to aggregate log labour productivity (value added over total employment), averaged across countries and industries at the 2-digit detail (unweighted), In cases the 2-digit details are not available, higher level industry groups are used. The industry level aggregates are employment weighted averages of all companies and self-employed businesses within the 2-digit industries, whereas the firm-level information is an unweighted average of companies with at least 20 employees. See details in Section 3.3.

Source: Authors' calculations based on the recent update of the OECD-Orbis firm-level productivity database (Gal, 2013) and detailed OECD National Accounts for the industry-level information.

Figure A2. Divergence: alternative labour productivity definition

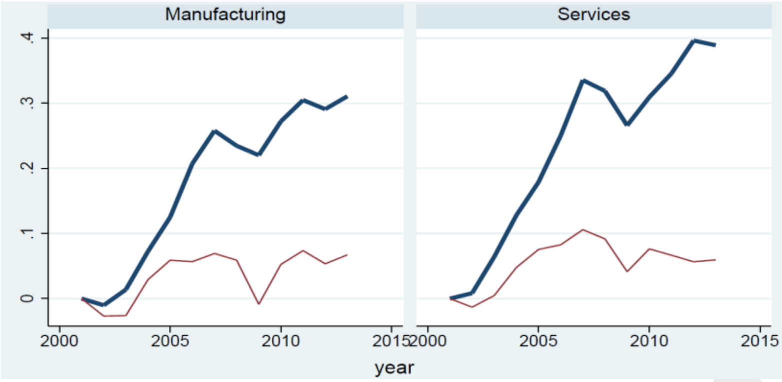


Notes: the global frontier is measured by the average of log labour productivity (measured as revenue per worker) for the top 5% of companies with the highest productivity levels within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. Services refer to non-financial business services. Time period is 2001-2013. See details in Section 3.3.

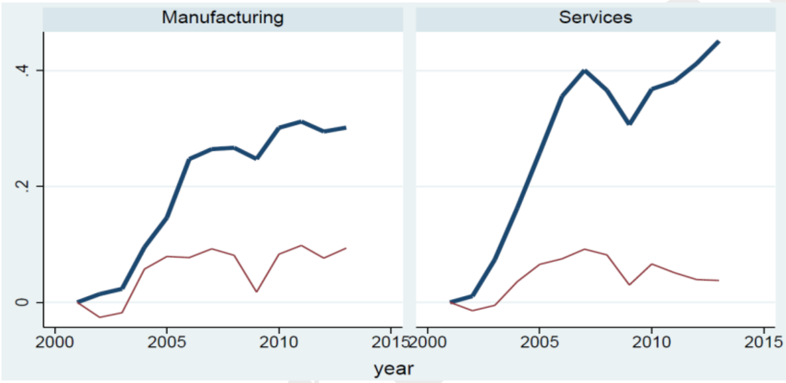
Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

Figure A3. Divergence: alternative frontier definitions

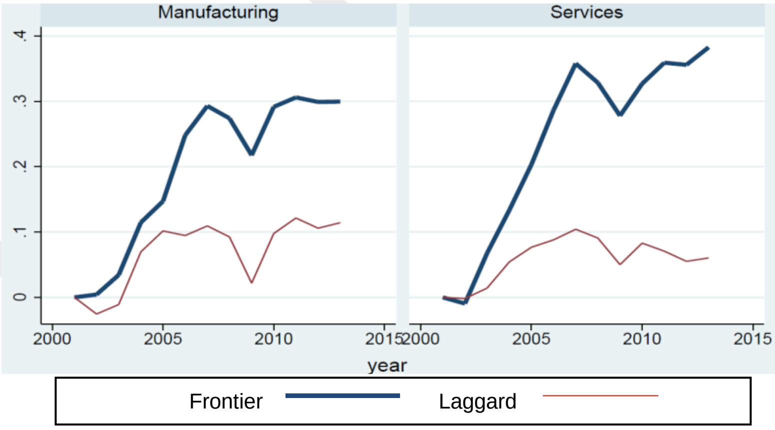
A: Frontier – 10% most productive firms within each sector



B: Frontier – 50 most productive firms within each sector



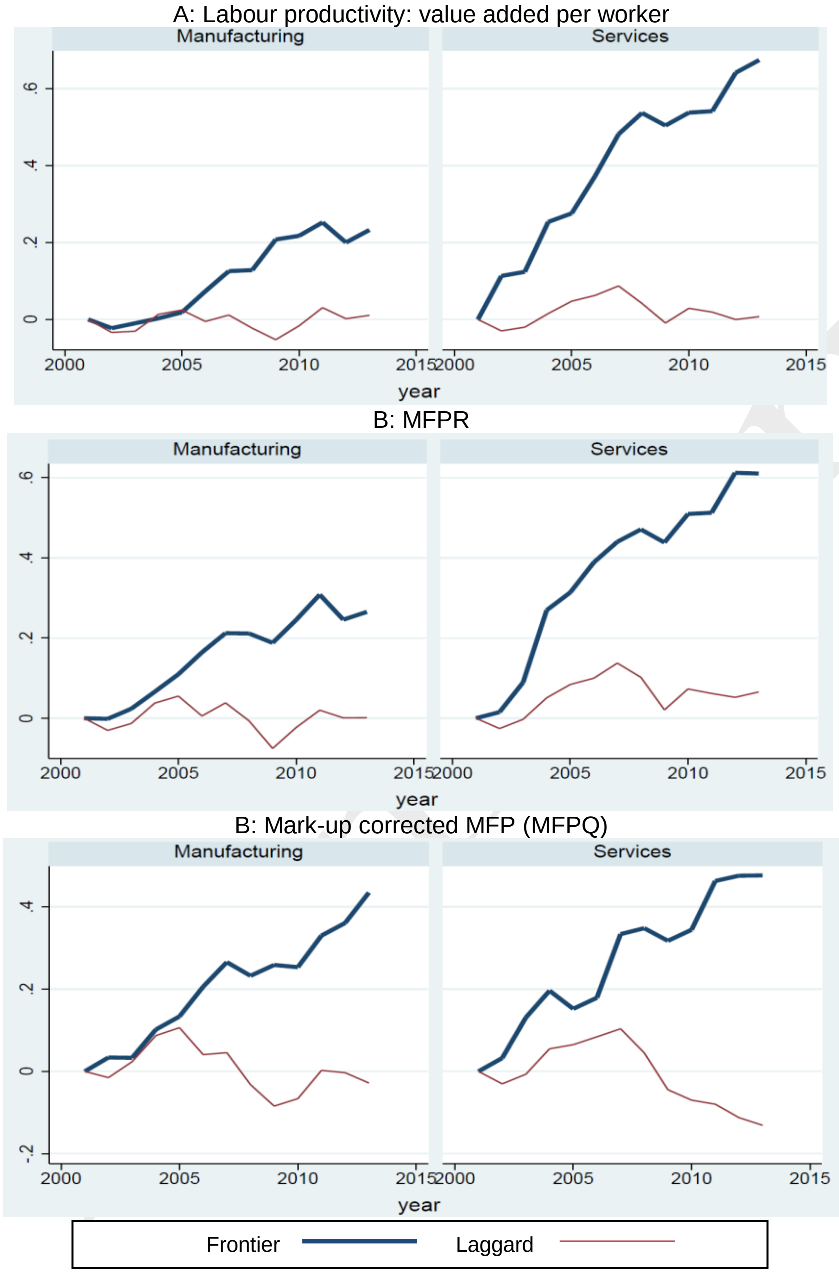
C: Frontier – 100 most productive firms within each sector



Notes: the global frontier is measured by the average of log labour productivity (value added per worker) for the top 10% of, top 50 and top 100 companies with the highest productivity levels within each 2-digit industry, in Panel A, B and C, respectively. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. Services refer to non-financial business services. Time period is 2001-2013. See details in Section 3.3.

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

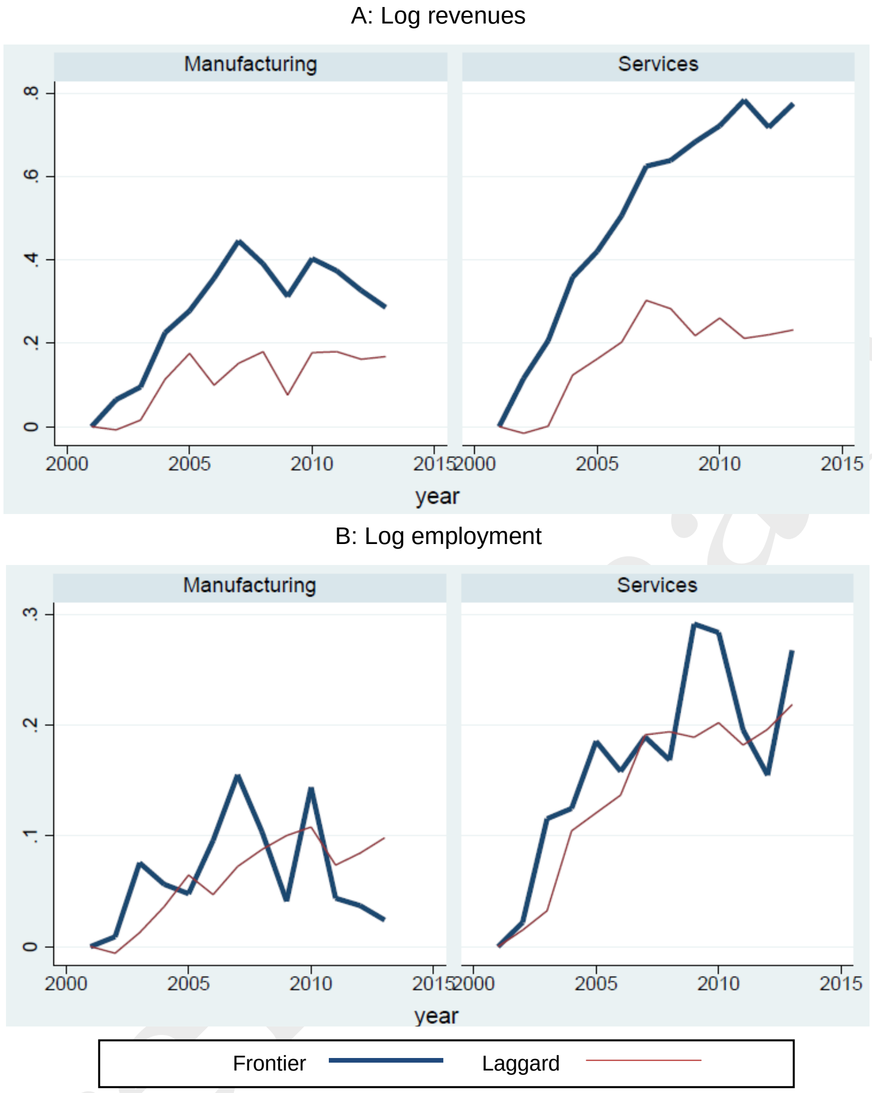
Figure A4. Divergence: excluding firms part of a MNE group



Notes: the global frontier is measured by the average of log labour productivity / MFPR / MFPQ for the top 5% of companies with the highest productivity levels within each 2-digit industry, respectively in Panel A, B and C. Laggards capture the average log productivity of all the other firms. MFPR uses the Wooldridge (2009) methodology based production function estimation, while the mark-up estimation used for MFPQ uses the De Loecker and Warzynski (2009) methodology. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. Services refer to non-financial business services. These figures retain only the consolidated accounts of the ultimate owners (headquarters) of groups or standalone firms that are not part of any group. Firms with an unknown status are omitted, leading to a substantial reduction in sample size. The available ownership link structure in Orbis may not be complete, especially for earlier years. Time period is 2001-2013. See details in Section 3.3.

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

Figure A5. Divergence: firm size indicators

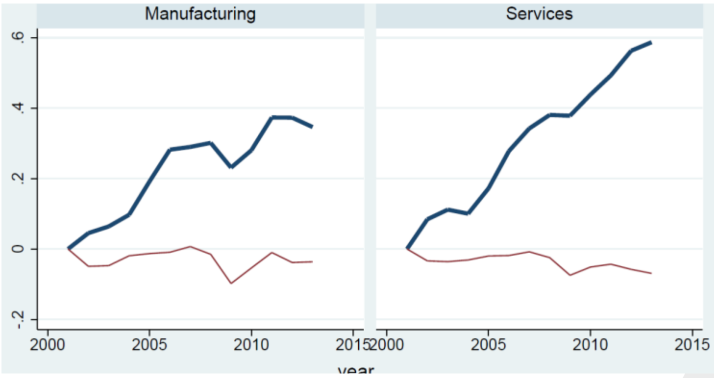


Notes: the global frontier group of firms is defined by the top 5% of companies with the highest productivity levels, measured by MFPQ (mark-up corrected MFP) within each 2-digit industry. Laggards capture the all the other firms. Unweighted averages across 2-digit industries are shown for log revenues and log employment, for Panels A and B, respectively, separately for manufacturing and services, normalized to 0 in the starting year. MFPR uses the Wooldridge (2009) methodology based production function estimation, while the mark-up estimation used for MFPQ uses the De Loecker and Warzynski (2009) methodology. Time period is 2001-2013. Services refer to non-financial business services. See details in Section 3.

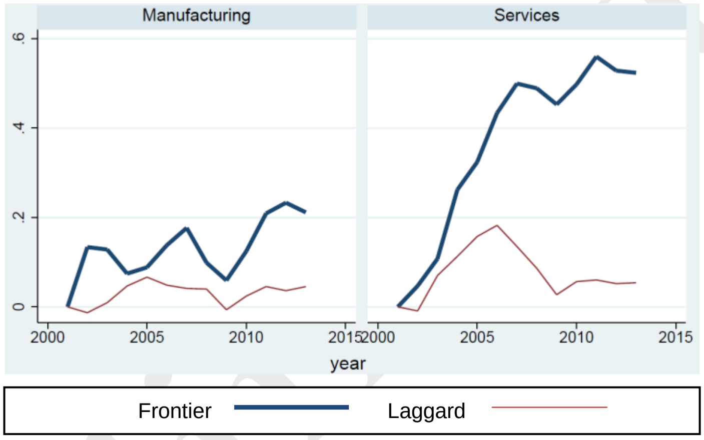
Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

Figure A6. Divergence: alternative MFPR definitions

A: MFP – Solow



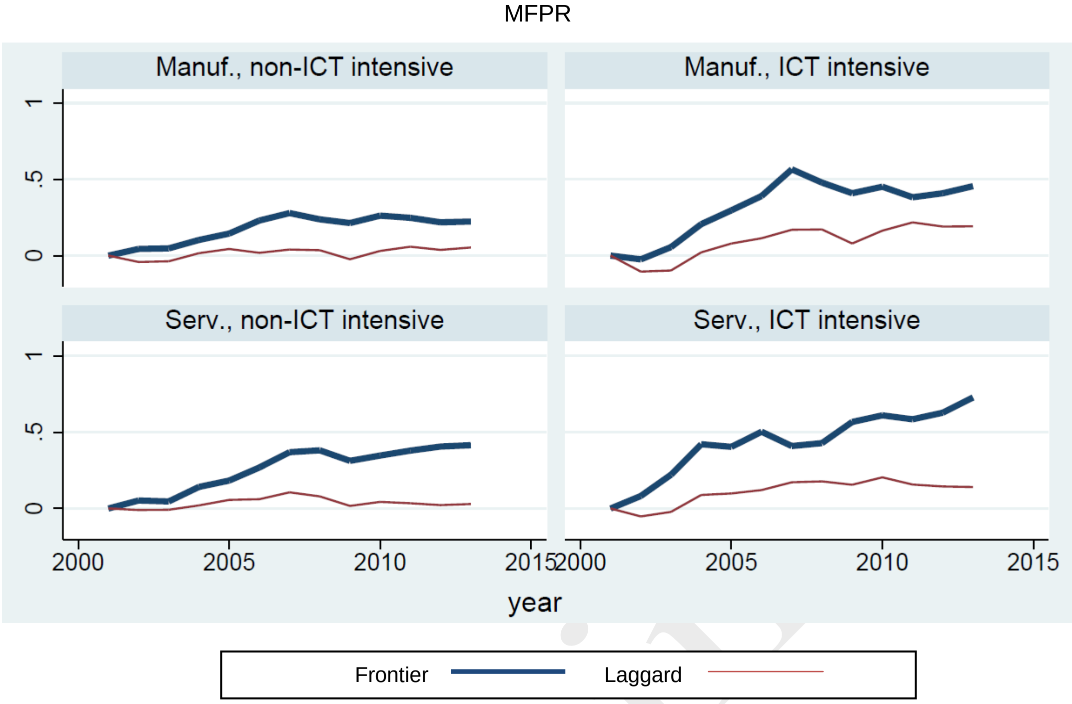
B: MFPR – Wooldridge gross-output



Notes: the global frontier is measured by the average of the log of an index-number based Solow residual MFP measure (using OECD National Accounts wage shares and assuming constant returns to scale) and a residual from a gross-output based Wooldridge (2009) production function estimation for the top 5% of companies with the highest MFP levels within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. Services refer to non-financial business services. Time period is 2001-2013. See details in Section 3.

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

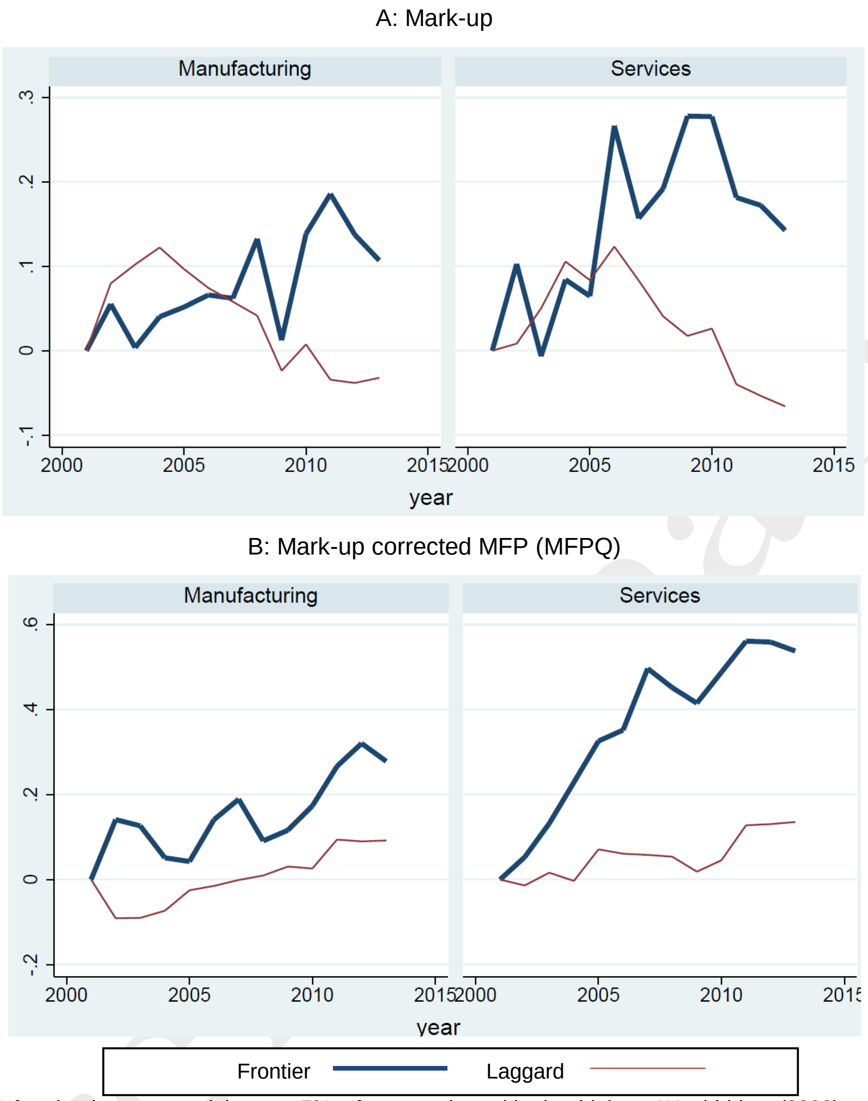
Figure A7. Divergence: by ICT intensity



Notes: the global frontier is measured by the average of productivity for the top 5% of companies with the highest Wooldridge (2009) production function estimation based productivity levels (MFPR) within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. Services refer to non-financial business services. ICT intensive services are information and communication services (industry code J in NACE Rev. 2) and postal and courier activities (industry code 53), while ICT intensive manufacturing refers to machinery and equipment, motor and other transport vehicles (28-30). Time period is 2001-2013. See details in Sections 3 and 4.4

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

Figure A8. Divergence: mark-up corrected MFP using materials as flexible inputs



Notes: the global frontier is measured by top 5% of companies with the highest Wooldridge (2009) production function estimation based productivity levels (MFPR) within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Panel A shows the average level of (log) mark-ups and Panel B the average level of MFPQ (mark-up corrected MFP) for these two groups. The mark-up estimation uses the De Loecker and Warzynski (2009) methodology. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. Services refer to non-financial business services. Time period is 2001-2013. See details in Sections 3

Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

APPENDIX B: MFP CONVERGENCE AT THE FIRM LEVEL

79. The Appendix presents firm level evidence on the extent to which the pace of productivity convergence to the global productivity frontier has changed over time. The empirical specification is based on the estimation of the Aghion and Howitt (1998) neo-Schumpeterian growth framework, which has been implemented in a number of studies (e.g. Griffith et al., 2006). Multi-factor factor productivity (A) is assumed to follow an error correction model of the form:

$$\Delta \ln A_{icst} = \delta_1 \Delta \ln A_{Fcst} + \delta_2 gap_{icst-1} + \sum_j \delta_3^j gap_{icst-1} * D_t^j + \sum_j \delta_4^j X_{isct}^j + \delta_s + \delta_{ct} + \varepsilon_{icst} \qquad [1]$$

80. Productivity growth of firm *i* is expected to increase with productivity growth of the frontier firm *F* and the size of the gap – as proxied by $\ln(A_{Fst-1}/A_{icst-1})$ – which measures how far each firm is away from the frontier F. We allow for the speed of productivity convergence to vary overtime by including various $gap*D^j$ interaction terms, where D is dummy variable corresponding to different time periods (i.e. 1997-2000, 2000-2002 … 2010-2014). If the pace of MFP convergence has slowed over time, then we expect that some of the $gap*D^j$ terms to be negative and significant. As above, the frontier firm is defined as the average MFP of the 5% most productive firms in sector *s* and year *t* in the sample of countries analysed (the frontier firms are excluded from the analysis). The specification also includes a number of controls in X – such as firm size and firm age classes, included separately in the baseline and interacted with the frontier growth and gap terms as an extension – as well as both industry and country*time fixed effects. The standard errors are clustered by country and sector to allow for correlation of the error term in an unrestricted way across firms and time within sectors in the same country (Moulton, 1991; Bertrand et al., 2004).

81. The results suggest that on average across time, firms further behind the technological frontier have higher MFP growth, reflecting their ability to catch-up based on the adoption of a larger stock of unexploited technologies. However, there is also evidence that the pace of technological convergence via this mechanism has declined significantly over time. For example, while the base effect for the gap term – which provides the effect for 1998-2000 – is positive, the interactions with subsequent time periods are often negative. For example, Column 1 of Panel A shows that the estimated coefficient on the lagged MFPR gap term declined by almost 30% from the late 1990s to the most recent period, with most of this decline realised by 2007 (Panel A). Moreover, this slowdown in the pace of productivity convergence is even more pronounced when the model is estimated using mark-up corrected MFP (column 2).

82. These patterns are broadly robust to: *i*) different measures of MFP (Columns 3); *ii*) including firm age/size interactions with the frontier growth and gap terms (Panel B); and *iii*) including industry*year fixed effects, which absorbs the frontier growth term (Panel C).

Table B1. The pace of productivity convergence has slowed over time

Dependent variable: indicators of MFP growth at the firm level; 1998-2014

Panel A: Baseline

	MFPR (Wooldridge)	MFPQ	MFPR (Solow residual)
	(1)	(2)	(3)
$Gap_{j,t-1}$			
Base effect	0.147***	0.191***	0.111***
	(0.004)	(0.009)	(0.009)
2000-2002	0.006	-0.013	0.004
	(0.007)	(0.013)	(0.011)
2002-2005	-0.016***	-0.056***	-0.016
	(0.006)	(0.010)	(0.010)
2005-2007	-0.037***	-0.070***	-0.031***
	(0.006)	(0.010)	(0.010)
2007-2010	-0.023***	-0.076***	-0.029***
	(0.007)	(0.011)	(0.010)
2010-2014	-0.041***	-0.087***	-0.040***
	(0.005)	(0.009)	(0.009)
Frontier $growth_{j,t-1}$			
Base effect	0.203***	0.233***	0.193***
	(0.049)	(0.059)	(0.045)
2000-2002	-0.077	-0.146**	-0.077
	(0.057)	(0.067)	(0.055)
2002-2005	-0.050	-0.104	-0.065
	(0.058)	(0.067)	(0.050)
2005-2007	-0.059	-0.105	-0.139***
	(0.057)	(0.065)	(0.051)
2007-2010	0.073	-0.138*	0.025
	(0.067)	(0.083)	(0.055)
2010-2014	-0.095*	-0.188***	-0.122**
	(0.054)	(0.064)	(0.049)
R-squared	0.085	0.091	0.068
Country X year FE	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
Firm size and age	Yes	Yes	Yes
Obs. / countries	898737 / 21	516062 / 17	898120 / 21

Panel B: Age/Size Interactions

	MFPR (Wooldridge)	MFPQ	MFPR (Solow residual)
	(1)	(2)	(3)
$Gap_{j,t-1}$			
Base effect	0.216***	0.240***	0.176***
	(0.007)	(0.013)	(0.010)
2000-2002	0.006	-0.012	0.004
	(0.007)	(0.013)	(0.011)
2002-2005	-0.016***	-0.052***	-0.016*
	(0.006)	(0.010)	(0.010)
2005-2007	-0.036***	-0.061***	-0.029***
	(0.006)	(0.010)	(0.010)
2007-2010	-0.021***	-0.070***	-0.027***
	(0.007)	(0.011)	(0.010)
2010-2014	-0.038***	-0.081***	-0.037***
	(0.005)	(0.009)	(0.009)
Frontier $growth_{j,t-1}$			
Base effect	0.184***	0.245***	0.151***
	(0.057)	(0.080)	(0.052)
2000-2002	-0.076	-0.135**	-0.076
	(0.056)	(0.067)	(0.055)
2002-2005	-0.048	-0.090	-0.071
	(0.058)	(0.067)	(0.051)
2005-2007	-0.055	-0.087	-0.142***
	(0.056)	(0.065)	(0.051)
2007-2010	0.074	-0.124	0.022
	(0.066)	(0.081)	(0.056)
2010-2014	-0.095*	-0.176***	-0.126**
	(0.053)	(0.064)	(0.049)
R-squared	0.087	0.094	0.070
Country X year FEs	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
Firm size and age controls	Yes	Yes	Yes
$Gap_{j,t-1}$ X Sizeclass FEs, Frontier $growth_{j,t-1}$ X Sizeclass FEs	Yes	Yes	Yes
$Gap_{j,t-1}$ X Ageclass FEs, Frontier $growth_{j,t-1}$ X Ageclass FEs	Yes	Yes	Yes
Obs. / countries	898737 / 21	516062 / 17	898120 / 21

Panel C: Industry*Year Fixed Effects

	MFPR (Wooldridge)	MFPQ	MFPR (Solow residual)
	(1)	(2)	(3)
$Gap_{j,t-1}$			
Base effect	0.158***	0.196***	0.115***
	(0.005)	(0.010)	(0.012)
2000-2002	0.008	-0.012	-0.002
	(0.008)	(0.014)	(0.019)
2002-2005	-0.025***	-0.063***	-0.018
	(0.007)	(0.011)	(0.014)
2005-2007	-0.044***	-0.076***	-0.028*
	(0.007)	(0.012)	(0.015)
2007-2010	-0.030***	-0.079***	-0.029**
	(0.007)	(0.011)	(0.014)
2010-2014	-0.053***	-0.093***	-0.050***
	(0.006)	(0.010)	(0.012)
R-squared	0.096	0.099	0.077
Country X year FEs	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes
Firm size and age controls	Yes	Yes	Yes
Obs. / countries	898737 / 21	516062 / 17	898120 / 21

Note: Cluster robust standard errors (at the industry-year level) in parentheses. Firm size and age captured by a rich set of fixed effects, corresponding to the following categories in employment: below 50, 50-99, 100-250, 25-999, 1000 and above; and in age: 0-2, 3-4, 5-9, 10-29, 30 and older. The sample is restricted to firms that have at least 20 employees on average over time. *** p<0.01, ** p<0.05, * p<0.1

APPENDIX C: POLICY ANALYSIS – DESCRIPTIVES AND ROBUSTNESS

Table C1. Descriptive statistics by broad sectors

	Regulated services*			Manufacturing		
	PMR	Gap in MFP	Gap in markup corr. MFP	Regulatory Impact	Gap in MFP	Gap in markup corr. MFP
Mean	0.607	1.294	1.272	-3.658	1.152	1.217
Median	0.811	1.163	1.127	-3.571	1.040	1.031
St.dev.	0.673	0.470	0.523	0.551	0.464	0.570
N	564	564	471	2042	2042	1703

Note: All variables are measured in logs. *Regulated services include those industries that are covered by the PMR indicator. :

Table C2. MFP divergence and PMR in services: robustness to long difference window

A: Estimation method – four-year long differences

	Y: Δ MFP gap		Y: Δ Mark-up corrected MFP gap	
	(1)	(2)	(3)	(4)
Δ Product Market Regulation$_{s,c,t}$	0.166*** (0.057)	0.190*** (0.064)	0.277** (0.112)	0.292** (0.142)
Country fixed effects	YES	NO	YES	NO
Industry fixed effects	YES	YES	YES	YES
Year fixed effects	YES	NO	YES	NO
Country X year fixed effects	NO	YES	NO	YES
Observations	512	512	421	421
R-squared	0.158	0.287	0.228	0.397

B: Estimation method – six-year long differences

	Y: Δ MFP gap		Y: Δ Mark-up corrected MFP gap	
	(1)	(2)	(3)	(4)
Δ Product Market Regulation$_{s,c,t}$	0.267*** (0.070)	0.277*** (0.096)	0.452*** (0.128)	0.452*** (0.149)
Country fixed effects	YES	NO	YES	NO
Industry fixed effects	YES	YES	YES	YES
Year fixed effects	YES	NO	YES	NO
Country X year fixed effects	NO	YES	NO	YES
Observations	400	400	329	329
R-squared	0.297	0.413	0.413	0.550

Notes: Cluster robust standard errors (at the industry-year level) in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Both the MFP gap and the PMR indicator are measured in log terms. The MFP gap is calculated at the country-industry-year level, by taking the difference between the average log productivity at the frontier and among other firms. The time period is 1998-2013.

Table C3. MFP divergence and PMR in services: robustness to median MFP of laggard firms

A: Estimation method – five-year long differences

	Y: Δ MFP gap		Y: Δ Mark-up corrected MFP gap	
	(1)	(2)	(3)	(4)
Δ Product Market Regulation$_{s,c,t}$	0.190** (0.076)	0.234** (0.089)	0.275*** (0.093)	0.262** (0.114)
Country fixed effects	YES	NO	YES	NO
Industry fixed effects	YES	YES	YES	YES
Year fixed effects	YES	NO	YES	NO
Country X year fixed effects	NO	YES	NO	YES
Observations	458	458	376	376
R-squared	0.199	0.316	0.330	0.459

B: Estimation method – dynamic OLS

	Y: MFP gap		Y: Mark-up corrected MFP gap	
	(1)	(2)	(3)	(4)
Product Market Regulation$_{s,c,t}$	0.198** (0.099)	0.328** (0.145)	0.300** (0.125)	0.343* (0.205)
Country X year fixed effects	YES	YES	YES	YES
Country X industry fixed effects	YES	YES	YES	YES
Industry X year fixed effects	YES	YES	YES	YES
Lag and lead length	1	2	1	2
Observations	564	429	471	358
R-squared	0.979	0.986	0.957	0.965

Notes: Cluster robust standard errors (at the industry-year level) in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Both the MFP gap and the PMR indicator are measured in log terms. The MFP gap is calculated at the country-industry-year level, by taking the difference between the global frontier and the median of log productivity of non-frontier firms. The time period is 1998-2013.

Table C4. MFP divergence in manufacturing and upstream product market regulation

A: Estimation method – dynamic OLS; average MFP of laggards

	Y: MFP gap		Y: Mark-up corrected MFP gap	
	(1)	(2)	(3)	(4)
Regulatory Impact$_{s,c,t}$	0.741***	0.862***	1.664***	1.980***
	(0.204)	(0.268)	(0.588)	(0.656)
Country X year fixed effects	YES	YES	YES	YES
Country X industry fixed effects	YES	YES	YES	YES
Industry X year fixed effects	YES	YES	YES	YES
Lag and lead length	1	2	1	2
Observations	2,042	1,618	1,703	1,341
R-squared	0.978	0.982	0.971	0.977

Notes: Cluster robust standard errors (at the industry-year level) in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Both the MFP gap and the PMR indicator are measured in log terms. The MFP gap is calculated at the country-industry-year level, by taking the difference between the global frontier and the average of log productivity of non-frontier firms. The time period is 1998-2013.

B: Estimation method – dynamic OLS; median MFP of laggards

	Y: MFP gap		Y: Mark-up corrected MFP gap	
	(1)	(2)	(3)	(4)
Regulatory Impact$_{s,c,t}$	0.968***	1.138***	1.667***	1.776***
	(0.224)	(0.302)	(0.611)	(0.679)
Country X year fixed effects	YES	YES	YES	YES
Country X industry fixed effects	YES	YES	YES	YES
Industry X year fixed effects	YES	YES	YES	YES
Lag and lead length	1	2	1	2
Observations	2,042	1,618	1,703	1,341
R-squared	0.975	0.978	0.966	0.972

Notes: Cluster robust standard errors (at the industry-year level) in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Both the MFP gap and the PMR indicator are measured in log terms. The MFP gap is calculated at the country-industry-year level, by taking the difference between the global frontier and the median of log productivity of non-frontier firms. The time period is 1998-2013.

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