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

Dan Andrews, Economics Department, OECD
Chiara Criscuolo, Directorate for Science, Technology, and Innovation, OECD
Peter N. Gal, Economics Department, OECD

SUMMARY

Since the late 1990s, labor productivity (total output per hour worked) growth has slowed markedly for many of the world's largest economies. Using a micro-level dataset of firms in OECD member countries, OECD researchers Dan Andrews, Chiara Criscuolo, and Peter Gal decompose the slowdown and show that the top ("frontier") firms have continued seeing productivity increases while the others (the "laggards") haven't, contributing to a growing productivity divergence between the top and the bottom.

According to their analysis, frontier firms in manufacturing experienced productivity increases of 2.8 percent per year on average between 2001 and 2013, whereas the others saw gains of only 0.6 percent per year. In the services sector, the gap was even larger: frontier firms' productivity increased at 3.6 percent per year, but for non-frontier firms that number was only 0.4 percent. The paper shows how these gains accrued from 2001 to 2013: the scale roughly corresponds to total percent increase (where 0.2 equals 20 percent).

The authors find that the productivity growth of the frontier firms, which are now three to four times more productive than non-frontier firms, is not the result of increased capital investment, and due only partly to increased monopolistic pricing power. Rather, it appears to be driven by growth in multi-factor productivity (MFP), or how efficiently firms can combine capital and labor into products.

As for what's causing the different MFP growth rates, they find some support for two theories. First, "winner takes all" dynamics appear to be at play. In industries with particularly scalable technologies like computer programming and telecommunications, the market share of the frontier firms has gone up, the divergence is "more pronounced," and there has been greater divergence between the top and bottom frontier firms. This could be good news if booming frontier firms raise industry averages, but in practice those industries where the frontier/non-frontier gaps have been the widest have seen lower growth rates overall, indicating that laggard growth has been very weak.

Second, they argue there has been a slowdown in technological diffusion. They see public policy as partly to blame because the productivity growth gap between frontier firms and laggards is greatest in industries in which regulation restricts competition. In fact, their estimates suggest "that up to 50% of the increase in MFP divergence may have been avoided if countries had engaged in extensive market liberalisation in services."

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1. INTRODUCTION AND MAIN FINDINGS

Aggregate productivity growth slowed in many OECD countries, even before the crisis, igniting a spirited debate on the future of productivity (e.g. Gordon, 2012 vs Brynjolfsson and McAfee, 2011).[1] This paper marshals new 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 this debate often concerns innovation prospects at the global productivity frontier, little is actually known about the productivity growth performance of global frontier firms over time both in absolute terms and relative to laggard (i.e. non-frontier) firms.[2] Even less is known about the policies that might help laggard firms close their productivity growth gap with the frontier. Yet, cross-country differences in aggregate-level productivity are increasingly being linked to the widespread heterogeneity in firm performance within sectors (Bartelsman, Haltiwanger and Scarpetta, 2013; Hsieh and Klenow, 2009).

To fill this gap, 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 24 countries, we 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 sector in each year across all countries since the early 2000s. Our analysis suggests that a striking feature of the productivity slowdown is not so much a slowing in productivity growth at the global frontier, but rather rising productivity at the global frontier coupled with an increasing productivity gap 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.

We show that this rising labour productivity gap between global frontier and laggard firms largely reflects divergence in revenue based MFP (MFPR), as opposed to capital deepening. Moreover, we explore the role of market power and conclude that divergence in MFPR does not simply reflect the increasing ability of frontier firms to charge higher mark-ups. While there is evidence that market power of frontier firms has increased in services, this amounts to less than one-third of the total divergence in MFPR. This leads us to the conclusion that the rising MFPR gap between global frontier and laggard firms may in fact reflect divergence in productivity or technology, broadly defined. Importantly, this is likely to relate not only to the diverging capacity of firms to technologically innovate but also to their success in tacitly combining various intangibles – e.g. computerised information; innovative property and economic competencies (see Corrado, Hulten and Sichel, 2009) – in production processes.

This pattern of MFP divergence might seem surprising for at least two reasons. First, neo-Schumpeterian growth theory (Aghion and Howitt, 2006; Acemoglu, Aghion and Zilibotti, 2006) and models of competitive diffusion (Jovanovic and MacDonald, 1994) imply productivity convergence: that is, firms further behind the global frontier should grow faster, given the larger stock of unexploited technologies and knowledge that they can readily implement. Second, the extent of productivity divergence that we observed in the data is difficult to reconcile with models of creative destruction and a world where the process of market selection is

1 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).

2 Throughout the paper we use the term "laggard" and "non-frontier" interchangeably – they refer to the group of firms that are not at the frontier.

productivity-enhancing (Aghion and Howitt, 1992; Caballero and Hammour, 1994; Campbell, 1998), raising questions about the competitiveness of markets. However, our results suggest that both the rate of convergence and growth-enhancing reallocation have slowed down during the last decade leading to the divergence evident in the data.

The paper then explores a set of structural factors underlying MFP divergence, links with aggregate productivity performance and public policy implications. Structural changes in the global economy – namely digitalisation, globalisation and the rising importance of tacit knowledge – could underpin MFP divergence through two interrelated channels introduced below. While it is difficult to pinpoint their relative importance, a number of smoking guns emerge to suggest that each may be important in explaining MFP divergence.

First, the increasing potential for digital technologies to unleash winner takes all dynamics in the global market (Brynjolfsson and McAfee, 2011) has enabled technological leaders to increase their performance gap with laggard firms. In support of this hypothesis, we find three distinct patterns in ICT-intensive services (e.g. computer programming, telecommunications and information service activities) – where winner take all patterns should be more relevant – that are less evident elsewhere: i) global frontier firms have increased their market share; ii) MFP divergence is more pronounced; and iii) within the global frontier, the productivity of the most elite firms (top 2%) has risen relative to other frontier firms (top 5%).

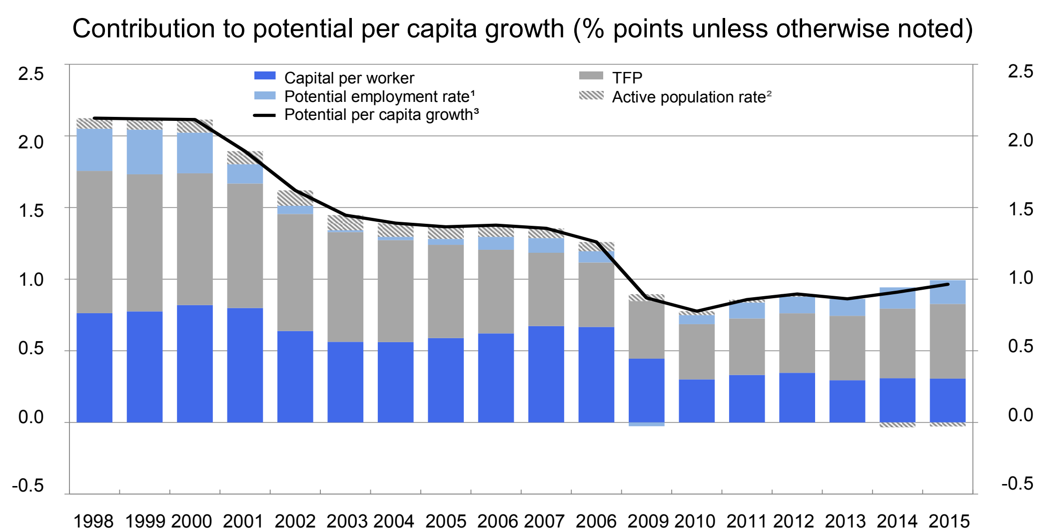
All else equal, these patterns are not necessarily a policy concern and could imply higher aggregate productivity growth via stronger innovation intensity and more efficient resource allocation. Yet, we find the opposite: aggregate MFP performance was significantly weaker in industries where MFP divergence was more pronounced. This suggests that the obstacles to the productivity growth of laggards increased, weighing on aggregate productivity growth. This leads us to explore a second source of MFP divergence and the aggregate productivity slowdown: stalling technological diffusion. One possible explanation is that the growing importance of tacit knowledge and complexity of technologies has increased the sophistication of complementary investments required for the successful adoption of new technologies, thereby creating barriers to the catch-up of laggard firms. At the same time, the concomitant decline in market dynamism and rising market power of frontier firms suggests that the stagnation in the MFP growth of laggard firms may be connected to rising barriers to entry and a decline in the contestability or competitiveness of markets.

This latter raises the prospect that while rising MFP divergence was somewhat inevitable due to structural changes in the global economy, there was scope for public policy to lean against these headwinds and to better align the regulatory environment with structural changes in the global economy. In fact, we find MFP divergence to be much more extreme in sectors where pro-competitive product market reforms or deregulation were least extensive. Given the link between product market competition and incentives for technological adoption (see Aghion and Howitt, 2006 and references therein), part of the observed rise in MFP divergence may be traced to policy failure to encourage the diffusion of best production practices 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 experienced by telecommunications – where reforms were most extensive – then the average increase in the MFP gap may have been up to 50% lower than what was actually observed. As most of the outputs produced by these heavily regulated sectors are used as inputs in production elsewhere in the economy (see Bourlès, Cette, Lopez, Mairesse and Nicoletti, 2013), this may in fact provide a lower bound of the total impact of excessively stringent service regulation on MFP divergence.

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 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 and then explores the relative roles of capital, MFP, market power, winner takes all dynamics and technology diffusion. In Section 5, we explore aggregate implications and the link between product market reforms and the MFP gap, with a particular focus on 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

Figure 1: Weak labour productivity underpinned decline in potential output in OECD countries



Notes: Assuming potential output (*Y**) can be represented by a Cobb-Douglas production function in terms of potential employment (*N**), the capital stock (*K*) and labour-augmenting technical progress (*E**) then $y^* = a * (n^* + e^*) + (1 - a) * k$, where lower case letters denote logs and *a* is the wage share. If *P* is the total population and *pwa* the population of working age (here taken to be aged 15-74), then the growth rate of potential GDP per capita (where growth rates are denoted by the first difference, d( ), of logged variables) can be decomposed into the four components depicted in the figure: $d(y^* - p) = a * d(e^*) + (1-a) * d(k - n^*) + d(n^* - pwa) + d(pwa - p)$.

1. Potential employment rate refers to potential employment as a share of the working-age population (aged 15-74).

2. Active population rate refers to the share of the population of working age in the total population.

3. Percentage changes.

Source: OECD Economic Outlook 99 database.

The productivity slowdown has sparked a lively debate on its underlying causes and the future of productivity more generally, and underpins the collapse in potential output growth – one metric of societies' ability to make good on promises to current and future generations (OECD, 2016). Indeed, potential output growth has slowed by about one percentage point per annum across the OECD since the late 1990s, which is entirely accounted for by a pre-crisis slowing in MFP growth and more recent weakness in weak capital deepening (Figure 1). Against this background, this section reviews some of the competing explanations for the productivity slowdown and places our research in the context of the existing literature.

2.1. Techno-pessimists and techno-optimists

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

Techno-pessimists 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 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) 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).[3] These problems are likely to be compounded if it becomes more costly for researchers to innovate the further technology advances and ideas cumulate (Jones, 2012). Such arguments are reinforced by the slowdown in business dynamism observed in frontier economies such as the United States (Decker, Haltiwanger, Jarmin and Miranda, 2013; Decker, Haltiwanger, Jarmin and Miranda., 2016; Criscuolo, Gal and Menon, 2014).

Against this, techno-optimists 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.[4] Similarly, Joel Mokyr argues that 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 and reducing access costs and thus igniting a virtuous circle between technology and science. However, Mokyr warns of the potential for bad institutions and policies to act as obstacles to this virtuous cycle.[5]

One interesting angle in the techno-optimist argument is that we might not have seen the full benefits of the "digital economy" 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

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3 Gordon also argues that future growth in the United States will slower further due to several headwinds, including ageing population, plateauing of gains from education, growing inequality, decelerating globalization, environmental unsustainability and the overhang of consumer and government debt.

4 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.

5 According to Mokyr, potential barriers could come 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).

slowdown may reflect the dynamics associated with these complementary investments (Fernald and Basu, 2006).

2.2. Macroeconomic factors

Although aggregate productivity slowed before the crisis in many economies, the debate has also focused on the role of non-technology macroeconomic factors, namely demand, savings and monetary policy. Accounts linking demand to the slowdown tend to emphasise "secular stagnation", whereby 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 (Summers, 2016). Significant growth, such as that characterizing the 2003-2007 boom, was achieved thanks to excessive levels of borrowing and unsustainable investment levels.

Christiano, Eichenbaum and Trabandt (2015) analysed the role of macro shocks and financial frictions during the crisis as triggers of the slowdown, but such models take the slowdown in MFP as exogenous. Of more interest for our purposes is a recent paper by Anzoategui, Comin, Gertler and Martinez (2016), which propose a theoretical model whereby the increase in demand for liquidity, as observed during the crisis, increases the spread between the 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

Gopinath, Kalemli-Ozcan, Karabarbounis and Villegas-Sanchez (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 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

Finally, the debate had also raised the possibility that the productivity slowdown might have just been a reflection of increasing mismeasurement of the gains from innovation in IT-related goods and services.[6] However, recent analysis for the US (Byrne, Fernald and Reinsdorf 2016; and Syverson, 2016) suggests that this is highly unlikely (see recent Brookings brief by Derviş and Qureshi for an overview). Given that IT producing sectors have seen rising import penetration and most of the IT production is now done outside

6 See also the discussion in Ahmad and Schreyer (2016) on measuring GDP in a digitalised economy.

the US, the effect (either way) would be small and in no way large enough to explain the slowdown observed in the US. In fact, "improving" measurement would, if anything, make the slowdown more pronounced to the extent that US domestic production of these products has fallen over the 1995-2004 period. Furthermore, mismeasurement of IT hardware is significant already prior to the slowdown. Finally, the largest benefits of recent innovations in ICT go to consumers in non-market production activities which again would not show up in GDP measures. In fact, Syverson (2016) shows that the slowdown is not correlated with IT production or use.

2.5. Our contribution

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 laggard firms. This micro evidence is both key to 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.

We show that a particularly striking feature of the productivity slowdown is not so much a lower productivity growth at the global frontier, but rather rising labour productivity at the global frontier coupled with an increasing labour productivity divergence between the global frontier and laggard firms.[7] This productivity divergence remains after controlling for differences in capital deepening and mark-up behaviour although there is evidence that market power of frontier firms has increased in services. This leads us to suspect that the rising MFPR gap between global frontier and laggard firms may in fact reflect technological divergence.

MFP divergence could plausibly reflect the potential for structural changes in the global economy – namely digitalisation, globalisation and the rising importance of tacit knowledge – to fuel rapid productivity gains at the global frontier. Yet, aggregate MFP performance was significantly weaker in industries where MFP divergence was more pronounced, suggesting that the divergence observed is not solely driven by frontier firm pushing the boundary outward. In this regard, we contend that increasing MFP divergence – and the global productivity slowdown more generally – could reflect a slowdown in the technological diffusion process. This stagnation could be a reflection of increasing costs for laggards firms of moving from an economy based on production to one based on ideas. But it could also be symptomatic of rising entry barriers and a decline in the contestability of markets. In both cases, public policy can play an important role in "alleviating" the productivity slowdown. Consistent with this, we find the rise in MFP divergence to be

7 Preliminary results from the OECD Multiprod project based on the micro-aggregation of official representative firm-level data for 15 countries over the last 20 years (Berlingieri, Blanchenay and Criscuolo, 2016) show that most countries have experienced growing labour and multi factor productivity dispersion coupled with increased dispersion in marginal revenue product of capital (MRPK) allowing for non-constant returns to scale. This rising productivity dispersion and misallocation is evident in both manufacturing and services, but is generally much stronger in the services sector. Gamberoni, Giordano and Lopez-Garcia (2016) use micro-aggregated firm-level data sources mainly based on firm level data from Central Banks compiled in the European Central Bank's CompNet project from 5 European countries and show increasing dispersion in MRPK and MRPL across firms in the 2000s up to the crisis. Under their assumptions of constant returns to scale, MRPK and MRPL are simply multiples of capital and labour productivity, hence their findings can also be interpreted as rising divergence in productivity levels. They also find that dispersion is stronger amongst the services sectors. By focusing on the frontier, our paper provides a discussion specifically on the upper half of the productivity distribution.

much more extreme in sectors where pro-competitive product market reforms were least extensive, suggesting that the observed rise in MFP divergence might be at least partly due to policy weakness stifling diffusion and adoption in OECD economies.

Evidence of technological divergence at the firm level is significant in light of recent aggregate level analysis suggesting that while adoption lags for new technologies across countries have fallen over time, long-run penetration rates once technologies are adopted diverge across countries, with important implications for cross-country income differences (Comin and Mestieri, 2013). More specifically, new technologies developed at the global frontier are spreading more and more rapidly across countries but their diffusion to all firms within any economy is slower and slower, with many available technologies remaining unexploited by a non-trivial share of firms. A key implication is that weak productivity performance in OECD countries may persist, unless a new wave of structural reforms can revive a broken diffusion machine.

3. DATA AND IDENTIFICATION OF THE GLOBAL PRODUCTIVITY FRONTIER

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 covers to 24 OECD countries[8] over the period 1997 to 2014 for the non-farm, non-financial business sector.[9]

As discussed in Gal (2013), these data are sourced from annual balance sheet and income statements, collected by Bureau van Dijk (BVD) – an electronic publishing firm – using a variety of underlying sources ranging from credit rating agencies (Cerved in Italy) to national banks (National Bank of Belgium for Belgium) as well as financial information providers (Thomson Reuters for the US).[10] It is the largest available cross-country company-level database for economic and financial research. However, since the information is primarily collected for use in the private sector typically with the aim of financial benchmarking, a number of steps need to be undertaken before the data can be used for economic analysis. The steps we apply closely follow suggestions by Kalemli-Ozcan, Sorensen, Villegas-Sanchez, Volosovych and Yesiltas (2015) and previous OECD experience (Gal, 2013; Ribeiro, Menghinello and Backer, 2010).[11] Three broad steps are: i) ensuring comparability of monetary variables across countries and over time (industry-level PPP conversion and deflation); ii) deriving new variables that will be used in the analysis (capital stock, productivity); and iii) keeping company accounts with valid and relevant information for our present purposes (filtering or cleaning). Finally, Orbis is a subsample of the universe of companies for most countries, retaining the larger and hence probably more productive firms. To mitigate problems arising from this – particularly the under-representation of small firms – we restrict our sample to firms with more than 20 employees on average over their observed lifespan. For more details, see the sections in Appendix E on Data and on Representativeness issues.

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8 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.

9 This means retaining industries with 2 digit codes from 5 to 82, excluding 64-66 in the European classification system NACE Rev 2, which is equivalent to the international classification system ISIC Rev. 4 at the 2-digit level.

10 See the full list of information providers to Bureau van Dijk regarding financial information for the set of countries retained in the analysis in Appendix E.

11 The authorsare grateful for Sebnem Kalemli-Ozcan and Sevcan Yesiltas for helpful discussions about their experience and suggestions with the Orbis database.

Further, a number of issues that commonly affect productivity measurement should be kept in mind. First, 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.[12] Secondly, measuring outputs and inputs in internationally comparable price levels remains an important challenge.[13] 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 total revenues or total value added. Even though we deflate these output measures by country-industry-year level deflators (at the 2-digit detail), differences in measured (revenue) productivity across firms within a given industry may still reflect both differences in technology as well as differences in market power.[14] 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

As a starting point, we focus on labour productivity, which is calculated by dividing real value added (in US 2005 PPP that vary by industry) by the number of employees. Using labour productivity 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 (proxied by materials) 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. We employ the one-step GMM estimation method proposed by Wooldridge (2009), which mitigates the endogeneity problem of input choices by using material inputs as proxy variables for productivity and (twice) lagged values of labour as instruments. The production function is estimated separately for each 2-digit industry but pooled across all countries, 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. For more details, see Appendix E.

3.2. Correcting for mark-ups

In order to mitigate the limitations from not observing firm-level prices, we correct our revenue based MFP measure by firm- and time-varying mark-ups. In order to do that, we apply the mark-up estimation methodology of De Loecker and Warzynski (2012). We introduce a notation for the “standard” MFP estimates as MFPR (denoting revenue based productivity) and the mark-up corrected MFP estimates as $MFPR^c$, and we define it for each firm i and year t as follows:

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

12 The measurement of intangible fixed assets in the balance sheets follows accounting rules, hence the total fixed assets (sum of tangibles and intangibles) may understate the overall capital stock (Corrado et al, 2009). Moreover, different depreciation rates and investment price deflators cannot be applied, since an asset type breakdown is not available. The implications of these limitations will be discussed in Section 4.2 where we analyse the patterns found in the data.

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

14 In the above example, it is unclear 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 because of a lack of competition, for example.

where the MFP values are measured in logs and μ denotes the estimated mark-up. The $MFPR^c$ measure provides an estimate for productivity that is purged from mark-up variations and hence is not influenced by market power changes under the assumption that at least one input of production is fully flexible (e.g. labour or materials).[15]

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, under the assumptions that at least one input is fully flexible and that firms minimize costs. Thus, the mark-up – defined as the ratio of the output price *P* over marginal cost *MC* – is derived from the first order condition of the plant's cost minimization problem with respect to the flexible input *k* as:

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

That is, the mark-up of firm *i* at time *t* can be computed as the ratio between the elasticity of output[16] with respect to the flexible input *k* (estimated in a first step) and flexible input k shares in output (observed in the data). In our baseline specification, we use labour (as opposed to materials) as flexible input to ensure the largest coverage of countries in our baseline specification. Thus mark-ups are calculated as the ratio between the estimated production function parameter for labour $\hat{\beta}_L^j$ in industry *j* where firm *i* operates and the "corrected" wage share $ws_{it} = \frac{\mathrm{WL_{it}}}{\widetilde{\mathrm{VA}}_{\mathrm{it}}}$:

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

The labour coefficient $\hat{\beta}_L^j$ in the numerator is estimated using the GMM estimation method by Wooldridge (2009). The denominator is obtained by using a prediction of firm-level value added by a rich polynomial function of observable inputs in order to retain only the anticipated part of output developments.[17] The rationale for using this correction is the assumption that firms do not observe unanticipated shocks to production when making optimal input decisions.

Given potential criticisms that labour input may not be fully flexible – especially in countries with rigid labour markets – we also calculated mark-ups using materials as the fully flexible input for a subset of 18 countries for which data are available. In that case, a gross-output based production function is estimated to obtain a coefficient for materials, again following Wooldridge (2009). As shown in Appendix A, the main result of a strong divergence in MFP is robust to these different choices.

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15 A further step would be a separation of market power and quality and/or demand. See Foster et al. (2008) and 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). Even if firm level prices were observed, complications would still arise – see Byrne and Corrado (2015) who demonstrate that official output prices of communication products are significantly under-estimated due to ignoring some quality improvements. Haltiwanger (2016) discusses in great detail the various types of MFP calculations and to what extent they are influenced by demand and market frictions.

16 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.

17 The polynomial includes all possible interactions between labour, capital and materials containing first and second degree terms, along with first and second degree base effects. This follows the Stata code provided by De Loecker and Warzynski (2012) with their online Appendix, with the difference that for computational reasons we omitted that third degree terms.

As De Loecker and van Biesebroeck (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 mark-up 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."

As noted in 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

In keeping with the (scarce) existing literature (Bartelsman, Haskel and Martin, 2008; Crespi and Iacovello, 2010; Arnold, Nicoletti and Scarpetta, 2011), we define the global productivity frontier as the top 5% 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.[18] One implication of the increasing coverage of Orbis over time is that 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 the heterogeneity of average firm size 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 the top 5% of the typical population of firms. Using a MFPR-based productivity frontier definition, for example, results in a global frontier size of about 80 companies for the typical 2-digit industry.[19]

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 other, previously productive, businesses can lose their advantages and fall out of the frontier. This will not necessarily lead to a bias where the frontier becomes relatively more productive over time,

18 In 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.
19 The number of firms at the global frontier is 83 for the median industry (i.e. manufacture of basic metals). For the industries populated with a large number of businesses, the frontier represents about 400-500 companies (e.g. retail and wholesale trade, construction).

however, since the composition of the laggard grouping is also allowed to change, the average productivity of this grouping could also in principle be boosted the entry (exit) of more (less) productive firms.[20] 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. Characteristics of frontier firms

Table 1: Mean firm characteristics, frontier firms versus laggards

A: Labour productivity based frontier definition

	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	21,191	12.0	0.4	825	1.3	***	10.4	0.7	22,053	11.9	0.7	627	1.5	***
Employees	49.3	52.1	21,191	45.1	33.8	825	-4.2	***	59.5	156.6	22,053	38.0	24.8	627	-21.6	***
Capital-labour ratio[1]	86.1	115.3	21,191	274.5	425.5	825	188.4	***	76.4	214.0	22,053	677.5	2,071.1	627	601.1	***
Revenues[2]	11.8	21.6	21,191	39.0	58.8	825	27.3	***	14.8	54.0	22,053	57.9	133.0	627	43.1	***
Markup (log)	0.1	0.4	21,191	0.1	0.4	825	0.05	***	0.1	0.4	22,053	0.3	0.5	627	0.19	***
Wages[1]	34.2	16.7	21,191	54.6	20.1	825	20.4	***	34.5	16.7	22,053	56.6	23.4	627	22.1	***

B: MFPR based frontier definition

	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	21,317	11.6	0.4	706	1.3	***	10.3	0.7	22,147	11.7	0.7	538	1.4	***
Employees	48.3	46.8	21,317	73.7	126.0	706	25.4	***	59.1	155.3	22,147	53.4	115.6	538	-5.6	
Capital-labour ratio[1]	89.3	125.1	21,317	214.3	406.0	706	125.1	***	81.1	245.5	22,147	579.6	2,131.7	538	498.5	***
Revenues[2]	11.5	19.9	21,317	50.5	74.1	706	39.0	***	14.4	40.1	22,147	80.2	268.0	538	65.7	***
Markup (log)	0.1	0.4	21,317	0.0	0.4	706	-0.02		0.1	0.4	22,147	0.2	0.5	538	0.12	***
Wages[1]	34.3	16.7	21,317	56.3	18.9	706	22.0	***	34.6	16.8	22,147	56.8	23.9	538	22.2	***

C: Mark-up corrected MFPR based frontier definition

	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	19,844	11.7	0.4	887	1.4	***	10.2	0.9	21,823	11.6	0.7	776	1.4	***
Employees	48.6	46.9	19,844	79.1	119.1	887	30.5	***	58.9	156.8	21,823	58.5	73.0	776	-0.4	
Capital-labour ratio[1]	95.1	138.9	19,844	114.1	272.6	887	18.9	**	88.7	330.8	21,823	211.6	1,389.1	776	122.9	**
Revenues[2]	12.0	22.5	19,844	34.7	51.4	887	22.7	***	15.3	58.0	21,823	36.7	59.6	776	21.5	***
Markup (log)	0.1	0.4	19,844	-0.2	0.2	887	-0.3	***	0.1	0.4	21,823	-0.2	0.3	776	-0.2	***
Wages[1]	34.5	16.5	19,844	60.6	15.8	887	26.1	***	34.2	16.5	21,823	60.7	21.2	776	26.5	***

Note: All statistics refer to 2013. Productivity and mark-up are measured in logs, and productivity denotes the measure mentioned in the panel titles (labour productivity, MFPR and mark-up corrected MFPR for panel A, B and C, respectively). The set of firms is restricted to a sample where all displayed variables in the table are jointly available. See details in Section 3.1 and 3.2 for the calculation of the frontier and the productivity measures. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.
[1]: in millions of 2005 USD; [2]: in thousands of 2005 USD; both using PPP conversions.

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

Table 1 reports cross-sectional differences in average characteristics for global frontier firms relative to non-frontier firms along a number of measurable dimensions, focusing on the last year of our sample, 2013. Panel A reports these differences based on a labour productivity measure while Panel B does likewise using MFPR and Panel C using mark-up corrected MFPR. A few interesting facts emerge from the tables.

20 The empirical literature on productivity-enhancing reallocations can indeed find an important role for the entry-exit margin of firms (e.g. Foster et al., 2001), and the theoretical literature also emphasizes its potential role (Caballero and Hammour, 1994; Campbell, 1998).

- First, firms at the global productivity frontier are on average 3 to 4 times more productive than non-frontier firms.[21] At first glance, these differences appear large but are to be expected given the widespread heterogeneity in firm productivity that is typically observed within narrowly defined sectors (Syverson, 2004).[22] A host of literature has focused on how such large differences in productivity can be sustained in equilibrium, given the expectation that market selection and the reallocation of resources would necessarily equalise them over the longer run. Supply-side explanations have typically emphasised factors related to technology shocks, management skill, R&D, or investment patterns (Bartelslman and Doms, 2000). The demand side also appear relevant, given evidence that imperfect product substitutability – due to geographical segmentation (i.e. transport costs), product differentiation (i.e. consumer preferences, branding/advertising) and intangible factors (customer-producer relationships) – can prevent industry customers from easily shifting purchases between industry producers (Syverson, 2004). The combination of demand and supply side imperfections can indeed lead to large and persistent differences in productivity levels across firms (Syverson, 2011). Note that most studies focus on within-country productivity dispersion, while our analysis pools together different countries, potentially further widening the productivity distribution.

- Second, on average, global frontier firms have larger sales and are more capital intensive –as expected, more so for labour productivity. However, frontier firms do not employ a significantly larger number of employees in services for any of the productivity measures analysed.

- Third, global frontier firms pay higher wages, which ranges between $20,000 and $26,000 (in 2005 USD terms) depending on the measure. These differences might reflect the sorting of better workers into frontier firms (Card, Heining and Kline, 2013; Song, Price, Guvenen, Bloom and von Wachter, 2016) and the potential sharing of higher rents by frontier companies with their workers.

- Fourth, in manufacturing, firms at the frontier in terms of MFP (MFPR and its mark-up corrected variant) have significantly higher employment size than laggards, in line with existing evidence that productivity is positively correlated with size of manufacturing firms.

- Fifth, frontier firms are also shown to charge higher mark-ups in the case of labour productivity and MFPR, particularly 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 mark-up corrected MFPR, frontier firms are found to charge lower mark-ups. This is consistent with the idea that the most productive firms can afford to charge lower prices and thus attract more demand. In particular, this is in line with the findings of Foster, Haltiwanger and Syverson (2008) using US firm level data on prices and quantities, who show that there is a strong negative relationship between measures of MFP based on physical output rather than revenues (and thus purged from markups) and firm level prices.[23]

- Finally global frontier firms are also more likely to belong to a multinational group/conglomerate and

21 Note that productivity is measured in logs, so relative to laggard firms, global frontier firms are exp1.3=3.6 times more productive.

22 For example, within 4 digit manufacturing industries in the United States, Syverson (2004) finds a 2-to-1 ratio in value added per worker between the 75th- and 25th-percentile plants in an industry's productivity distribution. Including more of the tails of the distribution amplifies the dispersion, with the average 90–10 and 95–5 percentile labour productivity ratios within industries in excess of 4-to-1 and 7-to-1, respectively.

23 Note that we abstract from potential differences in input prices when making the link between mark-ups and output prices.

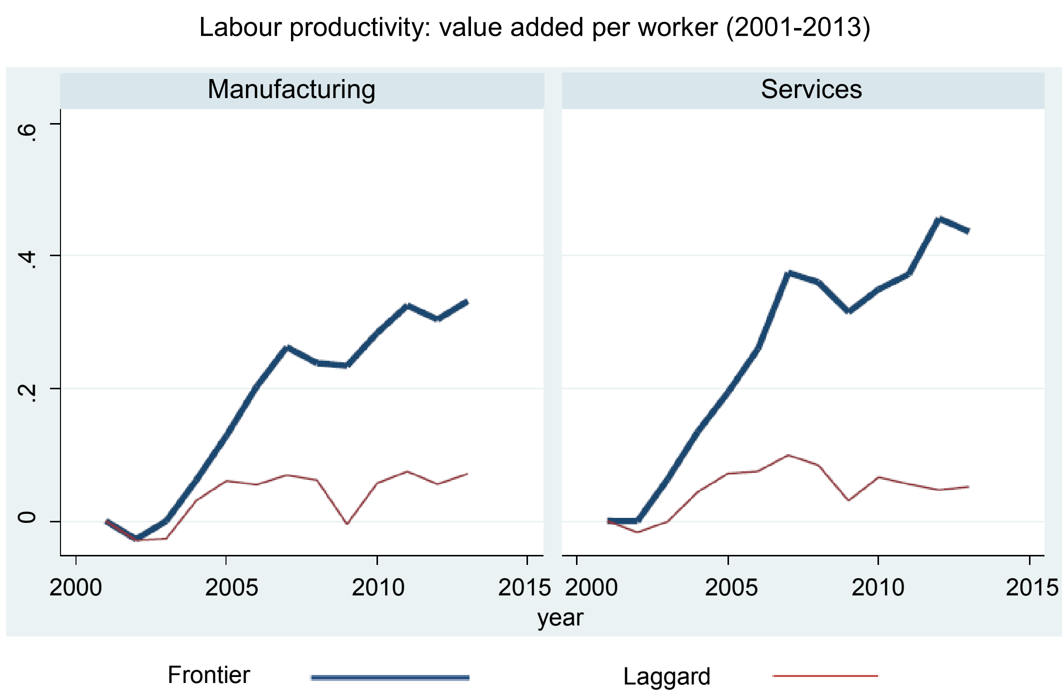
patent more intensively than other firms (Andrews, Criscuolo and Gal, 2015).[24]

4. PRODUCTIVITY DIVERGENCE BETWEEN GLOBAL FRONTIER, LAGGARD FIRMS

4.1 Labor productivity divergence

Figure 2 describes the evolution of labour productivity for firms at the global productivity frontier and no n-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 (see Section 3.3), 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, with the initial year – 2001 – indexed to 0 and separately for two broad sectors: manufacturing and business services.[25]

Figure 2: A widening labour productivity fap between global frontier firms and laggards



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. The time period is 2001-2013. The vertical axes represent log-point differences from the starting year: for instance, the frontier in manufacturing has a value of about 0.3 in the final year, which corresponds to approximately 30% higher in productivity in 2013 compared to 2001. Services refer to non-financial business sector services. See details in Section 3.3.

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

24 These results are based on our previous analysis for 2005, when information of firms' patenting activity and multinational status was available. The OECD is currently in the process of updating this information for the new vintage of Orbis. Reassuringly, both in the current and previous vintage of Orbis, numerous well-known multinational companies make it to the frontier, such as Google, Apple, Amazon or Microsoft among the ICT services, Samsung, Nokia, Siemens among electronics manufacturing as well as BMW, Ford and Volkswagen within the car manufacturing sector.
25 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).

Between 2001 and 2013, firms at the global frontier have become relatively more productive, with their labour productivity increasing at an average annual rate of 2.8% in the manufacturing sector, compared productivity gains of just 0.6% per annum for non-frontier firms (henceforth laggards). This pattern of divergence is even more pronounced in the market services sector, with the 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 laggards.[26] Given the concerns discussed above of sampling variation in Orbis, Figure A1 of Appendix A also reports figures for the industry average sourced from the OECD National Accounts. These statistics will tend to understate of the true gap between frontier and laggard firms as frontier firms will inflate the average industry level productivity, particularly when their weight in industry activity is large.[27] Reassuringly industry level trends look very much in line with the picture obtained with information from Orbis.

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.[28] 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.

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 iv) 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). Moreover, the analysis in Appendix B shows that the patterns in Figure 2 and subsequent Figures in Section 4 are robust to using more narrowly-defined industries (i.e. 3 and 4-digit industry classifications) to better ensure that firms are competing in the same market and producing similar products.[29] In some instances, however, this leads to a non-trivial reduction in the number of firms within each sector – raising difficulties for production function estimation and increasing the prevalence of idiosyncratic and noisy patterns. This leads us to conduct our baseline analysis at the two-digit level.[30]

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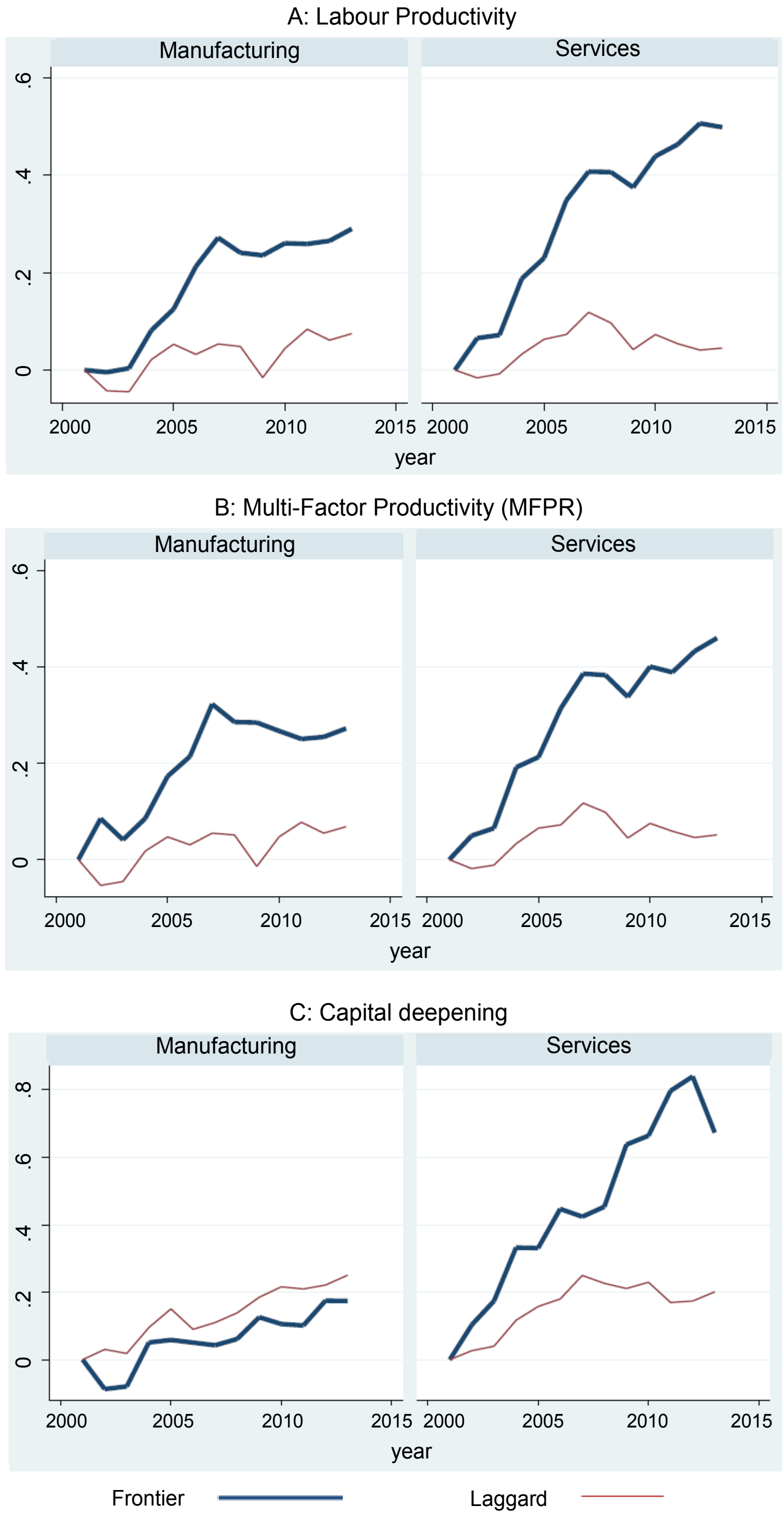
26 These growth rates, expressed in percentages, are approximated by changes in log-points multiplied by 100.
27 Since the detailed OECD National Accounts is an industry level database, its evolution over time reflects not only within-firm productivity developments but also changes in allocative efficiency. Further, 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. As such, it is not strictly comparable with the frontier and non-frontier firms but simply provides a benchmark against which the patterns obtained using the Orbis sample can be compared.
28 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.
29 In order to avoid estimating production functions with too few firms per industry (see next footnote), the production function parameters are still estimated at the 2-digit level and only the frontier definition is applied at the 3 or 4 digit level.
30 The median number of firms across 2-digit sectors and years is about 2000, but this figure falls to 210 and 130 for 3 and 4 digit sectors respectively. When looking across country*industry*year cells, these medians are 53, 8 and 6, respectively for 2, 3 and 4 digit industries. Thus, we chose the 2-digit detail level as our benchmark, which is a compromise between avoiding too small cells and the appropriate differentiation across economic activities.

4.2 Labour productivity divergence: Capital deepening or MFP?

Figure 3: A widening labour productivity gap between global frontier firms and laggards



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 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*) are allowed to vary by industry.

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

Since gains in labour productivity at the firm level can be achieved through either higher capital deepening or multi-factor productivity (MFP), Figure 3 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 2. Given that the sample of firms for which reliable capital stock is available is smaller than the baseline sample in Section 4.1, Figure 3, 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 labour productivity divergence illustrated in Figure 2.

From a comparison of Panels B and C in Figure 3, 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.[31] 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 MFPR than capital deepening. Even so, vintage capital models imply that weak capital deepening amongst laggards in the post-crisis period could exacerbate MFP divergence if new technology is embodied in new capital which often requires a retooling process in existing plants (see Cooper, Haltiwanger and Power, 1997).

Since our capital measure is based on balance sheet information, it misses some important elements of intangible investments such as brand-building, worker training, the development of organizational practices and also some types of R&D spending (Corrado, Hulten and Sichel, 2009). To the extent that the most productive businesses implement more and more of these type of investments, and at a faster pace than other firms, this may contribute to a widening gap in measured MFP.[32] Accordingly, our subsequent discussion on the likely drivers of MFP divergence (Section 4.4) explicitly acknowledges that measured MFP reflects these and other factors beyond narrowly defined technology or technical efficiency – such as management practices, the qualities of employees or tacit knowledge more generally (Hulten, 2001).

4.3 MFP divergence: mark-ups or technology?

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. 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, and thus profitability as opposed to differences in technical efficiency. Accordingly, we attempt to assess the contribution of mark-up behaviour to MFPR divergence, using the methodology outlined in Section 3.

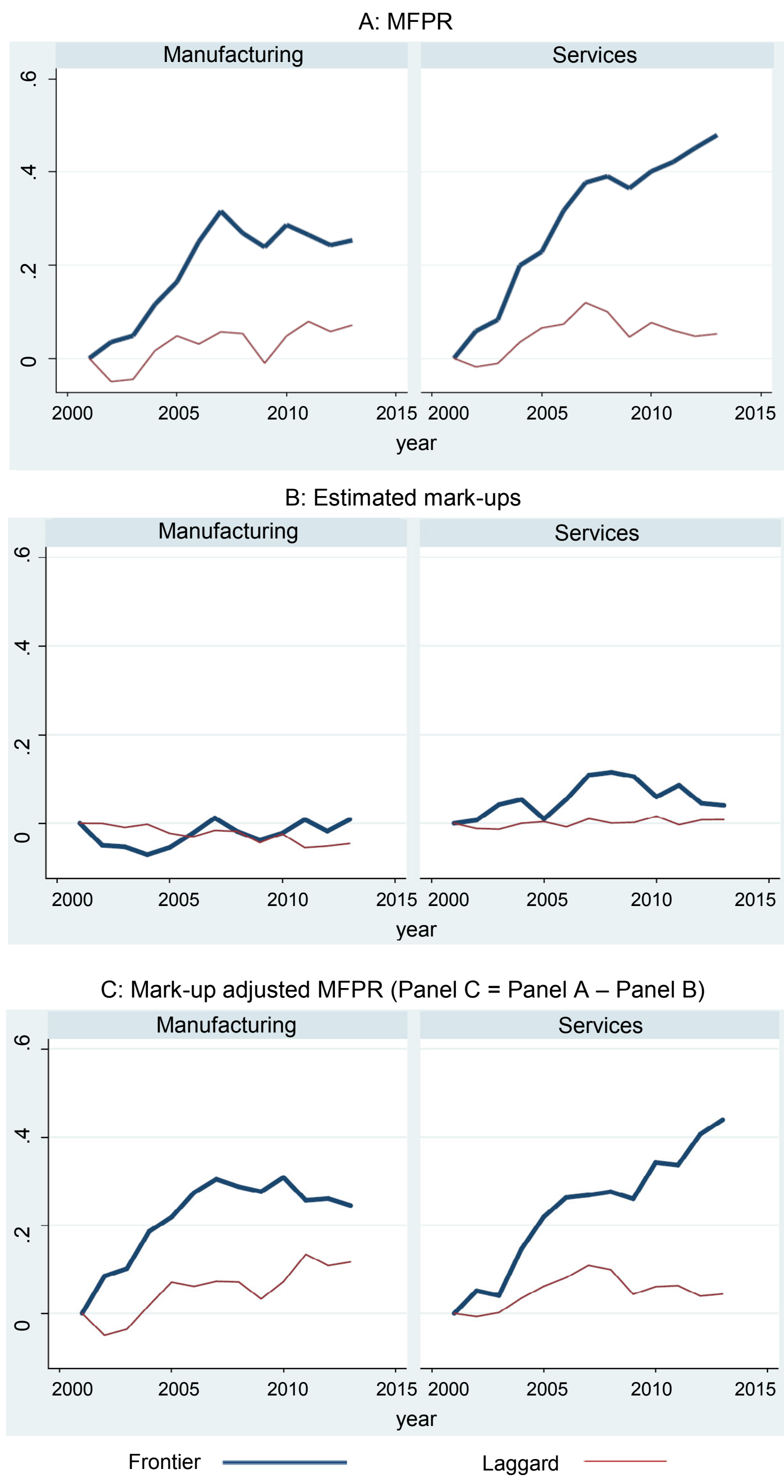
Given the focus on MFPR, the global frontier in Figure 4 is redefined in terms of the top 5% of firms in terms of MFPR levels within each two digit industry and year. Using such a definition, the divergence of MFPR in Figure 4, Panel A is very similar to that in Figure 3, Panel B, which defines the global frontier in terms of labour productivity. These patterns are robust to using alternative definitions of MFPR, based on a Solow

31 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.

32 As a flipside to this issue, our value added measure subtracts spending on these intangibles as costs. As discussed in Corrado et al (2009), the underestimation of capital and value added tends to lead to an upward bias on MFP.

residual or the Wooldridge gross-output estimation approach (Figure A6) and to using materials (a proxy for intermediate inputs) 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).

Figure 4: 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 all the other firms. Unweighted averages across 2-digit industries are shown for MFPR, estimated mark-ups and mark-up corrected MFPR for Panels A, B and C, 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 corrected MFPR uses the De Loecker and Warzynski (2012) methodology. Time period is 2001-2013. Services refer to non-financial business services. See details in Section 3.3.

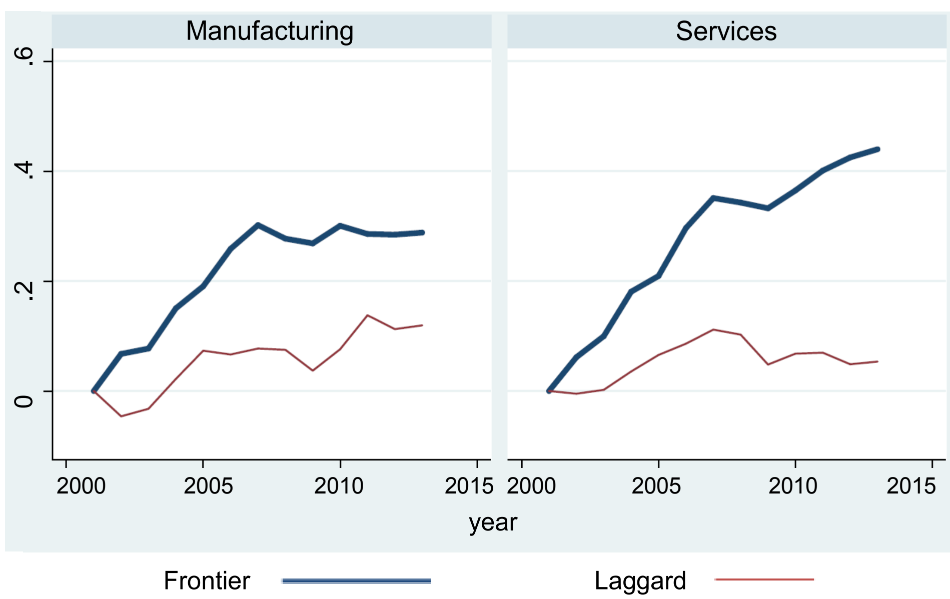
Source: Authors' calculations based on the recent update of the OECD-Orbis productivity database (Gal, 2013)

Figure 4, 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 increasingly higher mark-ups, relative to non-frontier firms. Turning to the services sector, there is evidence that frontier firms increased their mark-ups relative to non-frontier firms in the pre-crisis period, in particular after 2005, but this divergence in mark-up behaviour is significantly unwound in the post-crisis period. Still, their mark-up levels are significantly higher than those of non-frontier firms (Table 1, Panel B). Once we correct MFPR for these patterns in mark-ups, the divergence in mark-up corrected MFPR 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 4, Panel C).

For completeness, Figure 5 presents the evolution of mark-up corrected MFP where the global frontier is now defined as the top 5% of firms in terms of corrected MFPR levels within each two-digit industry and year. Taken together, the evidence in Figures 3 and 4 implies that even though rising mark-ups for frontier firms plays a non-trivial role in services, divergence seems mainly unrelated to the evolution of mark-ups. This suggests that the divergence is likely to be related to growing differences in the capacity of frontier firms vs laggards to invest in and successfully combininge technological and non-technological innovations (intangibles), and the concomitant increasing importance of tacit knowledge (e.g. organisational know-how) for succeeding in the market.

Figure 5: A widening gap in mark-up corrected MFPR

Global frontier defined in terms of mark-up corrected MFPR



Notes: the global frontier group of firms is defined by the top 5% of companies with the highest mark-up corrected MFPR levels within each 2-digit industry. Laggards capture all the other firms. Unweighted averages across 2-digit industries are shown for corrected MFPR, 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 mark-up corrected MFPR uses the De Loecker and Warzynski (2012) methodology. 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: contributing factors

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. This might be surprising as it is at odds with neo-Schumpeterian growth theory (Aghion and Howitt, 2006; Acemoglu, Aghion and Zilibotti, 2006), models of competitive diffusion (Jovanovic and MacDonald, 1994) and of growth enhancing creative destruction (Aghion and Howitt, 1992; Caballero and Hammour, 1994; Campbell, 1998), but as shown below, might be the result of structural changes in the global economy. To the extent that these developments reflect digitalisation, globalisation and the rising importance of tacit knowledge, MFP divergence could either reflect "winner takes all" dynamics propelling productivity growth at the global frontier, or stalling technological diffusion and market dynamism inhibiting productivity gains amongst laggard firms. In practice, it is difficult to distinguish with the data at hand the relative importance and causality of these factors, but a number of smoking guns emerge to suggest that each may be relevant.

4.4.1 Frontier firms and winner takes all dynamics

The productivity divergence patterns unveiled so far may partly reflect the increasing potential for digital technologies to unleash winner takes all dynamics (Brynjolfsson and McAfee, 2011), which allows the technological leaders to increase their MFP gap with laggard firms. More specifically, by making the replication of informational goods and business processes at near zero marginal cost possible, digital technologies enable the top-quality provider to capture most, or all, of the market, while only a small market share accrues to the next-best provider (even if they are almost as good as the best provider). These patterns are reinforced by network externalities that favour the emergence of a single dominant player (e.g. providing a specific network; platform or standard) vis-à-vis other firms, even though their products are not necessarily inferior. 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).[33]

While it is hard to think of a single statistic that could capture winner takes all dynamics with the data at hand, a number of findings may support the existence of such dynamics:

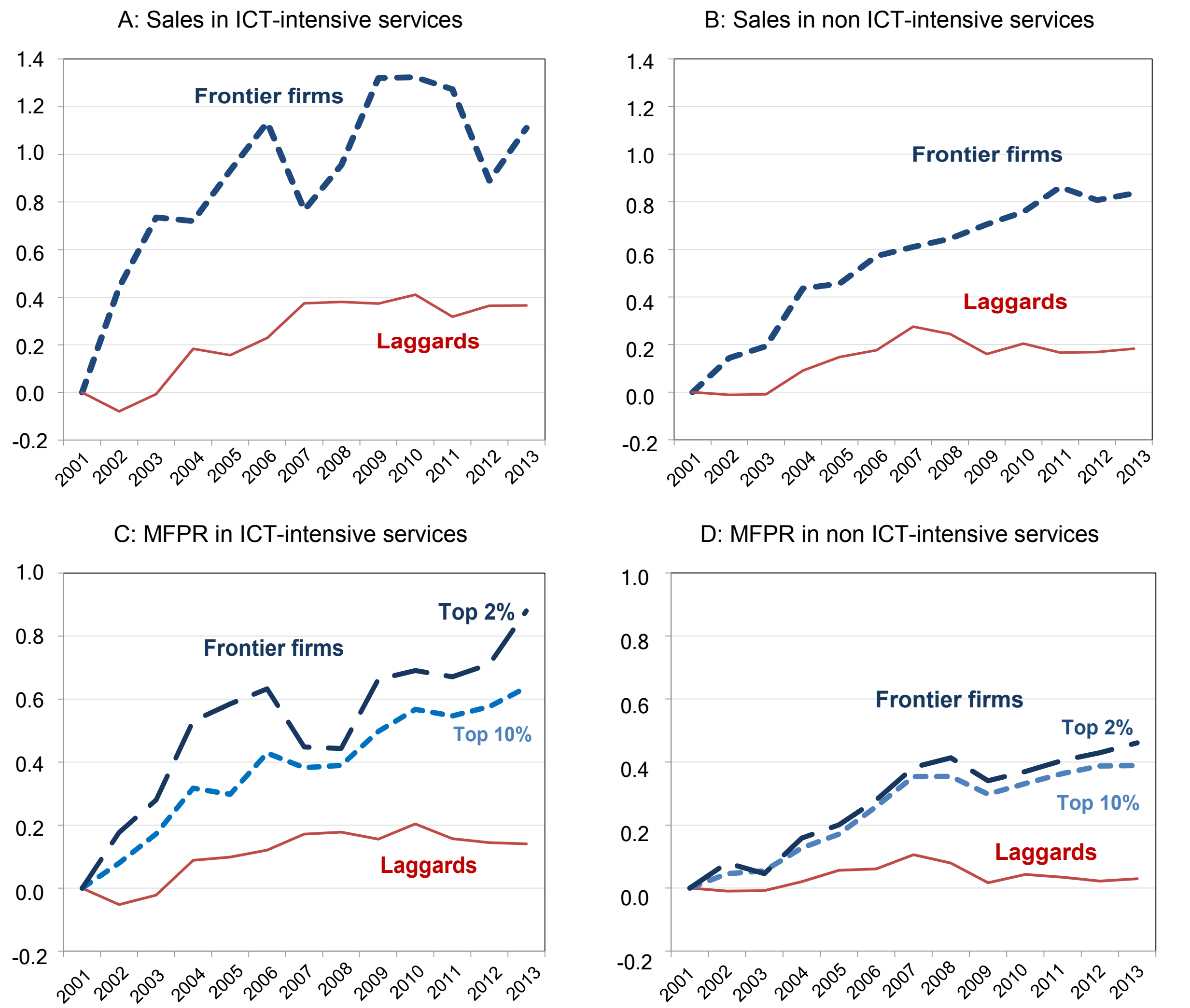
- Divergence in MFPR is accompanied by divergence in sales between frontier and laggard firms, particularly in ICT-intensive services.
  - Figure A5 (Panel A) shows that the divergence in sales has been growing over time: global frontier firms have gained significant market share relative to laggards in manufacturing and to a larger extent in services.[34]
  - Divergence in sales is particularly stark in ICT intensive services (Figure 6, Panel A), compared to non ICT-intensive services (Figure 6, Panel B). This divergence is also apparent within the global frontier grouping: sales of firms in the top 2% of the global MFPR distribution grew by 14% on average in ICT intensive services over the sample period, compared to 7% in non ICT-

33 The rise of "winner takes all" dynamics amongst firms could also have a knock-on effects on CEOs, for whom the rise of "superstars" with big salary premiums reflect differences in capital value of the firms they work for rather that in their talent (Gabaix and Lander, 2008).
34 In contrast, the average size of frontier firms and laggards in terms of employment show similar trends over time (Figure A5, Panel B).

intensive services.[35] In comparison, sales on average across firms in the top 5% of the global MFPR distribution grew by 6% and 3.5% in ICT-intensive services and non ICT-intensive services respectively.

- One concern is that firms that make it to the top might gain too large of a market share, making entry into the frontier more difficult and more generally leading to lower competition in the market.[36] This may entail a cost to aggregate productivity performance, above and beyond any gains associated with higher allocative efficiency (Section 5.1).

Figure 6: Evidence on winner takes all dynamics



Notes: In Panels A and B, the global frontier group of firms is defined by the top 5% of companies with the highest MFPR levels within each 2-digit industry, while Panels C and D employ two definitions of the global frontier based on the top 2%, and 10% of the MFPR distribution to emphasize a growing dispersion at the top of the productivity distribution. Laggards capture all the other firms. Unweighted averages across 2-digit industries are shown for sales and MFPR, separately for services and ICT 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). MFPR uses the Wooldridge (2009) methodology based production function estimation. 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)

35 Given the relative volatility of the sales data for firms in the top 2% of global MFPR distribution, we do not show these estimates for presentational reasons.

36 Exploring mark-up developments in ICT intensive sectors vs other services is outside the scope of this paper, given the challenges faced by current methodologies aimed at disentangling price-, quality- and quantity, which are particularly severe for these activities.

- A more pronounced MFP divergence in ICT-intensive services between frontier and laggard firms as well as within the global frontier grouping.
  - Figure A7 shows that the rise in the MFPR gap is indeed most pronounced in ICT-intensive services.[37]
  - 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 6, Panel C), while this pattern is not particularly evident within non ICT-intensive services (Figure 6, Panel D).[38]

- A divergence in mark-up corrected MFPR, notwithstanding developments in the mark-up.

4.4.2 Laggard firms, stalling technological diffusion, and market dynamism

The rising gap in MFPR between frontier and laggard firms might also signal stalling technological diffusion and market dynamism amongst laggards. This stagnation could reflect the increasing costs for laggards firms of moving from an economy based on production to one based on ideas. This would be the case if the strength of global frontier firms not only reflects their capacity to technologically innovate but also to optimally combine intangibles, i.e. 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 increasingly complex technologies were to increase the amount and sophistication of complementary investments required for technological adoption.[39] But it could also be symptomatic of rising entry barriers and a decline in the contestability of markets, which could reflect the inability of the policy environment to adapt to structural changes in the global economy and the rising market power of frontier firms, particularly in services. Both factors 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 between 1950-1995 (OECD, 2015) – to break down.

To more robustly test whether the pace of technological convergence has slowed over time, we estimate a neo-Schumpeterian model where firm level MFP growth depends principally on a firm's lagged MFP gap with the global frontier (see Appendix C), controlling for a battery of fixed effects (i.e. industry and country*year) , firm size and age. 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 productivity 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).[40] This pattern holds within firm size and age classes (Table C1, Panel B) and is even more pronounced when the model is estimated using mark-up corrected MFPR (Panel B), providing further evidence that the pace of technological convergence has slowed.

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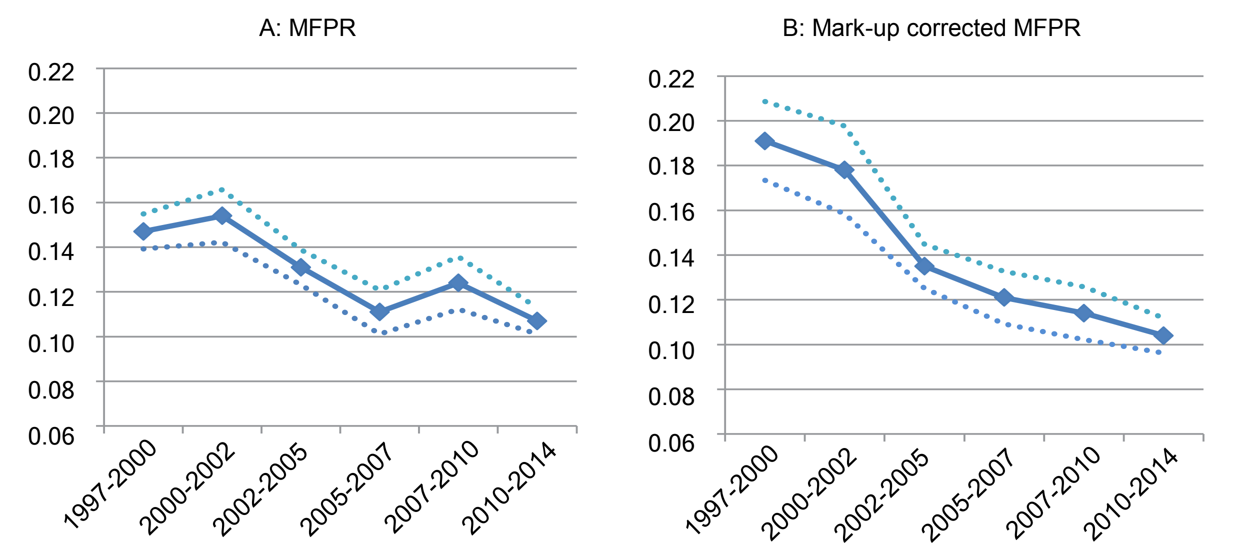
37 This is also in line with findings by Gamberoni, Giordano and Lopez-Garcia (2016) using alternative firm-level sources, which show strongest increases in capital-productivity dispersion in the ICT sector.
38 One limitation with the data at hand is that we do not have firm level information on ICT capital so we are obliged to abstract from differences in ICT capital across firms within ICT intensive sectors.
39 We attribute this idea to Chad Syverson's comments at the *OECD-NBER Conference on Productivity and Innovation in the Long-Run*.
40 The coefficient estimate (0.15 for the period 1997-2000 and 0.11 for the period 2010-2014) imply that the time it takes for the average laggard firm to catch-up half its initial MFPR gap with the global frontier has risen from about 4.3 years (log(1/2) / log(1-0.15) = 4.265) in the late 1990s to about 6 years by 2010-14.

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

Estimated convergence parameter from neo-Schumpterian model and 95% confidence interval

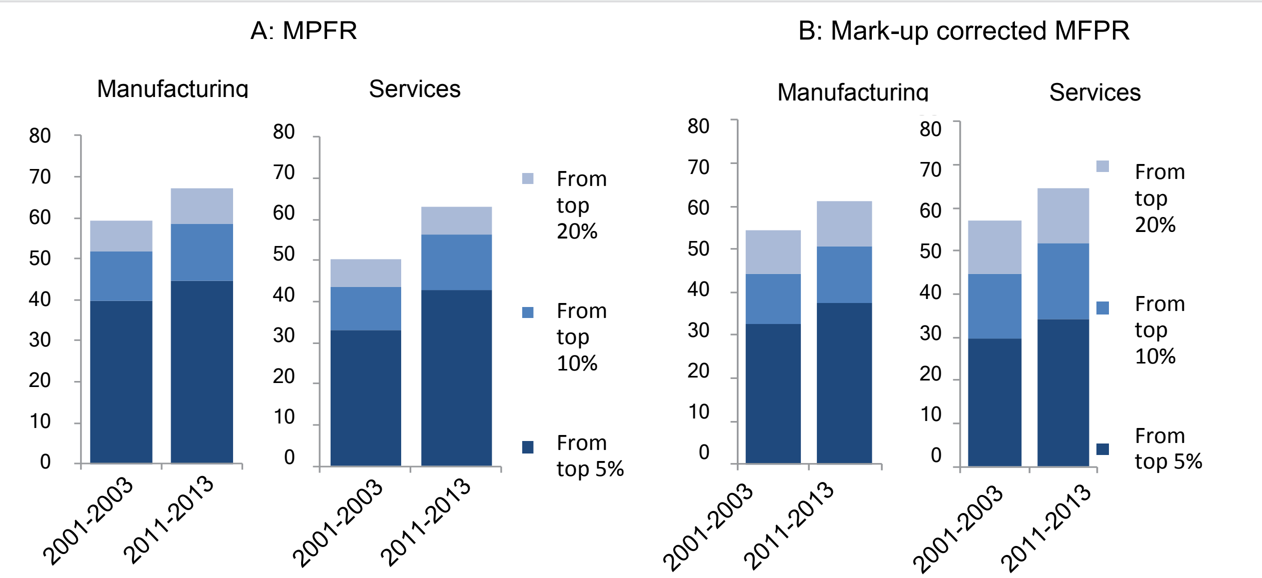


Notes: The marker line shows the evolution over time of the estimated $GAP_{i,t-1}$ coefficient from the firm level MFP growth regression in Table C1 Appendix C (Column 1, Panel A), while the dashed line provides the 95% confidence interval around this coefficient estimate.

One symptom of stalling diffusion could be the increasing persistence of incumbents at the frontier or churning that increasingly comes from firms close to the frontier (i.e. within the top decile or top quintile of the MFP distribution). We might also expect these patterns to be especially evident in the services sector where intangibles and tacit knowledge are becoming ever more important and where the increase in market power at the frontier is most apparent.

Figure 8: Entry into 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*

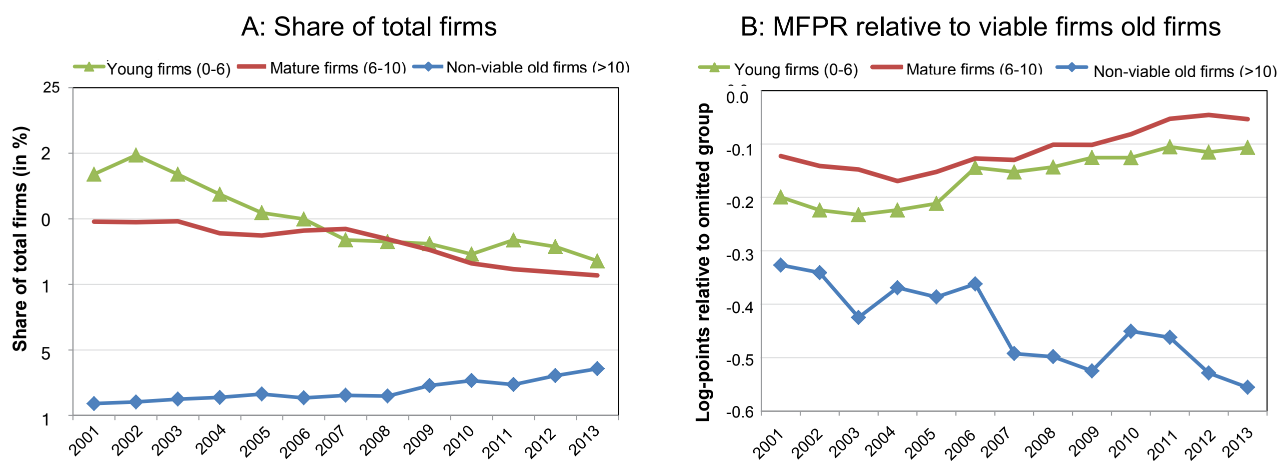


Notes: The figure shows the proportion of firms classified as global frontier firms at time *t* – i.e. in the top 5% of the industry MFPR or mark-up corrected MFPR distribution – according to their status two years earlier (*t-2*). Estimates are averaged over each three year time period. For example, 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%)

Figure 8 provides supporting evidence to these conjectures. On average over 2001-2003, 50% of firms at the global frontier in terms of MFPR in the services sector (Figure 8 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 decile (10% of firms) or top quintile (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 decile (13%) some two years early. These patterns – which are also evident for corrected MFPR (Figure 8, Panel B) – suggest that it has become more difficult for laggard firms outside the top quintile of the MFP distribution to enter the global productivity frontier over time.

Figure 9: Indicators of declining market dynamism amongst laggard firms

Frequency and productivity of firms by age and financial viability



Notes: The figure shows the frequency and relative productivity of three groups of firms: firms aged 5 years or less (young firms), firms aged 6 to 10 years (mature firms) and firms older than 10 years that record negative profits over at least two consecutive years (non-viable old firms). The omitted group are firms older than 10 years that do not record negative profits over at least two consecutive years (viable old firms). The age of the firm is inferred from the incorporation date. The estimates are an unweighted averages across industries in the non-farm non-financial business sector.

Rising entrenchment at the frontier is consistent with the broader decline in business dynamism observed across OECD countries (Decker, Haltiwanger, Jarmin and Miranda, 2014 for the US and Criscuolo, Gal and Menon, 2014 for 18 countries), which in turn raises the prospect that the degree of competitive pressure – a key driver of technological diffusion (see Section 5) – may have declined. To explore the role of market dynamism among laggard firms, Figure 9 distinguishes between four groups of firms: i) young firms (aged 0-5 years) to proxy for recent entrants; ii) mature firms (aged 6 to 10 years); iii) firms teetering on the brink of exit in a competitive market firms, proxied by firms older than 10 years that record negative profits over at least two consecutive years (non-viable old firms); and iv) all other firms (i.e. viable old firms; the excluded category). Two key patterns emerge. First, the data suggest that firm turnover has fallen, as reflected by a decline in the share of young firms and a higher survival probability of marginal firms that would typically exit in a competitive market (Panel A).[41] Second, the average productivity of recent entrants relative to viable

41 We use these categories to have a more robust picture of market dynamism and selection instead of working directly with entry and exit rates. They tend to be more volatile and noisy, in particular because our sample contains only those firms which have at least 20 employees on average over their observed lifespan. Also, the incidence of non-viable firms is likely to be understated since we compute them for the sample where MFP is available, and this excludes cases with negative value added, i.e. firms that have larger negative profits (in absolute value) than labour costs.

incumbent firms has risen, while the average productivity of firms on the margin of exit has fallen over time (Panel B).

These patterns are consistent with a decline in the contestability or competitiveness of markets, which implies less indirect pressure on incumbent firms to improve their productivity via the adoption of superior technologies and business practices (Bartelsman, Haltiwanger and Scarpetta, 2004).[42] The corollary is that it has become relatively easier for weak firms that do not adopt the latest technologies to remain in the market. Moreover, the decline in firm turnover coupled with an increase in the implied productivity gap between entering and exiting businesses is what one would typically observe if barriers to entry had risen (Bartelsman, Haltiwanger and Scarpetta, 2009). This leads us to suspect that there may be more to the stagnation of laggard firm productivity than just the rising importance of tacit knowledge, thus motivating an analysis of the link between product market regulations and MFP divergence in the next section. Taken together, the estimated decline in convergence, the entrenchment of the frontier and the decline in business dynamism, provide reasonable pointers behind the unintuitive divergence that is observed in the data.

5. PRODUCTIVITY DIVERGENCE: AGGREGATE IMPLICATIONS AND THE ROLE OF POLICY

Before proceeding, it is important to recognise that some degree of MFP divergence across firms is organic to the working of a market economy – especially during periods of rapid technological change where experimentation looms large. Indeed, while MFP divergence may have contributed to the slowdown in aggregate productivity if technological adoption became increasingly difficult for laggard firms, the aggregate consequences are less clear if MFP divergence reflects higher innovation intensity at the frontier and more efficient resource allocation associated with the rapid gains in market shares of the globally most productive firms – a potentially positive aggregate consequence of winner takes all dynamics. Accordingly, this section begins by presenting evidence which suggests that aggregate MFP performance was weaker in industries where MFP divergence was more pronounced, suggesting that MFP divergence is a relevant policy concern for growth.

As we have seen, the increase in the MFP gap is not uniform across sectors. Productivity divergence is particularly apparent in service sectors that are typically more sheltered from competitive pressures due to lower exposure to international competition and more stringent product market regulations. This generates two sets of potentially relevant policy issues: To what extent is divergence itself creating barriers to technology diffusion by stifling competitive forces? And to what extent is the failure of policy to encourage competition in service sectors contributing to maintain such barriers? We present evidence in the remainder of this section which suggests that the rise in the MFP 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.

5.1 Aggregate implications

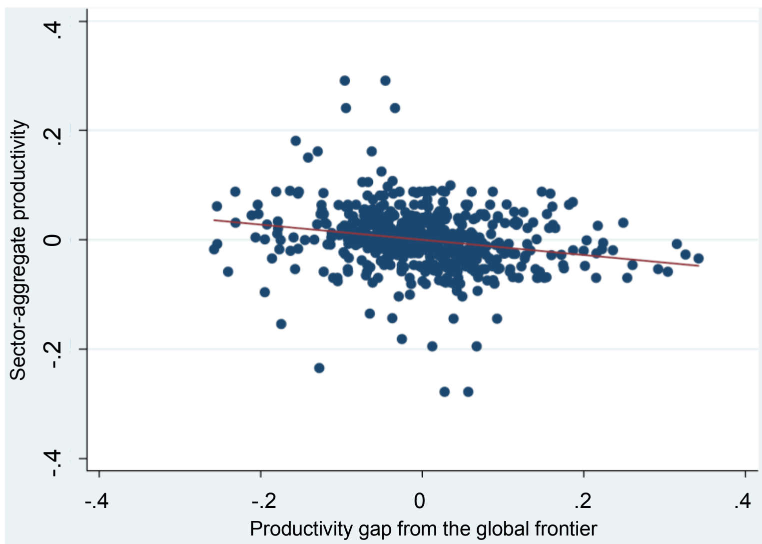
To provide suggestive evidence on a link between MFP divergence and weakness in aggregate productivity

42 For example, using cross-country microdata aggregated to the industry level, Bartelsman, Halitwanger and Scarpetta (2004) find that productivity growth within incumbent firms is positively correlated with the firm turnover rate.

performance, Figure 10 relates aggregate industry-level MFP (sourced from the EU KLEMS sectoral-level database) to the MFPR gap between frontier and laggard firms. The data are collapsed to the industry-year level by taking an unweighted average of both variables across countries. Moreover, each variable is purged of industry fixed effects and year fixed effects to facilitate a within-industry interpretation and to abstract from time-varying global shocks. A robust negative relationship emerges, whereby above-average MFP divergence between frontier and laggard firms within industries is associated with below-average aggregate MFP performance. Moreover, the coefficient estimates imply that a 0.3 log-point (around 35%) rise in the MFPR gap – roughly equivalent to that observed between 2001 and 2007 (Figure 4) – is associated with a 3.5% decline in the level of aggregate MFP across industries. This is economically significant given that the cumulative loss in MFP due to the productivity slowdown in OECD countries over this period amounts to about 6%.[43]

Figure 10: Aggregate MFP performance was weaker in industries where MFPR divergence was greater

Residual aggregate MFP and the MFPR gap at the industry level; 1998-2007



Notes: The figure plots two-digit industry-year observations of aggregate MFP from EU-KLEMS against the MFPR gap (as defined in Figure 2) based on two steps. First, an unweighted average of each variable is computed across 12 OECD countries – Austria, Belgium, Germany, Spain, Finland, France, the United Kingdom, Italy, Japan, the Netherlands, Sweden and the United States – at the industry level for each year between 1998 and 2007. Second, the industry-year observations are purged of two-digit industry fixed effects and year fixed effects. Outlier observations outside the range of 0.4 are removed from the graph. The relationship is statistically significant at the 5% level and is robust to various outlier filtering techniques and to looking within manufacturing or services sectors (see Table D2 of Appendix D).

As shown in Table D2 (Panel A) of Appendix D, this negative relationship between aggregate MFP and MFPR divergence is statistically significant and holds within both manufacturing and services.[44] While

43 This is relative to a counterfactual where MFP growth had not slowed from its 2001 rate of 0.9%:

$$CumulativeLoss_{2001-2007} = \sum_{t=2001}^{2007} (MFP_{2001}(1.009)^{t-2001} - MFP_t),$$

where MFP is expressed as an index number with a base year of 2001. This means that $MFP_{2001} = 1$ and 1.009 represents the (gross) growth rates under the counterfactual of steady growth at the pace observed in 2001. MFP_t is cumulated using the actual observed growth rates (see Figure 1).

44 These results are also significant in light of the fact that the aggregate data also reflect the MFP performance of firms that employ fewer than 20 employees and the changes in allocative efficiency (i.e. resource shifts across firms within sectors), which we do not account for in our analysis.

this analysis is restricted to the pre-crisis period due to the lack of more recent industry-level MFP data, a negative relationship is also evident between aggregate labour productivity and labour productivity divergence over 1998-2013, although this relationship is mainly driven by the manufacturing sector (see Table D2, Panel B).[45] In any case, even with a growing market share accrued to frontier firms, aggregate productivity is not benefiting positively from a widening gap between the frontier and laggards. This illustrates that winner takes all dynamics discussed in the previous section do not necessarily translate into aggregate gains, because they tend to imply poor productivity performance of laggard firms.

5.2 Productivity divergence and product market regulation

At the margin, there are a 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.[46] 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:

- First, higher competition underpins within-firm productivity gains by weeding out inefficient firms and sharpening the incentives for incumbent laggard firms to adopt better technologies and business practices (Bloom, Draca and Van Reenen., 2015; Perla, Tonetti and Waugh, 2015; Steinwender, 2015; Baily, 1993; Baily et al., 2005).

- 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 returns expected by firms in downstream manufacturing sectors from adopting best-practice techniques (Bourlès, Cette, Lopez, Mairesse and Nicoletti, 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.

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45 We also attempted to more directly assess the contribution of the MFP gap to the slowdown in aggregate productivity growth – i.e. by regressing the change in MFP growth on change in the MFP gap in a long difference specification – but these attempts were frustrated by the limited availability of reliable industry-level MFP data over a sufficiently long time span.

46 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).

5.3 Product market reforms in OECD countries

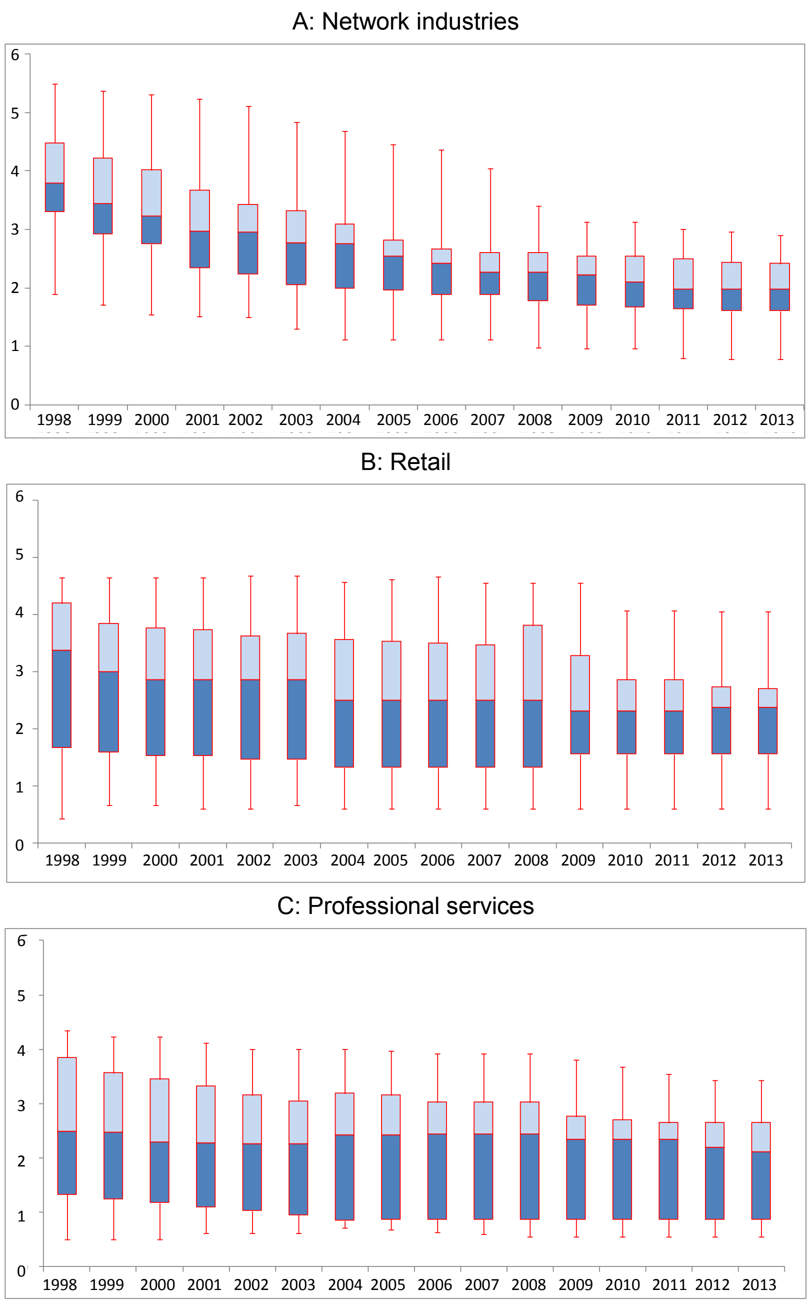
To measure market reforms, we utilise the OECD database on product market regulations, which is based on a highly detailed questionnaire sent out to governments every five years (Nicoletti and Scarpetta, 2003).[47] These indicators measure the extent of “anti-competitive” regulations; that is, regulations “that inhibit competition in markets where competition is viable.”[48] A key strength of these indicators is their de jure nature – i.e. they focus on rules and regulations – which facilitates meaningful cross-country comparisons, but it is important to note that they do not account for differences in implementation and enforcement across countries. The indicators range from 0 to 6 and are increasing in the restrictiveness of product market regulations.

We exploit information on sector-specific provisions in 10 separate industries (7 in network industries, 1 in retail, and 2 in professional services; see Conway and Nicoletti, 2006), as opposed to the economy-wide indicators.[49] 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.

According to the OECD indicators, 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. 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 11, Panel A). While there remains some scope for further reform action in specific network industries (particularly road and rail transportation) and countries, the need for reforms in retail trade and professional services is clear. 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?

47 For example, the 2013 questionnaire includes around 1400 questions on economy-wide and sector-specific provisions (see Koske et al., 2015).
48 As outlined in Nicoletti et al. (2000), the restrictions to competition captured by the OECD indicators of Product Market Regulation 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). Given that the indicators cover a relatively homogenous set of countries, the underlying assumption is 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.
49 Network industries include two energy sectors (electricity and gas), three transport sectors (road, rail and air) and two communication sectors (post and telecommunications). The two professional services industries refer to the business services sector (accounting and legal services) and the technical services sector (engineering and architecture services).

Figure 11: The restrictiveness of product market regulations over time, 1998-2013



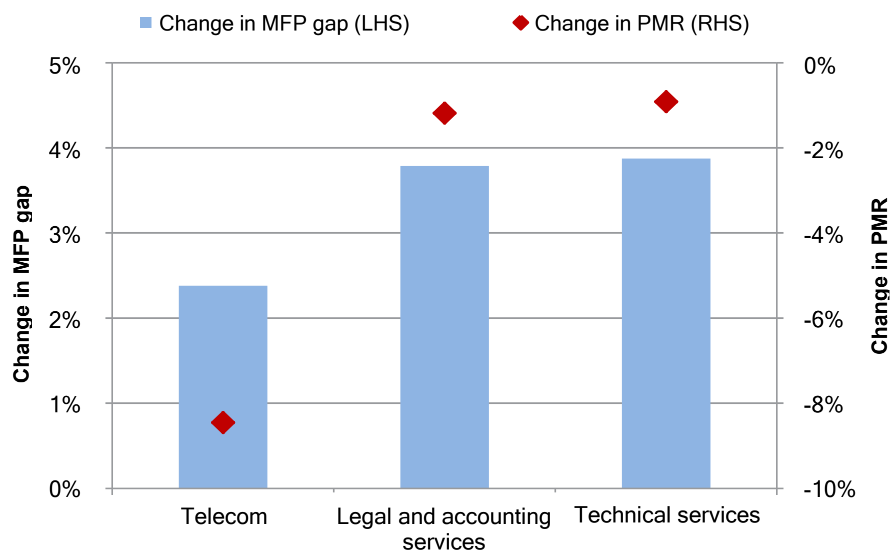
Note: The PMR indicator varies between 0 and 6, and higher values indicate more stringent and less competition-friendly regulation. The horizontal line in the boxes represents the median, the upper and lower edges of each boxes reflect the 25th and 75th percentiles and the markers on the extremes denote the maximum and the minimum across OECD countries.

Source: calculations by Gal and Hijzen (2016) based on OECD indicators on product market regulation (PMR; Conway and Nicoletti, 2006; Koske, Wanner, Bitetti and Barbiero. 2015) and additional information on the timing of reforms for retail and professional services (Duval, Furceri, Jalles and Nguyen, 2016). For more information on the OECD PMR indicator, go to: http://www.oecd.org/eco/growth/indicatorsofproductmarketregulationhomepage.htm.

By way of introduction and purely for illustrative purposes, Figure 12 provides some preliminary evidence on the link between the pace of market reforms and the evolution of the MFPR gap between global frontier and laggard firms (as defined in Section 4) 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 global factors to establish a more robust link between regulations and the MFP gap. Herein lies the aim of the next section.

Figure 11: 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. Growth rates expressed in percentages are approximated by log-point differences (multiplied by 100).

5.4 Empirical strategy

5.4.1 Baseline model

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.[50]

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;[51] $MFPgap_{s,c,t}$ refers to the difference between the (unweighted) average MFP (MFPR or mark-up corrected MFPR) of global frontier firms and the (unweighted) average MFP of laggard firms in country *c*, industry

50 Throughout the analysis of PMR's impact on the productivity gap, the coverage is restricted to cases where the annual PMR indicators are available and where at least 10 firms are present in Orbis. The included 14 OECD countries are Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, Korea, Portugal Slovenia, Spain, Sweden and the United Kingdom.

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

s and year t; $PMR_{s,c,t}$ refers to the overall restrictiveness of product market regulation in key service industries (expressed in log terms),[52] 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.

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.[53] 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. To 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.

Second, we estimate a dynamic ordinary least squares (see Stock and Watson, 1993; DOLS) equation in [3], on the same sample of 10 market services sectors over the period 1998-2013. This specification 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.[54] It also includes a rich battery of fixed effects to control for unobserved time-varying country-specific shocks (δ_{ct}), time-varying global industry-specific shocks (δ_{st}) and time invariant industry-specific factors within countries (δ_{cs}).

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

5.4.2 Addressing identification concerns

One identification concern is that rigid services regulation might be a consequence, not a cause of the MFP gap (e.g. reverse causality). This would be the case if in service sectors with many firms lagging behind the global productivity frontier, there was a greater incentive for firms to exert political pressures for raising anticompetitive regulations. While such lobby activity by inefficient firms would upwardly bias the estimate of β_1, the tendency for product market reforms to be conducted when economic conditions are weak (Bouis, Duval and Eugster, 2016) would bias the estimate of β_1 in the opposite direction.

We adopt two identification strategies to confront the potential endogeneity of market regulation to economic conditions and at the industry level. First, we employ an instrument variables (IV) approach in the context of our long difference framework, which exploits the existence of liberalization waves across

52 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.
53 The employment variable is based on information from the Orbis database, and is calculated as the average of log employment levels across firms.
54 DOLS estimates are presented based on both one and two lags and leads.

countries and the role of external pressure in driving them (see Bouis et al., 2016).[55] Here, we utilise two instruments which are unlikely to be affected by sector-level economic outcomes in the country considered, and should not have any effect on $MFPgap_{s,c,t}$ other than through pressure on domestic authorities to undertake reform:

- The lagged level of market regulation, based on the idea that the scope for reform as well as the push to implement reform is larger the in country-sector pairs where the initial stance of product market regulation is stricter.

- Average reform activity in other countries – as measured by the 5-year change in product market regulation in the given sector – to capture peer pressure from reforms in other countries.

Second, if these baseline estimates are robust, then one might 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, 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. While political economy factors may again be a source of bias – for example, if firms in downstream industries that use regulated (upstream) intermediate inputs, and whose productivity growth is low as a result, were to lobby for and obtain upstream deregulation – if anything, this would make it more difficult to find a positive relationship between upstream regulation and the MFP gap in downstream sectors (Bourles et al., 2013).

5.5 Empirical results

5.5.1 Baseline results

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%. The coefficient estimates in Column 1 of Table 2 – Panel A imply that a one standard deviation increase in PMR

55 We employ the IV approach in the context of our baseline long-difference specification since it's easier to find plausible instrument variables for reform – i.e. PMR change – then the level of PMR.

is associated with about one-third of a standard deviation increase in the MFP gap.[56]

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.

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***	0.231***	0.332***	0.311**
	(0.065)	(0.083)	(0.103)	(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*	0.292**	0.281**	0.395*
	(0.098)	(0.139)	(0.134)	(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

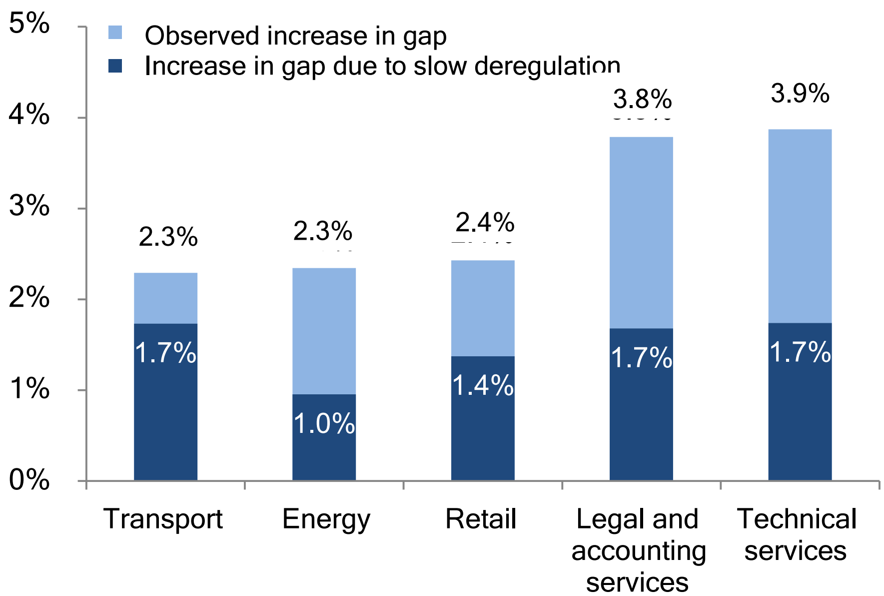
Notes: Cluster robust standard errors (at the country-industry level) in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. Both the MFP gap and the PMR indicator are measured in log terms. The MFP gap is calculated at the country-industry-year level, by taking the difference between the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

To better illustrate the economic magnitude, Figure 13 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

56 As documented in Table D2 of Appendix D, the standard deviation of PMR and the MFP Gap are 0.673 and 0.470 respectively.

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 our estimates imply that 1.7% of this increase may have been avoided if market liberalisation in this sector accelerated more rapidly. On average across the sectors analysed, our estimates imply that up to 50% of the increase in MFP divergence may have been avoided if countries had engaged in extensive market liberalisation in services.

Figure 13: MFP divergence and market reforms in services



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. Growth rates expressed in percentages are approximated by log-point differences (multiplied by 100).

5.5.2 Sensitivity analysis

The baseline results 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 D3 of Appendix D); iii) the median (rather than mean) productivity of laggards to construct the MFP gap (Table D4); and iv) alternative lag and lead lengths in the DOLS estimator (Table 2, Panel B).

Additional analysis suggests that it is unlikely that the baseline estimates are upwardly biased by the potential endogeneity of market reforms to industry-specific economic conditions:

- Columns 1 and 2 of Table D5 in Appendix D confirm a positive relationship between the change in the MFPR gap and the change in PMR when the latter is instrumented using two plausibly exogenous measures of external reform pressure. The IV estimates are larger in magnitude than the baseline estimates although less precisely estimated (Table 2), suggesting that weak sectoral performance may trigger market reforms, as opposed to lobbying for anticompetitive regulation.

- The IV regressions in Table D5 also show a positive relationship between the mark-up corrected MFPR gap and PMR (Columns 3 and 4), although the imprecise estimation means that the coefficients are not always statistically significant. That PMR is more strongly related to MFPR gap than the corrected MFPR gap provides tentative evidence that market reforms may also operate through decreasing mark-up gaps between frontier and laggards.

- We also checked the existence of 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 D6 of Appendix D 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 13.

5. CONCLUSION AND FUTURE RESEARCH

In this paper, we aim to contribute to 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 motivating new theoretical work and to identifying areas where there may be more traction for policy reforms to revive productivity growth in OECD countries.

The most striking feature of the productivity slowdown is not so much a slowing in the rate of productivity growth 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. This productivity divergence remains after controlling for differences in capital deepening and mark-up behaviour although there is evidence that market power of frontier firms has increased in services. This leads us to suspect that the rising MFPR gap between global frontier and laggard firms may in fact reflect technological divergence.

We show that this pattern of MFP divergence, which is at odds with existing models of new-Schumpeterian growth and of creative destruction, could plausibly reflect the potential for structural changes in the global economy – namely digitalisation, globalisation and the rising importance of tacit knowledge – to fuel rapid productivity gains at the global frontier. Yet, aggregate MFP performance was significantly weaker in industries where MFP divergence was more pronounced, suggesting that the divergence observed is not solely driven by frontier firm pushing the boundary outward. In this regard, we contend that increasing MFP divergence – and the global productivity slowdown more generally – could reflect a slowdown in the technological diffusion process. This stagnation could be a reflection of increasing costs for laggards firms of moving from an economy based on production to one based on ideas. But it could also be symptomatic of rising entry barriers and a decline in the contestability of markets. Crucially, in both cases, there is scope for policy to alleviate the productivity slowdown.

Indeed, we find the rise in MFP divergence to be much more extreme in sectors where pro-competitive product market reforms were least extensive, suggesting that the observed rise in MFP divergence might be 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 50% less than what was actually observed. Put differently, structural changes in the global economy meant that 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.

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, Coming, Gertler and Martinez (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, Blanchenay and Criscuolo, 2016) and weakening market selection, particularly the distorting effects on resource reallocation of 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, Heining and Kline, 2013; Song et al., 2016).

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, Sadun and Van Reenen, 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.

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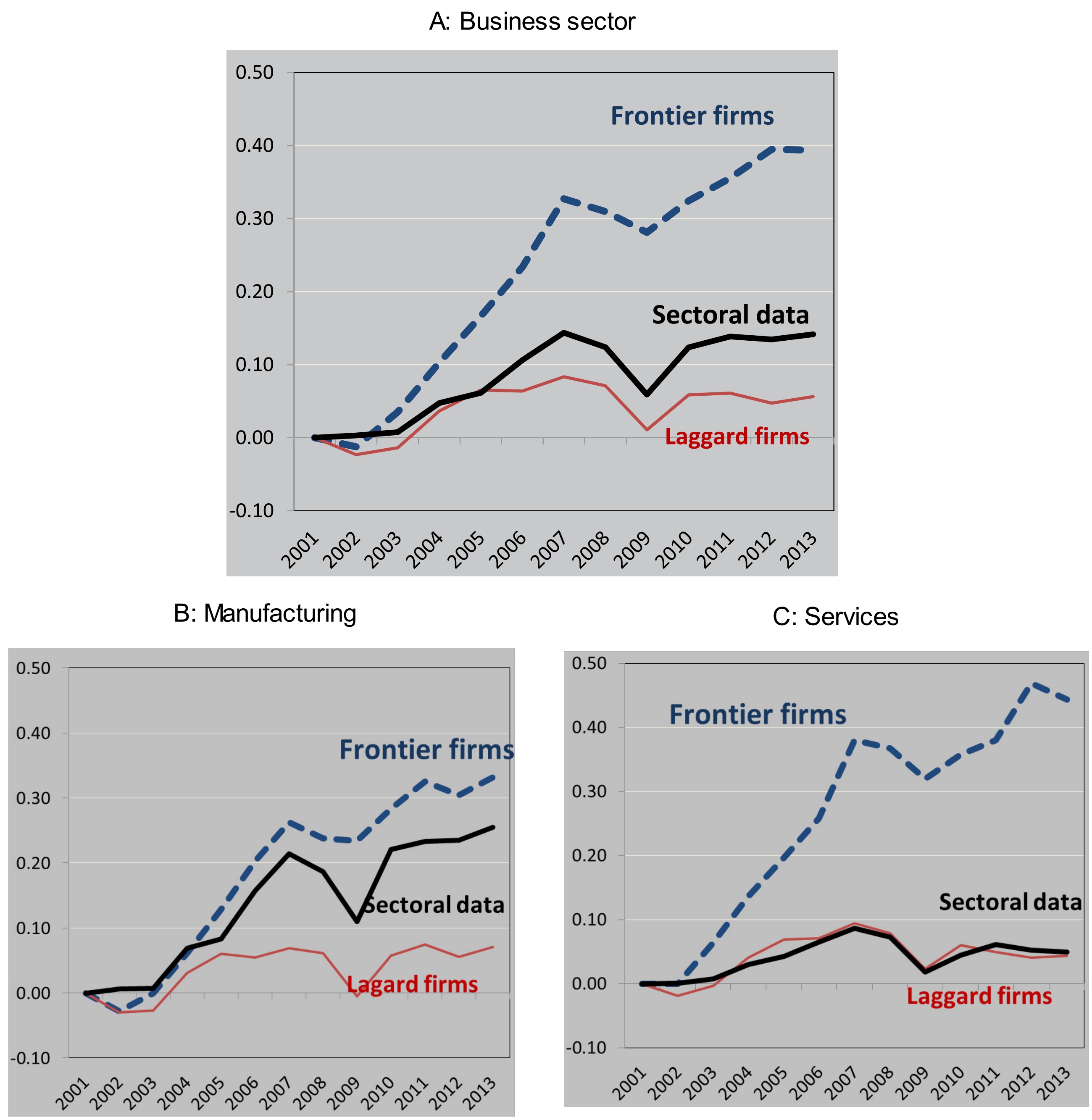
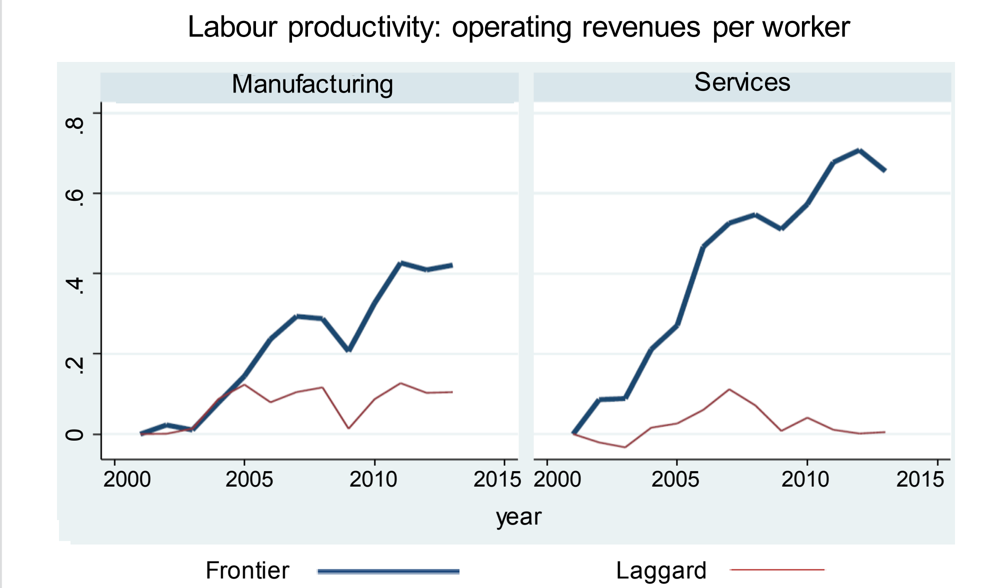
APPENDIX A: DIVERGENCE INDICATORS

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

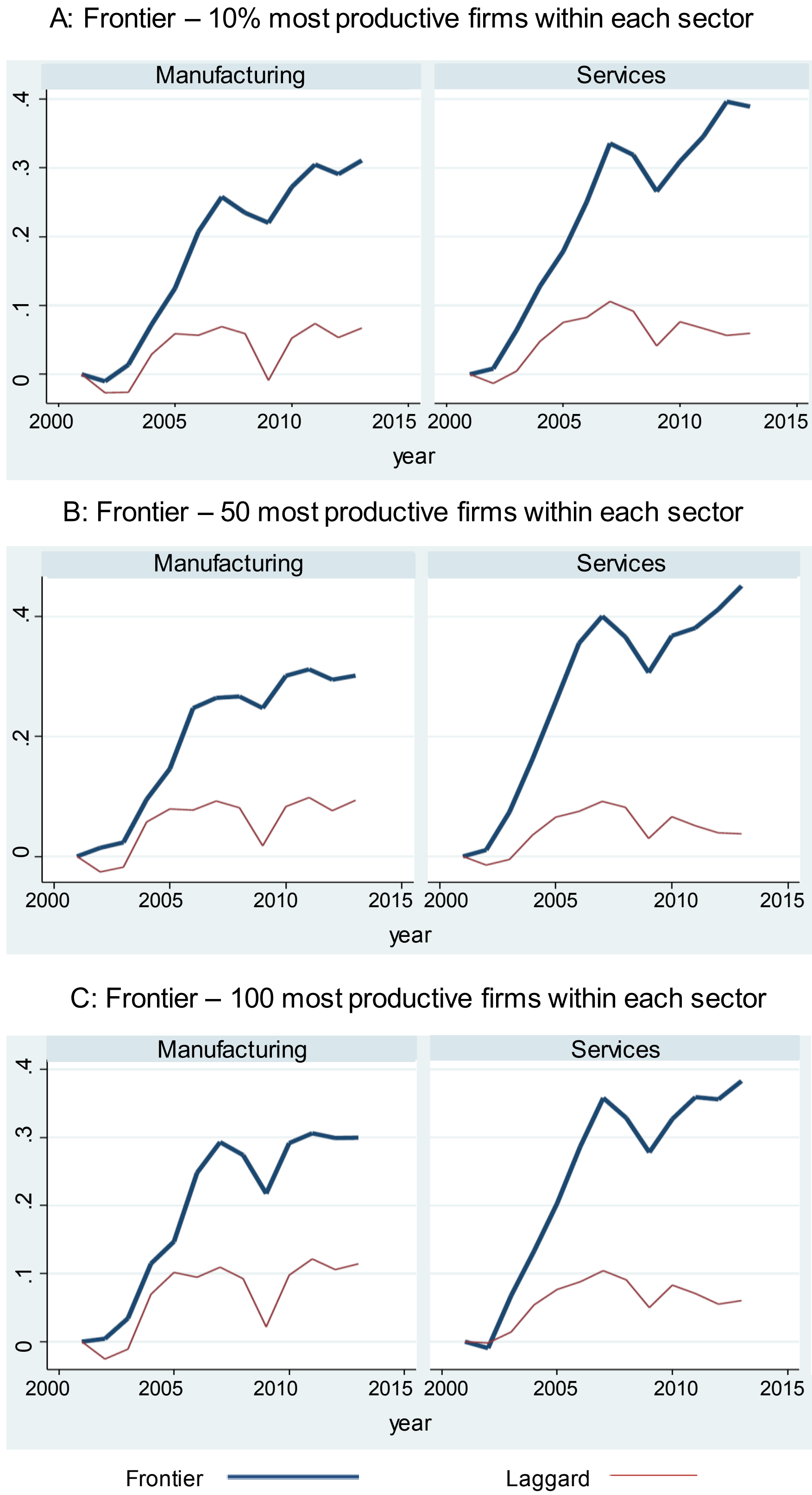
Figure A2: Divergence, alternative labour productivity definition



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)

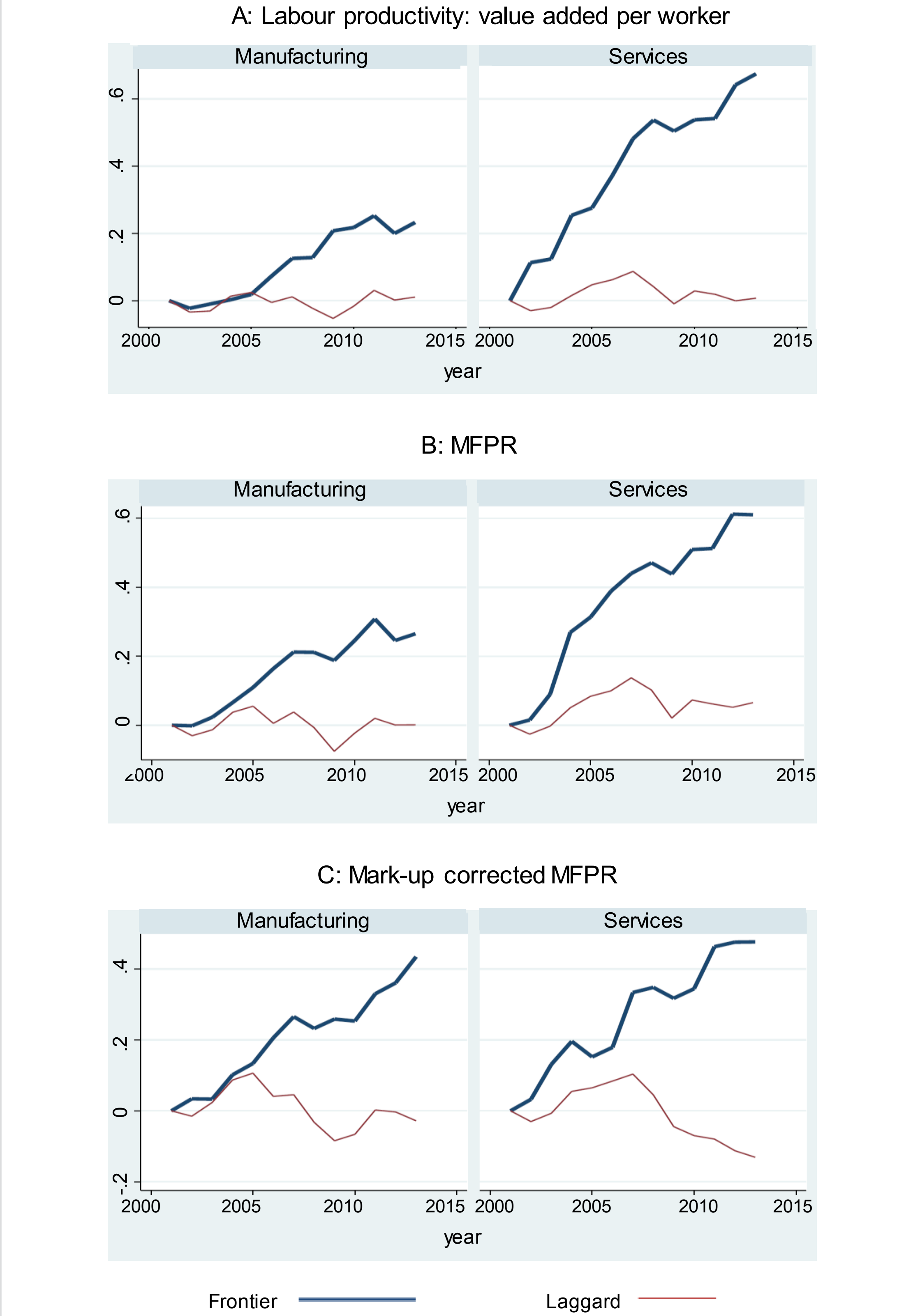
Figure A3: Divergence, alternative frontier definitions



Notes: the global frontier is measured by the average of log labour productivity (measured as revenue per w orker) for the top 5% of companies w ith the highest productivity levels w ithin each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unw eighted averages across 2-digit industries are show n 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)

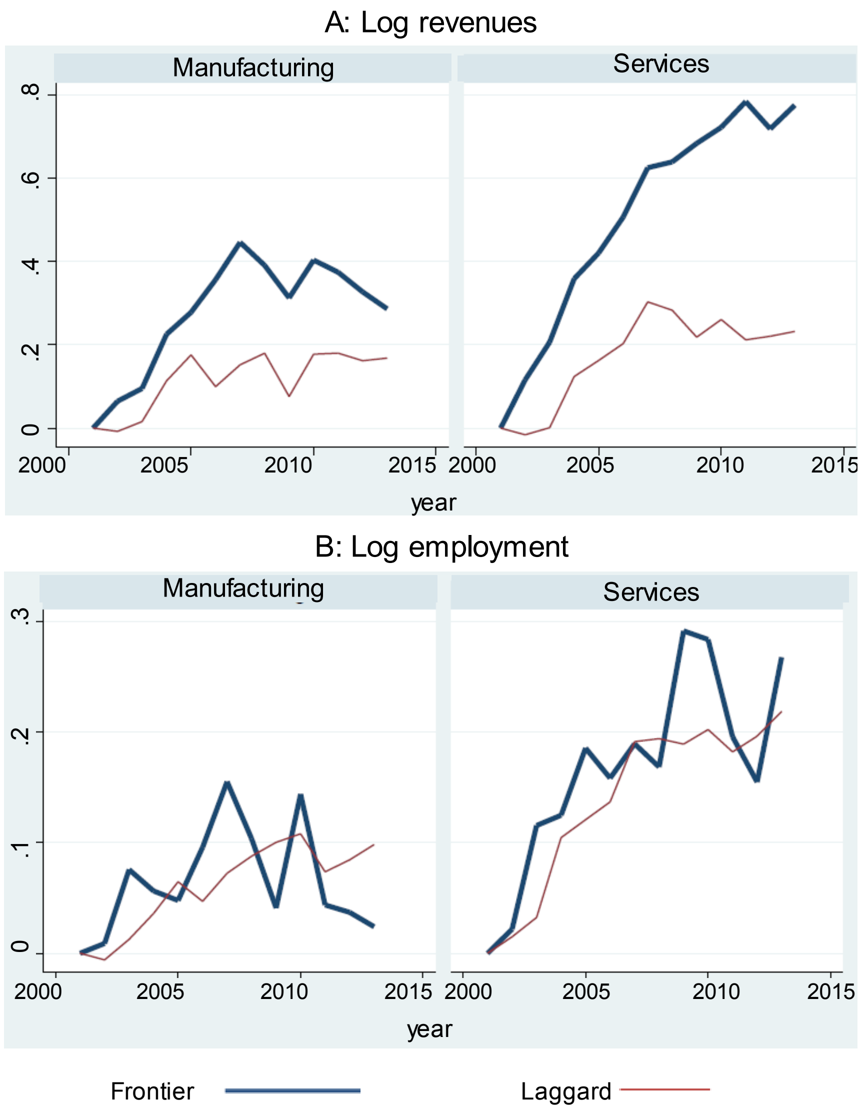
Figure A4: Divergence: excluding firms part of a MNE group



Notes: the global frontier is measured by the average of log labour productivity (measured as revenue per w orker) for the top 5% of companies w ith the highest productivity levels w ithin each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unw eighted averages across 2-digit industries are show n 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)

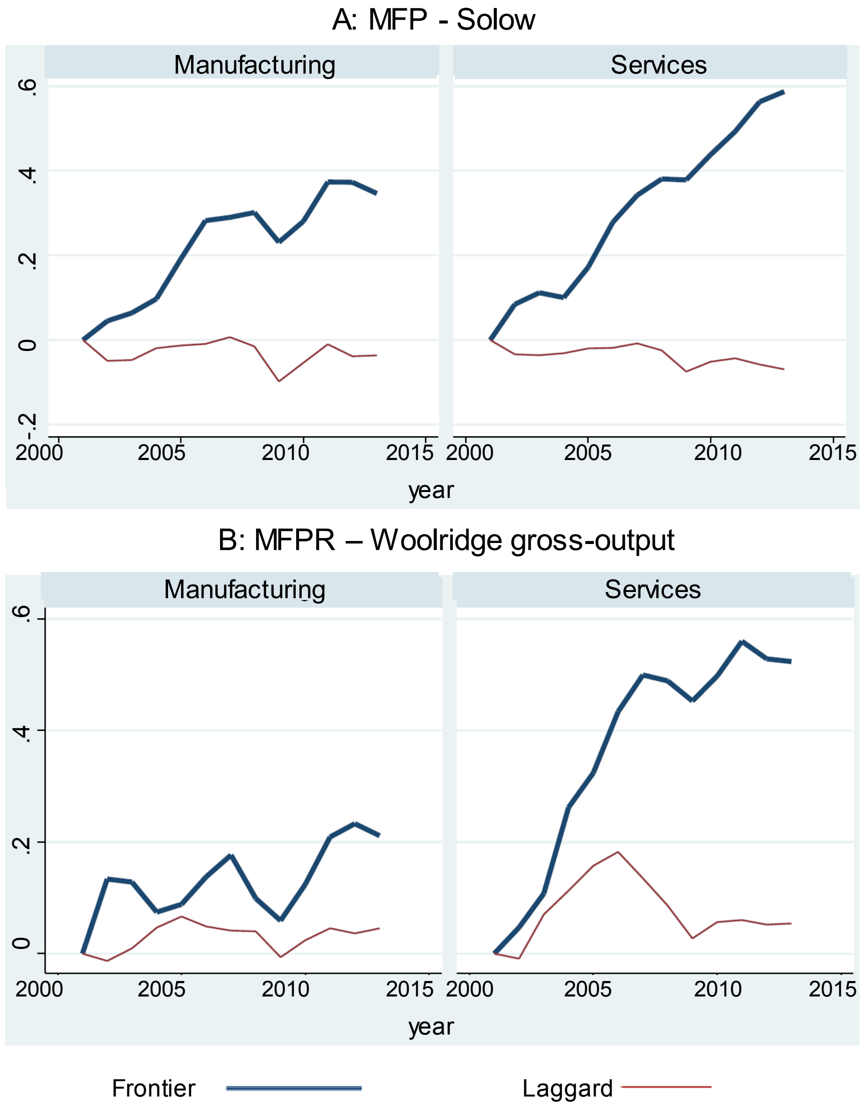
Figure A5: Divergence, firm size indicators



Notes: the global frontier group of firms is defined by the top 5% of companies with the highest productivity levels, measured by mark-up corrected MFPR within each 2-digit industry. Laggards capture 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 corrected MFPR uses the De Loecker and Warzynski (2012) 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)

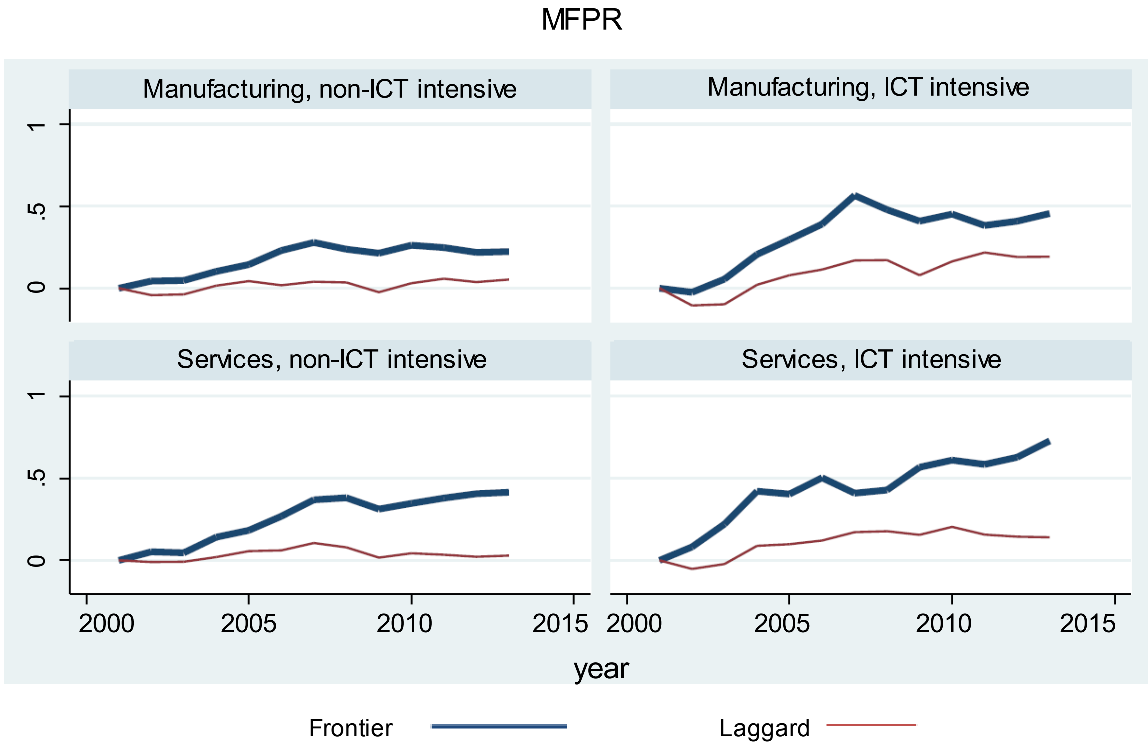
Figure A6: Divergence, alternative MFPR definitions



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)

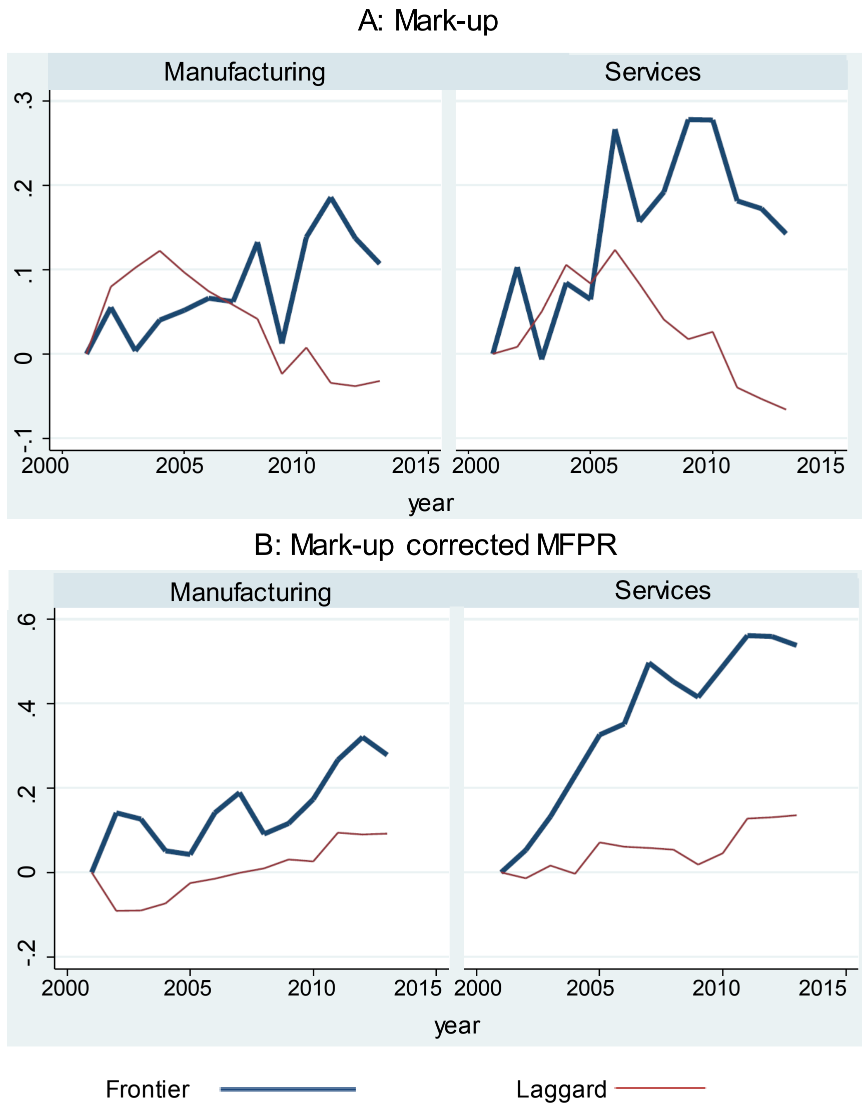
Figure A7: Divergence, by ICT intensity



Notes: the global frontier is measured by the average of productivity for the top 5% of companies w ith the highest Wooldridge (2009) production function estimation based productivity levels (MFPR) w ithin each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unw eighted averages across 2-digit industries are show n 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), w hile 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 corrrected MFP using materials as flexible inputs

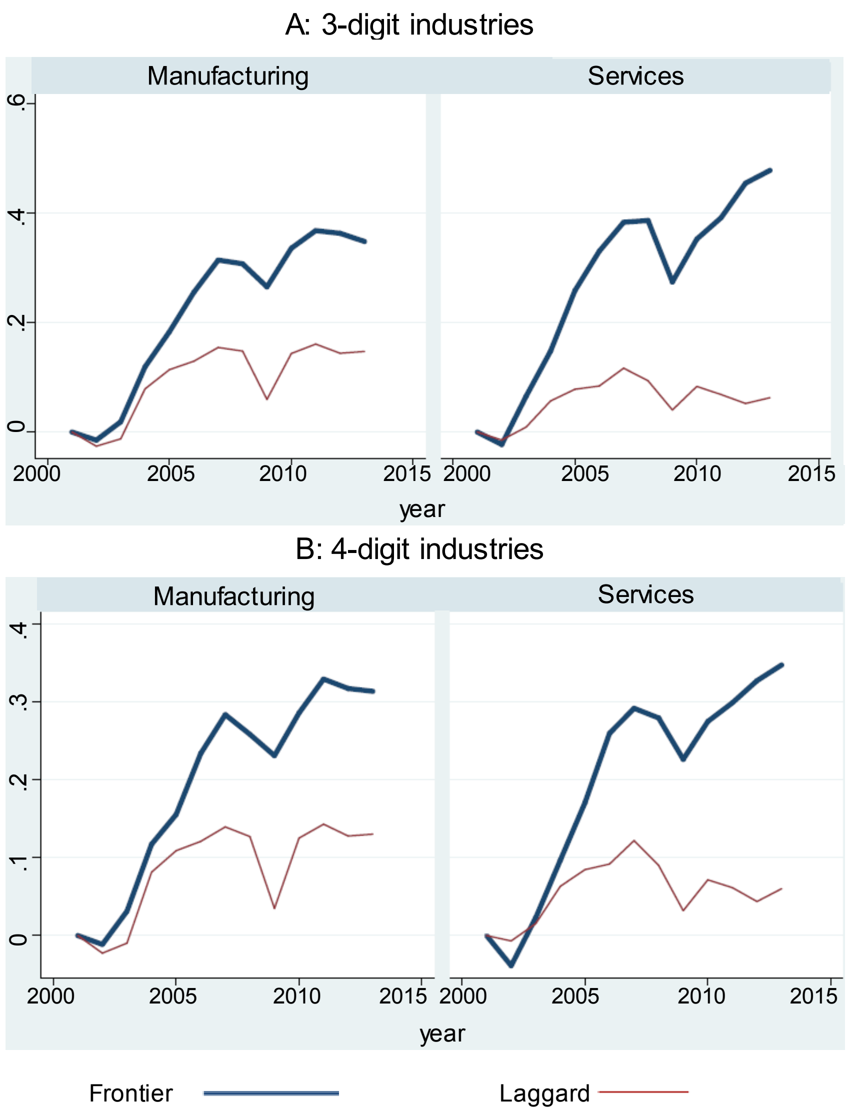


Notes: the global frontier is measured by top 5% of companies w ith the highest Wooldridge (2009) production function estimation based productivity levels (MFPR) w ithin each 2-digit industry. Laggards capture the average log productivity of all the other firms. Panel A show s the average level of (log) mark-ups and Panel B the average level of mark-up corrected MFPR\ for these two groups. The mark-up estimation uses the De Loecker and Warzynski (2012) methodology. Unw eighted 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: DIVERGENCE WITHIN MORE NARROWLY DEFINED INDUSTRIES

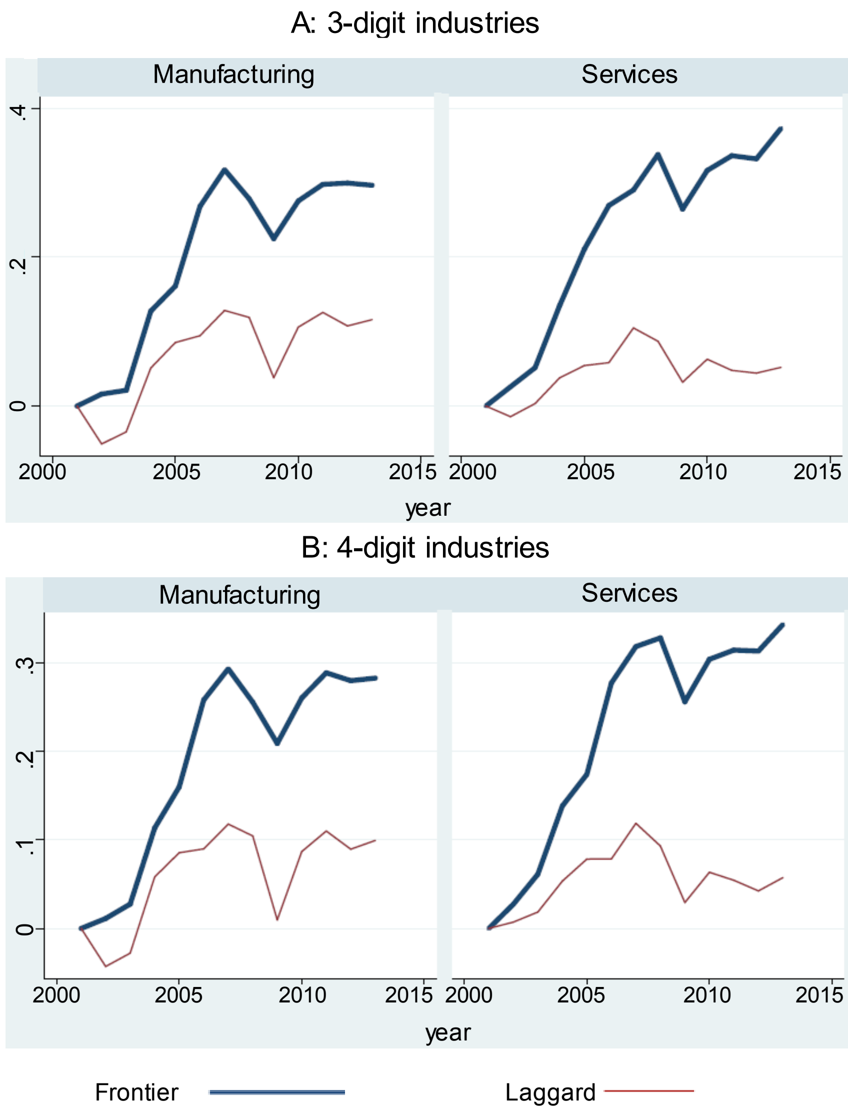
Figure B1: Labour productivity divergence within more narrowly defined industries



Notes: the global frontier is measured by the average of log labour productivity for the top 5% of companies w ith the highest productivity levels w ithin each 3-digit (panel A) or 4-digit (panel B) industry. Laggards capture the average log productivity of all the other firms. Unw eighted averages across 3 (or 4)-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. The time period is 2001-2013. The vertical axes represent log-point differences from 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)

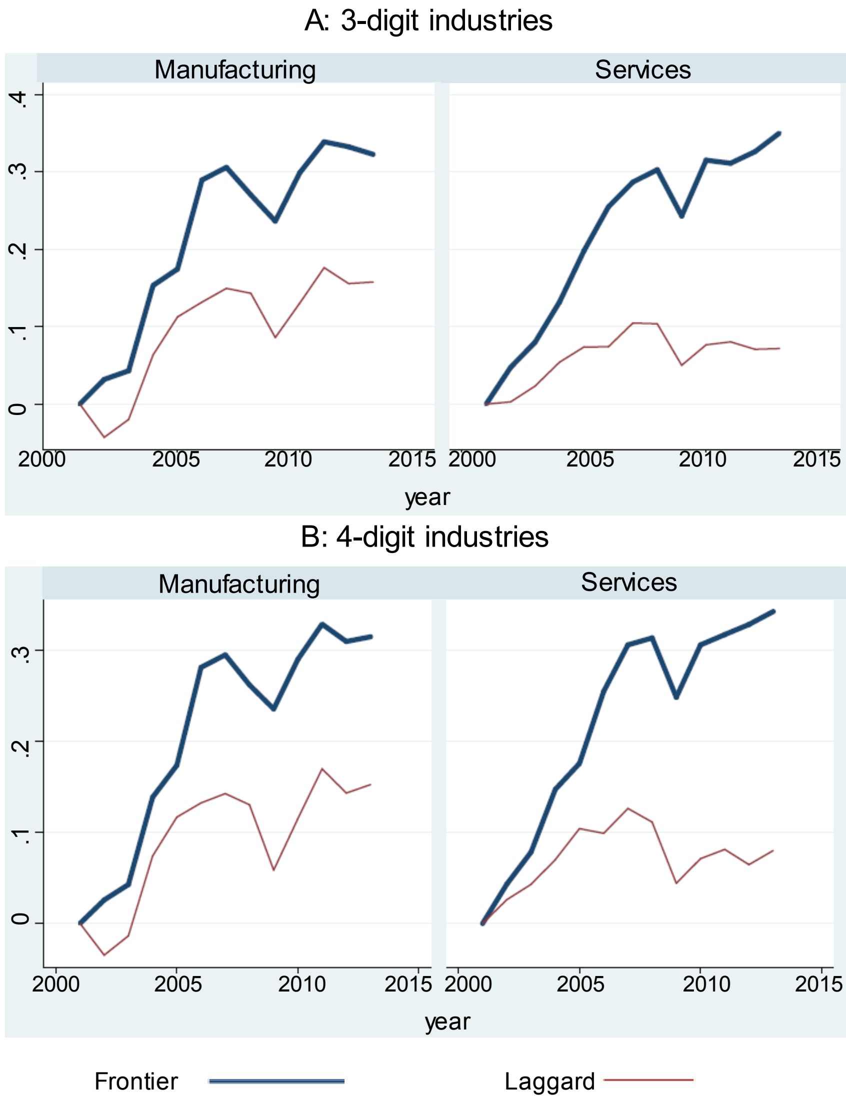
Figure B2: MFPR divergence within more narrowly definted industries



Notes: the global frontier group of firms is defined by the top 5% of companies with the highest MFPR levels within each 3-digit (panel A) or 4-digit (panel B) industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 3 (or 4)-digit industries are shown for manufacturing and services, normalized to 0 in the starting year. The time period is 2001-2013. MFPR uses the Wooldridge (2009) methodology based production function estimation conducted at the 2-digit level to avoid having to work with too few observations per industry. The vertical axes represent log-point differences from 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)

Figure B3: Mark-up corrected MFPR divergence within more narrowly defined industries



Notes: the global frontier group of firms is defined by the top 5% of companies w ith the highest MFPR levels w ithin each 3-digit (panel A) or 4-digit (panel B) industry. Laggards capture the average log productivity of all the other firms. Unw eighted averages across 3 (or 4)-digit industries are show n for manufacturing and services, normalized to 0 in the starting year. The time period is 2001-2013. MFPR uses the Wooldridge (2009) methodology based production function estimation conducted at the 2-digit level to avoid having to w ork w ith too few observations per industry. The vertical axes represent log-point differences from 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)

APPENDIX C:
MFP CONVERGENCE AT THE FIRM LEVEL

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, Redding and Simpson, 2006). Multi-factor productivity (A) is assumed to follow an error correction model of the form:

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

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 over time by including various gap $*D^j$ interaction terms, where D is a 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 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 (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, Duflo and Mullainathan, 2004).

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).

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 th¬e frontier growth term (Panel C).

Table C1: The pace of productivity convergence has slowed over time

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

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. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

APPENDIX D:
POLICY ANALYSIS, DESCRIPTIVENESS AND ROBUSTNESS

Table D1: Descriptive statistics

A: Unit of observation: industry-year

	Gap in MFP	Aggregate MFP	Gap in labour productivity	Aggregate labour productivity
Mean	1.426	4.584	1.618	11.687
Median	1.368	4.603	1.421	11.612
St.dev.	0.383	0.078	0.698	0.482
N	600	600	1056	1056

B: Unit of observation: country-industry-year

	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. Industry refers to 2-digit level detail according to ISIC Rev. 4 / NACE Rev 2, covering the non-farm, non-financial and non-rental business sector (industry codes 5-82 except 64-68). *Regulated services include those industries that are covered by the PMR indicator.

Sources: Orbis (for productivity gaps); EU KLEMS ISIC4 (for aggregate MFP, 12 countries, 1998-2007); OECD Detailed National Accounts (for aggregate labour productivity, 22 countries, 1998-2013); OECD Product Market Regulation Database (for the PMR indicator).

Table D2: Productivity divergence, link with aggregate productivity performance

OLS regression of aggregate productivity on productivity divergence at the industry-year level

OLS regression of aggregate productivity divergence at the industry-year level

	A. MFPR (1997-2007)			**B. Labour Productivity (1998-2013)**		
	Business sector (1)	Manufacturing (2)	Services (3)	Business sector (4)	Manufacturing (5)	Services (6)
Productivity Gap$_{i,t}$	-0.1172** (0.0479)	-0.1145** (0.0524)	-0.0605* (0.0303)	-0.0235* -0.014	-0.2103*** (0.0314)	0.0177 (0.0560)
Industry fixed effects	YES	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES	YES
Observations	600	230	280	1,056	384	464
R-squared	0.525	0.751	0.468	0.958	0.953	0.951

Note: The table utilises industry-year variation to relate aggregate MFP from EU KLEMS to the MFPR gap between frontier and laggard firms (Panel A) and aggregate labour productivity from the OECD national accounts to the labour productivity gap between frontier and laggard firms (Panel B). To construct industry-year observations, an unweighted average of each variable is computed across 12 OECD countries for MFPR – Austria, Belgium, Germany, Spain, Finland, France, the United Kingdom, Italy, Japan, the Netherlands, Sweden and the United States – and across 22 OECD countries for labour productivity. The productivity gap terms are calculated at the industry-year level, by taking the difference between the average log productivity at the frontier and among other firms. The results are robust to outlier filtering techniques, employing a productivity gap based on the median productivity of frontier and laggard firms and estimation via dynamic OLS to control for regressor autocorrelation and some degree of endogeneity. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table D3: 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	
	(2)	(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 country-industry 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. See more details in the Section 5.4.

Table D4: 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: Δ MFP gap		Y: Δ Mark-up corrected MFP	
	(2)	(2)	(3)	(4)
Δ 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 country-industry 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. See more details in the Section 5.4.

Table D5: IV estimation, MFP divergence and product market regulations in services

A: Instrument – Lagged level of PMR

	Y: Δ MFP gap		Y: Δ Mark-up corrected MFP gap	
	(1)	(2)	(3)	(4)
Δ Product Market Regulation$_{s,c,t}$	0.326** (0.163)	0.338* (0.194)	0.349* (0.196)	0.158 (0.251)
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	0.193	0.318	0.327	0.459

B: Instrument – Average PMR reform activity in other countries

	Y: Δ MFP gap		Y: Δ Mark-up corrected MFP gap	
	(2)	(2)	(3)	(4)
Δ Product Market Regulation$_{s,c,t}$	0.569*** (0.189)	0.676*** (0.179)	0.383 (0.341)	0.418 (0.351)
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	0.125	0.235	0.326	0.461

Notes: The table reports second-stage instrumental variable estimates. In Panel A, ΔPMR (denoting a five-year difference in PMR) is instrumented by the lagged level of PMR (in t-5). In Panel B, ΔPMR for a given country is instrumented by the average 5-year change in PMR in the given sector across all other countries in the sample. In each case, the instrumental variable is highly significant with the expected signs in the first-stage equation. Cluster robust standard errors (at the country-industry level) are in parentheses. 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. See more details in the Section 5.4. *** p<0.01, ** p<0.05, * p<0.1.

Table D6: 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*** (0.204)	0.862*** (0.268)	1.664*** (0.588)	1.980*** (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 country-industry 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	
	(2)	(2)	(3)	(4)
Regulatory impact$_{s,c,t}$	0.968*** (0.224)	1.138*** (0.302)	1.667*** (0.611)	1.776*** (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 country-industry 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. See more details in the Section 5.4.

APPENDIX E: DATA AND PRODUCTIVITY MEASUREMENT

Table E1: Information providers underlying the Orbis Database

Information provider	Country
Bisnode	Czech Republic Slovakia
Bureau van Dijk	Luxembourg
Cerved	Italy
Cortera	US
Coface Slovenia	Slovenia
Creditreform Austria	Austria
Creditreform Latvia	Latvia
Creditreform Luxembourg	Luxembourg
Creditreform-Interinfo	Hungary
Ellisphere	France
Experian	Norway Denmark
ICAP	Greece
InfoCredit	Poland
Informa	Spain
Informa Portugal	Portugal
Jordans	United Kingdom Ireland
Kamer van Koophandel	Netherlands
Krediidiinfo	Estonia
LexisNexis	Netherlands
National Bank of Belgium	Belgium
NICE Info	Korea
Suomen Asiakastieto	Finland
Thomson Reuters	US - Listed companies
TSR	Japan
UC	Sweden
Verband der Vereine Creditreform	Germany

Source: Bureau van Dijk, reflecting their set of information providers as of March 2016.

DATA

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 covers up to 24 OECD countries over the period 1997 to 2014 for the non-farm, non-financial business sector.[57] 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, given the limited availability of the policy indicators, or lack thereof, for some of the 24 countries considered. The industry coverage means retaining industries with 2 digit codes from 5 to 82, excluding 64-66 in the European classification system NACE Rev 2, which is equivalent to the international classification system ISIC Rev. 4 at the 2-digit level.

As discussed in Gal (2013), these data come from annual balance sheets and income statements, collected by an electronic publishing firm called Bureau van Dijk, using a variety of underlying sources ranging from credit rating agencies (e.g. Cerved in Italy) to national banks (e.g. National Bank of Belgium for Belgium) as well as financial information providers (e.g. Thomson Reuters for the US). See the full list of information providers to Bureau van Dijk regarding financial information for the set of countries retained in the analysis in Table E1.

Orbis is the largest cross-country company-level database that is available and accessible for economic and financial research. However, since the information is primarily collected for use in the private sector typically with the aim of financial benchmarking, a number of steps need to be undertaken before the data can be used for economic analysis. The steps we apply closely follow suggestions by Kalemli-Ozcan, Sorensen, Villegas-Sanchez, Volosovych and Yesiltas (2015) and previous OECD experience (Gal, 2013). Three broad steps are (i) ensuring comparability of monetary variables across countries and over time (PPP conversion and deflation); (ii) deriving new variables that will be used in the analysis (capital stock, productivity); and (iii) keeping company accounts with valid and relevant information for our present purposes (filtering or cleaning). Finally, Orbis is a subsample of the universe of companies for most countries, retaining the larger and hence probably more productive firms. To mitigate problems arising from this, we exclude firms with less than 20 employees on average over their observed lifespan.

VARIABLE DEFINITIONS

- **Value added** is defined as the sum of gross profits and the costs of employees. More specifically, value added is the sum of the following accounting categories as available from earnings statements: Profit (net income) for the period + Depreciation + Taxation + Interests paid + Cost of employees.

- **Capital stock** is derived from the book value of fixed assets using the perpetual inventory method on

57 This means retaining industries with 2 digit codes from 5 to 82, excluding 64-66 in the European classification system NACE Rev 2, which is equivalent to the international classification system ISIC Rev. 4 at the 2-digit level.

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, but applied only for growth rates and not (log) levels since it is crucial for our purposes that we retain in the analysis the most productive firms. Specifically, within each country, the top and bottom 0.5% of the annual growth rate distribution of productivity, capital intensity and mark-ups are left out, to avoid the influence of extreme outliers in terms of productivity (mark-up, capital-intensity) growth.

- **MFP** We employ the one-step GMM estimation method proposed by Wooldridge (2009), which mitigates the endogeneity problem of input choices by using material inputs as proxy variables for productivity and (twice) lagged values of labour as instruments. 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).

  The production function is estimated separately for each 2-digit industry but pooled across all countries, 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.

  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 corrected MFP measures.

DEFLATION AND CURRENCY CONVERSION

Real values are obtained by applying 2-digit industry value added deflators from detailed OECD National Accounts. This uses the ISIC Rev. 4 variant of the classification of activities. If deflators are missing at the two-digit industry detail, they are filled up by applying the growth rate in the price index at the immediate higher level of aggregation. For instance, if textile manufacturing (industry code 13) has missing information on the value added deflator for a particular country in a particular year, the growth rate from the immediate higher level (Textiles and wearing apparel, industry group 13-14) is used. If that is missing as well, then once more the immediate higher level (Textiles, wearing apparel, leather and related products industry group 13-15) is used. The same practice is followed for the other deflators used in the paper: gross output, value added, intermediate inputs and gross fixed capital formation.

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

FILTERING AND CLEANING

In order to limit the influence of erratic or implausible firm-behaviour, we exclude information for firms that report an extreme annual log-change (growth). More precisely, the variable is set to missing for the whole observed life of the firm if at least once, the variable has a growth rate that is in the top or bottom 1% of the growth distribution, at least once during their observed period. We do this procedure for the following variables: labour productivity measures, MFP measures, employment, capital, capital ratio, intermediates, value added and gross output. The rationale behind being relatively strict is that when a big growth rate – i.e. level shift – is observed, it is difficult to know whether the pre- or the post- shift period should be retained for the analysis. By removing the whole firm, we are also likely to exclude cases when a firm purchased another (relatively large) one as well as when a firm is being split-up.

REPRESENTATIVENESS ISSUES

A key drawback of Orbis is that it is a selected sample of larger and more productive firms and thus tends to under-represent smaller and younger firms in some economies. Accordingly, we exclude firms with less than 20 employees. Even so, the analysis of the MFP growth of laggard firms should be interpreted with particular caution, to the extent that laggards are likely to be less well represented in the sample.

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.[58] 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,

58 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 measure 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.

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).

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 to 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.

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.