The Future of Productivity
Improving the Diffusion of Technology and Knowledge

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Abstract: Productivity growth is the main driver of living standards. But productivity has slowed down over the past decade, starting already before the crisis. This paper shows that this is linked to a slowdown in the diffusion of global frontier innovations to other firms and difficulties in reallocating resources to the most productive firms. The paper also points to some key barriers to the diffusion of new innovations that prevent new knowledge and technology from flowing to less productive firms. Finally, it explores policy reforms that can help revive the diffusion machine and strengthen productivity growth.

Key words: productivity; innovation; technological change.

■ Productivity: now more than ever

Productivity reflects our ability to produce more output by better combining inputs, thanks to new ideas, technological innovations and new business models. Ultimately, productivity is about "working smarter", rather than "working harder". Innovations such as the steam engine, electrification and digitalisation have underpinned radical changes in the way in which we produce goods and services, in turn increasing living standards, well-being and leisure time. For these reasons, existing differences in income per capita across countries mainly reflect gaps in productivity (OECD, 2015a). However, productivity growth has slowed down in most OECD countries and also beyond over the past decade (Figure 1), fuelling concerns of persistent low growth. Against this backdrop, this paper discusses some impediments to productivity growth and proposes a policy approach to reviving growth in the global economy.

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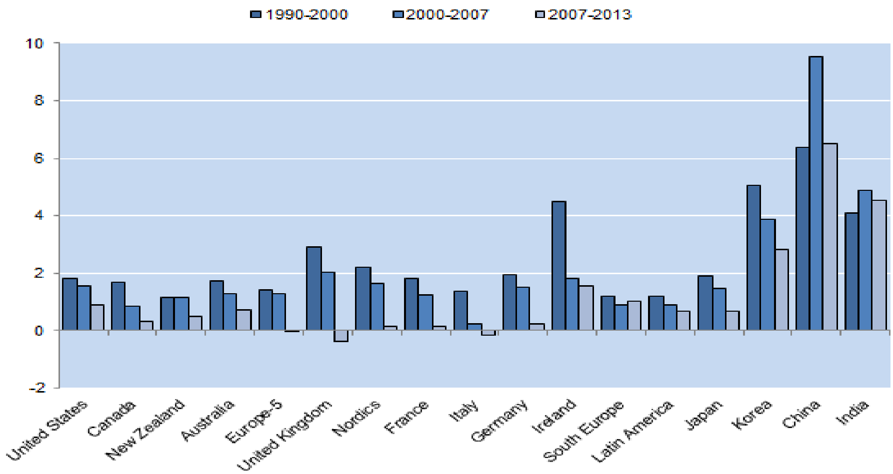
Figure 1 - Productivity growth slowed down even before the crisis

GDP per hour worked (unless otherwise noted)



Notes: Growth rates for the period ranges are the annual averages. Country groupings are aggregated using GDP-PPP weights. Europe-5 includes: Austria, Belgium, Luxembourg, the Netherlands and Switzerland; Nordic countries include: Denmark, Finland, Iceland, Norway and Sweden; Southern Europe includes: Greece, Portugal and Spain; and Latin America includes: Brazil, Chile and Mexico. Labour productivity data for China and India refer to GDP per worker.

Source: OECD calculations based on the Conference Board Total Economy Database

Over the coming decades, the OECD projects potential global growth to slow down further due to a number of headwinds, despite the continued rise of emerging economies (BRACONIER *et al.*, 2014). Besides population ageing, this reflects a slowdown in the growth of the labour force and in educational attainment. Productivity will therefore become the main driver of growth.

Nevertheless, the outlook for future productivity growth is hotly debated. For some, all the low hanging fruits have already been picked, the information and communications technology (ICT) revolution has run its course and other promising advances in biotechnology or highly-automated manufacturing are distant apparitions. 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 etc.) are far more significant than anything that has taken place since then (e.g. ICT), or indeed, likely to transpire in the future (GORDON, 2012; COWEN, 2011). These arguments are reinforced by the slowdown in business dynamism observed in frontier economies such as the United States. Gordon also argues that several headwinds will further slowdown future productivity growth in the US, including ageing population, deterioration of education, growing inequality, globalization, sustainability, and the overhang of consumer and government debt. Finally, the more technology advances and ideas cumulate, the more costly it becomes for researchers to innovate (JONES, 2009).

In contrast, technological optimists argue that the underlying rate of technological progress has not slowed down and that the ICT revolution will continue to dramatically transform frontier economies. According to BRYNJOLFSSON & 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). Similarly, MOKYR (2014) argues that economic history shows no evidence of diminishing returns with respect to technological progress. In fact, science and technology's main function in history is to make taller and taller ladders to get to the higher-hanging fruits (and to plant new and possibly improved trees). With respect to future developments, Mokyr emphasises three key factors: i) artificial revelation – whereby technological progress provides the tools that facilitate scientific advances, which then feed back into new technologies in a virtuous cycle (e.g. advances in ICT technologies raises the productivity of R&D); ii) access costs; and iii) a good institutional set-up for intellectual innovation. For instance, advances in computing power and information and communication technologies have the potential to fuel future productivity growth by making advances in basic science more likely (i.e. via artificial revelation) and reducing access costs.

■ The breakdown of the diffusion machine

Recent OECD work adds to this debate by distinguishing productivity growth at the global frontier with that of other firms. Research on the global frontier (GF) is scarce – e.g. most existing studies take developments at the GF as a given – and industry level MFP studies (see Bourles *et al.*, 2013) often assume that one country (i.e. the United States) occupies the position of the global leader. New OECD evidence identifies the 100 most globally productive firms in each industry at the frontier each year and shows that the global productivity frontier is actually comprised of firms from different countries, reflecting varying patterns of comparative advantage and natural endowments. [1] Moreover, they are very much "global firms" in the sense that they operate in different countries (often part of a MNE group), and are interconnected with suppliers/customers from different countries along global value chains (GVCs).

The new evidence shows that productivity growth of the globally most productive firms remained robust in the 21st century, despite the slowdown in aggregate productivity, but the gap between those high productivity firms and the rest has been increasing over time. Labour productivity at the global technological frontier increased at an average annual rate of 3.5% in the manufacturing sector over the 2000s, compared to just 0.5% for non-frontier firms, (Figure 2). The gap is even more pronounced in the services sector, partly due to low competitive pressures, which blunt the incentives to adopt best practices. This suggests that the main source of the productivity slowdown is not so much a slowing of innovation – which is continuing apace in the most globally-advanced firms – but rather a slowing of the pace at which innovations spread throughout the economy, i.e. a breakdown of the diffusion machine.

Firms at the global productivity frontier are typically larger, more profitable, and more likely to patent, than other firms. Moreover, they are on average younger, consistent with the idea that young firms possess a comparative advantage in commercialising radical innovations (HENDERSON, 1993; BAUMOL, 2002) and firms that drive one technological wave often tend to concentrate on incremental improvements in the subsequent one (BENNER & TUSHMAN, 2002). The relative strength of such global frontier firms likely reflects their capacity to both "innovate" and to optimally combine technological, organisational and human capital in production processes throughout global value chains (GVCs) and harness the power of digitalisation to rapidly diffuse and replicate leading-edge ideas.

More importantly, the rising gap in productivity growth between firms at the global frontier and other firms since the beginning of the century suggests that the capacity of other firms in the economy to learn from frontier firms may have diminished. While questions remain on why this is the case, it is consistent with some recent trends, including: a) longer run evidence on the penetration rates of new technologies (e.g. COMIN &

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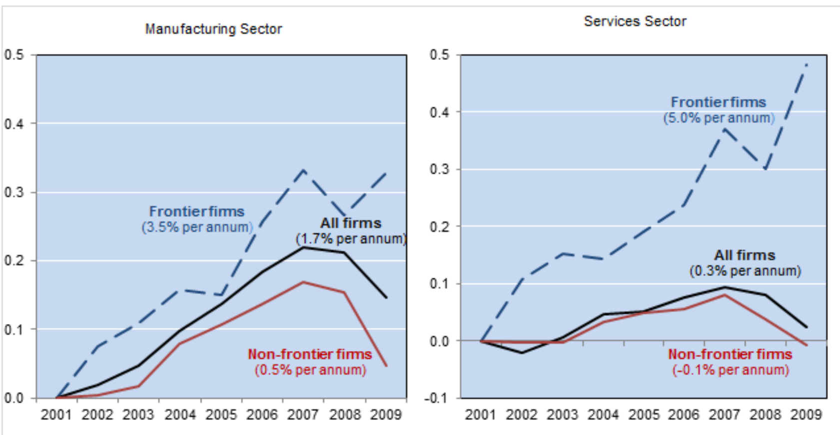
[1] See ANDREWS, CRISCUOLO & GAL (2015) for further detail on the distinction between global frontier and other firms and the underlying analysis. This paper also discusses the various data limitations, including the use of industry level deflators, which is typical in the literature due to the absence of firm level prices.

MESTIERI, 2013), which suggest that's while adoption rates for new technologies have fallen, there has been a divergence in long-run penetration rates once technologies are adopted; b) winner takes all dynamics (GABAIX & LANDIER, 2008), which are now important in several industries; and c) the rising importance of tacit knowledge in particular, and knowledge-based capital (KBC) more broadly (OECD, 2013; ANDREWS & CRISCUOLO, 2013).

Figure 2 - Solid growth of the globally most productive firms but spillovers to the other firms have been weak

Labour productivity; index 2001=0



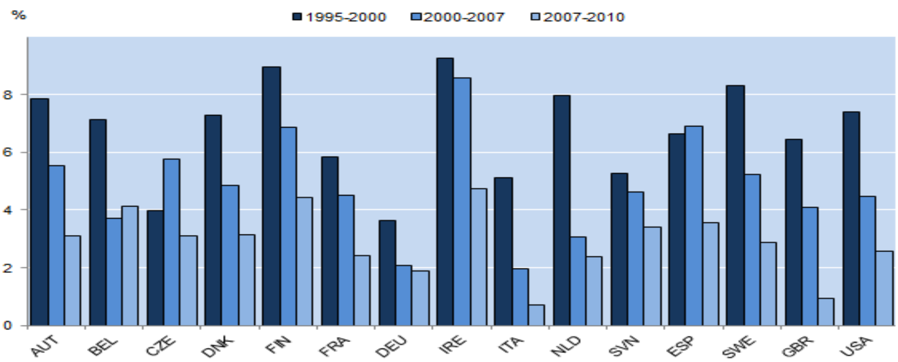
Notes: "Frontier firms" corresponds to the average labour productivity of the 100 globally most productive firms in each 2-digit sector. "Non-frontier firms" is the average of all other firms. "All firms" is the sector total from the OECD STAN database. The average annual growth rate in labour productivity over the period 2001-2009 for each grouping of firms is shown in parentheses. The broad patterns depicted in this figure are robust to: i) using different measures of productivity (e.g. MFP); ii) following a fixed group of frontier firms over time; and iii) excluding firms that are part of a multi-national group (i.e. headquarters or subsidiaries) where profitshifting activity may be relevant. See source for further detail on the methodology and sources used.

Source: ANDREWS, CRISCUOLO & GAL (2015)

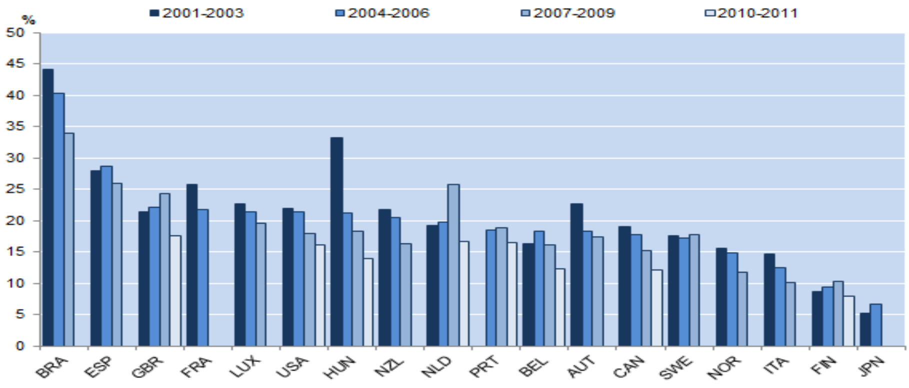
With respect to the latter, it is important to recognise that innovation is underpinned by investments in knowledge-based capital (KBC), including: R&D, firm specific skills, organisational know-how, software, databases, design and various forms of intellectual property (OECD, 2013). The intangible nature of KBC implies that these investments are often only partially excludable, which gives rise to knowledge spillovers. This raises the possibility that the productivity slowdown may partly reflect the pull-back in the pace of KBC accumulation observed in many OECD economies during the early 2000s (OECD, 2015a; Figure 3, Panel A). This factor has been cited as an important contributor to the productivity slowdown in the United States and the United Kingdom (FERNALD, 2014).

Figure 3 - Business dynamism has declined in OECD countries

A: Investment in KBC; annual average growth



B: Share of start-ups in all firms; average over period



Notes: Panel B reports start-up rates (defined as the fraction of firms which are from 0 to 2 years old among all firms) averaged across three-year periods for the manufacturing, construction, and non-financial business services sectors. Data refer to 2001-2010 for AUT, BRA, ITA, LUX, NOR, ESP and SWE; 2001-2009 for JPN and NZL; 2001-2007 for FRA; and 2006-2011 for PRT. Owing to methodological differences, figures may deviate from officially published national statistics. For Japan, data are at the establishment level. Data for Canada refer only to organic employment changes and abstract from M&A activity.

Source: Panel A is sourced from CORRADO et al.*, (2012)*
Panel B is sourced from CRISCUOLO, GAL & MENON (2014)

Investments in KBC play an important role in facilitating the diffusion of technologies and knowledge from the global frontier, as in the case of R&D, skills and software. Moreover, it is likely that the competitive advantage of frontier firms arises not only from their investments in technology and KBC, but how they tacitly combine different types of technology, notably ICT, and KBC – e.g. computerized information; innovative property and economic competencies – in the production process. It is this complementarity of technology and KBC that supports productivity growth (CORRADO *et al.*, 2014).

Closely related to the key role of KBC is that of ICT. In 2013, ICT investment in the OECD area represented 13.5% of total fixed investment and 2.7% of GDP (OECD, 2015b). Over 2001-13, ICT investment in the OECD area dropped from 3.4% to 2.7% of GDP, as part of an overall slowdown in investment in fixed capital. This decrease was accompanied by a shift in the composition of investment, with a declining share of IT and communication equipment and an increase in software (OECD, 2015b). [2]

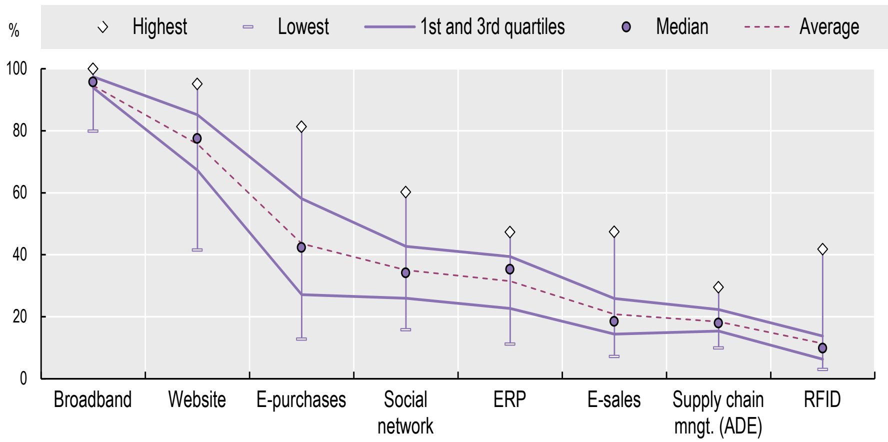
ICT has had considerable impacts on productivity growth over the past decades, in particular in some OECD countries, but typically only when investment in ICT was combined with investments in complementary assets, such as human capital, organisational changes and process innovations, i.e. knowledge-based assets (PILAT, 2005). Moreover, ICT-related changes in firms are typically part of a process of search and experimentation, where some firms succeed and grow and others fail and disappear. Countries with a business environment that enables this process of creative destruction may be better able to seize benefits from ICT – and KBC – than countries where such changes are more difficult and slow to occur.

This is particularly important as available data suggest that while almost 95% of enterprises in the OECD had a broadband connection in 2014, the use of ICT still differs heavily across firms and across countries. For example, only 21% of firms conduct e-sales and differences among countries in the use of various ICT technologies remain considerable (Figure 4). This is partly related to differences in the share of smaller firms across countries, supporting the results on productivity and its diffusion discussed above, but also suggests the presence of other barriers that prevent firms from using the potentially available ICT tools to their full extent.

[2] The shift in the composition of ICT investment may reflect a range of factors, including price effects.

Figure 4 - The diffusion of selected ICT tools and activities in enterprises, 2014

Percentage of enterprises with ten or more persons employed



Source: OECD (2015b), Digital Economy Outlook 2015

The rising gap between those high productivity firms and the rest discussed above raises key questions about the obstacles that prevent all firms from adopting seemingly well-known and replicable innovations. Future growth will depend on re-harnessing the forces of knowledge diffusion, which propelled productivity growth for much of the 20th century. While this is important across the economy, this is particularly vital in the services sector, given that services have typically had slower productivity growth than manufacturing. However, as they account for an increasing share of economic activity, improving their productivity performance is crucial for strengthening aggregate productivity growth.

■ Strengthen diffusion and resource allocation

It is important to understand the factors which shape the ability of firms that are the most advanced at home to learn from the globally most advanced firms. This learning creates scope for the diffusion of technologies and business practices from the home frontier firms to laggard firms within the same country. Moreover, given that cross-country differences in penetration rates of new technologies have increased over time (COMIN & MESTIERI, 2013), understanding barriers to the diffusion of unexploited existing technologies from national frontier firms to laggards is key in understanding cross-country differences in aggregate performance.

The evidence suggests that innovations at the global frontier do not immediately or inevitably diffuse to all firms. At first, innovations tend to become accessible to the most productive firms in an economy. Even then, frontier innovations often need to be adapted to national circumstances, by national frontier firms, and only then can they be adopted by laggards. This diffusion process is shaped by several factors:

- Global connections via trade, FDI, participation in GVCs and the international mobility of skilled labour provide scope for knowledge diffusion from global frontier firms to national frontier firms. Global openness also enhances competition, which can bolster incentives to adopt best practices.

- Experimentation by firms – especially new entrants – with new technologies and business models, and the ability of firms to reach a sufficient scale.

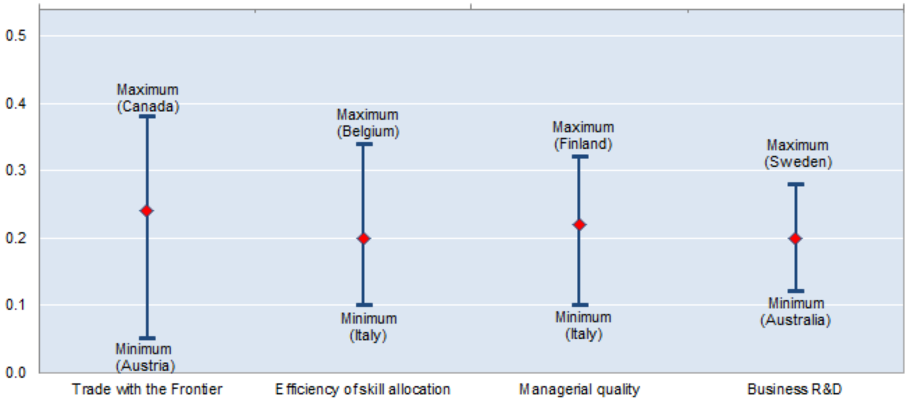
- A combination of investments in R&D, skills, organisational know-how (i.e. managerial quality) and other forms of knowledge-based capital to enable economies to absorb, adapt and reap the full benefits of new technologies.

Efficient reallocation of scarce resources, including skills and human capital, to underpin the growth of the most innovative firms. This is particularly vital given that firms need to achieve sufficient scale to cover the fixed costs of entry into global markets and to incentivise experimentation, by making it easier to scale-up successful ideas.

OECD countries differ significantly with respect to these structural factors – implying that diffusion comes easier to firms in some economies than others. Figure 5 presents estimates of how the benefits of a 2% acceleration in productivity growth at the global frontier – roughly equivalent to that observed in the United States during the late 1990s ICT boom – diffuse to economies, depending on four of these factors, i.e. trade openness, efficiency of skill allocation, managerial quality and investment in business R&D. For example, countries that trade very intensively with the frontier economy (e.g. Canada) would realise 0.35 percentage points higher productivity growth per annum from more rapid diffusion, compared to a country with fewer such trade linkages (e.g. Austria). Higher efficiency of skill allocation, R&D investment and managerial quality have similar effects and these gains are economically significant, particularly given an average MFP growth of only ½ per cent per annum over the period of analysis.

Figure 5 - Structural factors shaping productivity diffusion from the global frontier

Estimated frontier spillovers (% per annum) associated with 2% point increase in MFP growth at the global frontier



Notes: The chart shows how the sensitivity of MFP growth to changes in the frontier leader growth varies with different levels of policy variables. The diamond refers to the estimated frontier spillover effect associated with a 2% MFP growth at the frontier around the average level of the policy. The label "Minimum" (Maximum) indicates the country with the lowest (highest) value for the given structural indicator in a given reference year.

Source: SAIA, ANDREWS, & ALBRIZIO (2015)

One way to raise aggregate productivity is to improve the performance of national frontier firms towards the global productivity frontier. Besides supporting diffusion of productivity enhancements at the frontier, efficient resource allocation has important direct effects on productivity growth. The larger the more productive firms, the greater the extent to which their good performance gets reflected in overall economic growth. Unfortunately, the most productive and dynamic firms do not always grow to optimal scale. In some economies, the most advanced firms have productivity levels close to the global frontier, but they are under-sized. Estimates suggest that productivity in Italy's manufacturing sector could rise by 15% if its national frontier firms were as large as those at the global frontier (OECD, 2015a). More specifically, in Italy, approximately three-quarters of this productivity gap can be explained by the fact that national frontier firms – while actually quite productive in global terms – are relatively small compared to those at the global frontier. A similar phenomenon is also observed in the auto-parts manufacturing sector in Mexico (BOLIO *et al.*, 2014). By contrast, while national frontier firms in the United States are larger than those at the global frontier, aggregate productivity could rise by around 10% if they were also as productive as those at the global frontier. Understanding better why productive firms in some countries stay so small is important to removing barriers that prevent growth in overall productivity.

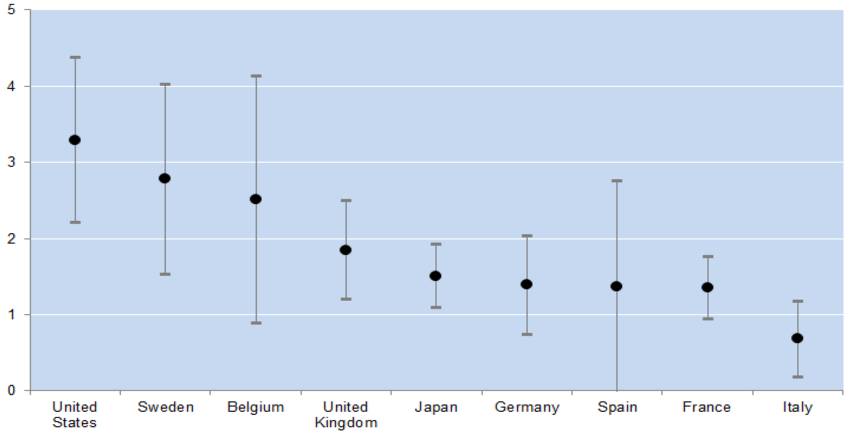
Overall, these differences in the size of national frontier firms are consistent with recent firm-level research for the broader economy which highlights that: i) the share of small firms is much higher in Italy, than in the United States and other OECD countries (CRISCUOLO *et al.*, 2014); and ii) the United States is much more successful than Italy at channelling scarce resources to the most productive firms (ANDREWS & CINGANO, 2014) and to innovative firms (ANDREWS *et al.*, 2014). Countries that are more successful at channelling resources to the most productive firms also tend to invest more in knowledge and innovation, i.e. knowledge-based capital (KBC). Incentives to invest in KBC will partly depend on perceptions about the ease with which labour and capital will flow to successful firms (i.e. can be reallocated from less productive to more productive firms), which would ultimately result in a more efficient allocation of resources in an economy.

To effectively implement and commercialise new ideas, firms require a range of complementary tangible resources to test ideas (e.g. to develop prototypes and business models), develop marketing strategies and eventually produce at a commercially viable scale. New OECD evidence (ANDREWS *et al.*, 2014) reveals important differences across countries in the extent to which capital and labour flow to innovative firms. For example, a 10% increase in the patent stock – one measure related to innovation that is widely available – is associated with an increase in the typical firm's capital stock of about 3% in Sweden and the United States; 1½% in Japan, Germany, France and Spain; and a ½% in Italy (Figure 6). Similarly, the ease with which patenting firms in the United States can attract labour is roughly twice as large as Italy, Germany, and Japan (ANDREWS *et al.*, 2014). [3]

[3] The low sensitivity of resources to patenting in countries such as Denmark, Finland and the Netherlands may reflect the fact that firms in small open economies may expand abroad rather than domestically.

Figure 6 - Do resources flow to more innovative firms?

Additional capital attracted by a firm that increases its patent stock by 10%; selected OECD countries (2002-2010)



Notes: The black dot shows the country-specific point estimate while the grey bands denote the 90% confidence interval (note that the confidence intervals vary across countries due to differences in the number of observations). These estimates are obtained from the following baseline fixed effects regression specification:

$$\ln Y_{i,s,c,t} = \beta_1 \ln(PatS_{i,s,c,t}) + \eta_i + \mu_{s,c,t} + \varepsilon_{i,s,c,t}$$

Where: Y is the economic characteristic (employment or capital) for firm i, in sector s, in country c at time t and PatS is the depreciated patent stock of firm i. The specification also includes firm fixed effects and industry*country*year fixed effects. To obtain the country-specific estimate, PatS is interacted with various dummy variables for each country.

Source: OECD calculations based on firm level data from the ORBIS-Patstat Database for the non-farm business sector. See ANDREWS, CRISCUOLO & MENON (2014)

These cross-country differences tend to be driven by younger firms: the sensitivity of capital with respect to patenting is about five times as large in the United States as compared with Italy for young firms, but this differential is only about double amongst older firms. The significance of these findings is enhanced by the fact that the extent to which young firms patent varies considerably across countries and that, while young firms account for a smaller number of patents, they are significantly more likely to file a radical patent than older firms (ANDREWS, *et al.*, 2014). Moreover, the resource flows associated with radical patents are around two times larger in Sweden and the United Kingdom compared to Italy. One interpretation of these findings is that in countries where reallocation costs are lower, firms may be more willing to experiment with disruptive technologies than in environments where reallocation costs are higher. This lack of resource reallocation in some countries also affects productivity growth, as it reduces the growth of the most innovative firms.

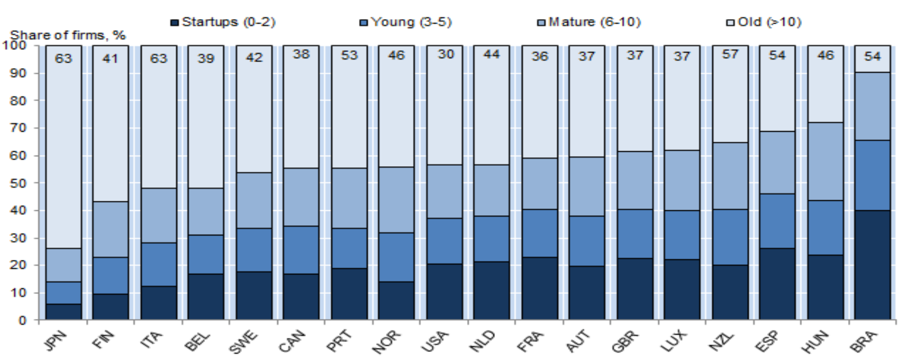
These findings are also informative from a policy perspective, and suggest that policy reforms in countries such as Italy should focus on improving the efficiency of resource reallocation mechanisms, while in the United States, policies that can improve within-firm productivity decisions could yield a greater marginal benefit.

The significant differences in the size of national frontier firms across countries extend to the whole population of businesses and intensify with the age of the firm. To a certain extent, these differences reflect barriers to up-scaling after firm entry. Indeed, cross-country differences in the post-entry performance tend to be more marked than differences in entry and exit patterns (BARTELSMAN *et al.*, 2003). If small firms are (on average) old, this might reflect barriers to post-entry growth and weak market selection mechanisms. For instance, only 22% of small firms in Finland – which account for 41% of total employment – can be classified as "young" (i.e. less than 5 years old), against more than 50% in the United States and other countries (Figure 7, Panel A). There are also significant cross-country differences in the relative sizes of old and new businesses: while old businesses in the United States are more than seven times larger than start-ups, this ratio drops to just above two in Italy and Norway, and below two in France, Finland or the Netherlands (Figure 7, Panel B).

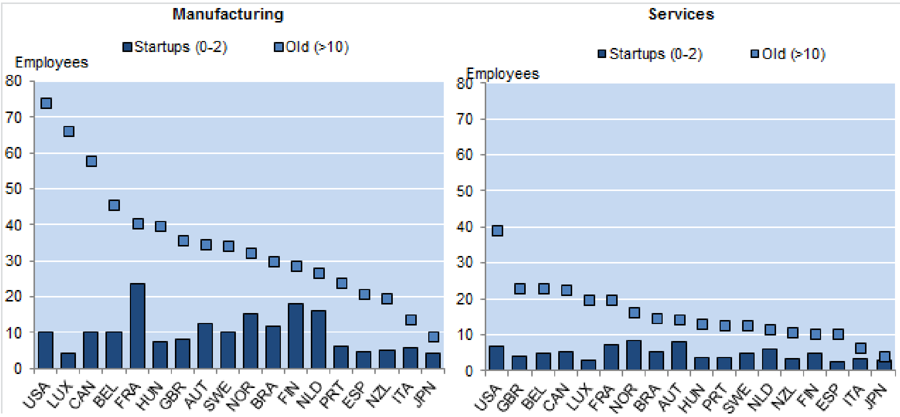
Similar differences can be observed following cohorts of firms across countries. A key message is that creative destruction and up-or-out dynamics are central: entry matters but what happens next is crucial – all else equal, young firms should grow rapidly or exit (i.e. "up-or-out") but not linger and become small-old firms (CALVINO *et al.*, 2015).

Figure 7 - The strength of market selection and post-entry growth varies across countries

A: Many small and old firms suggest less intense market selection in some countries



B: Post-entry growth – average size of young and old firms



Notes: Panel A shows the share of firms by age group in the total number of micro and small firms (below 50 employees). The numbers at the top of the chart shows the share of small firms in the overall population of firms. Panel B reports the average size of start-up firms (from 0 to 2 years old) and firms more than 10 years old.

Source: CRISCUOLO, GAL & MENON (2014).

These findings suggest that in some countries there are lower entry barriers for new firms; as a consequence, entrants can start off at a smaller size as they have more room for experimentation. Moreover, they can exit more easily if they are not successful. This, in turn, might contribute to stronger growth prospects for very productive and successful businesses. Also it indicates that in some countries barriers to growth (access to markets; burdensome regulation on starting businesses; lack of competition; etc.) might hinder the growth potential of young businesses.

■ Keeping the innovation engine running

Although productivity growth at the global frontier appears robust enough, the rising age of firms at the global productivity frontier could foreshadow a slowdown in the arrival of radical innovations. A policy framework that incentivizes frontier innovation – centred on innovation-specific policies and policies that foster experimentation – is therefore crucial.

One important area of innovation-specific policies concerns basic research. Basic research results in significantly larger knowledge spillovers than applied research and basic research also makes applied innovation 60% more productive (AKCIGIT *et al.*, 2014). Over recent decades, the developmental and applied stages of research have represented the largest share of the research expenditure of industry across OECD economies. At the same time, cross-country differences in basic research investment are significant and higher public spending on basic research enhances the ability of economies to learn from new innovations at the global frontier (SAIA *et al.*, 2015).

Despite emerging evidence of a positive link between basic research and productivity, the question on how best to support basic research remains. Given the high social value of basic research, which is maximised when accompanied by full public disclosure, governments often perform (as well as fund) research themselves through universities or public laboratories. One concern is that government research expenditure might crowd-out private sector research but recent research suggests that public funding of basic research at the National Institutes of Health in the United States results in significant spillovers, crowding-in private sector innovation and patenting activity (AZOULAY *et al.*, 2014).

Incentivizing risk taking by researchers and entrepreneurs alike requires a long-horizon structure with tolerance for early failure associated with reward for long-term success (MANSO, 2011; EDERER, 2009). Grants that are not based on short review cycles or strictly predefined deliverables but are rather forgiving of (early) failure and encourage experimentation are important (AZOULAY *et al.*, 2011). Of course, this may also lower the willingness of (private profit making) financiers to fund experimentation and radical innovations (NANDA & RHODES-KOPF, 2012). Thus, higher and more efficient public funding of basic research – which should provide the right incentives for researchers – is crucial, particularly since public innovation budgets are increasingly being directed towards more applied forms of research. Given the tight fiscal climate, rectifying this situation may be easier if countries share the costs and risks of such research through stronger collaboration.

To enhance the contribution from academic research to business innovation, governments in some OECD countries allow patented inventions from academic staff to be commercialized exclusively by university Technology Licensing Offices (TLOs) and the license royalties to be shared between the academic institutions and the academic inventor. The available, albeit scarce, evidence suggests that academic research and inventive activity respond positively to such monetary incentives (LACH & SCHANKERMAN, 2008), and thus such measures may play a role in raising productivity growth.

R&D collaboration between private firms and public research entities has also become increasingly common (OECD, 2002) and can support the diffusion of foreign advanced technologies (SAIA *et al.*, 2015; ANDREWS, CRISCUOLO & GAL, 2015). This reflects the fact that university researchers might be more connected to the global knowledge frontier, while financial support from industry might increase research possibilities and scope for international collaboration (by increasing the mobility of human talent). OECD research shows that R&D collaboration can also provide smaller and less productive firms with access to sources of knowledge – e.g. advanced machinery and skilled scientists – that typically require large upfront costs, thus supporting their catch-up to the national productivity frontier.

Experimenting with new products and processes is a defining feature of innovation at the firm level. Moreover, the innovation process is inherently uncertain and the highly skewed nature of the returns on venture capital (VC) investments suggest that the rapid success of frontier firms in some IT markets is impossible to predict a priori, even amongst the savviest VC investors (KERR *et al.*, 2014). In this environment, experimentation allows agents to assess and commercialize projects without investing the full amount and terminate projects quickly if they are not successful (NANDA & RHODES-KOPF, 2012). While advances in ICT technologies have significantly lowered the cost of experimentation for frontier firms, policies that can reduce the costs of experimentation on the entry (regulations affecting product and financial markets) and exit (EPL and bankruptcy law) margins will be important. In parallel, the uncertainty highlighted above demonstrates the dangers for governments using industrial policies to promote national champions.

■ Policies to revive the diffusion machine

Securing future growth prospects also depends on re-harnessing the forces of knowledge diffusion. This requires a policy framework that supports basic research and experimentation but also one that fosters pro-competition reforms to product markets, especially in services, incentivising firms to adopt better technologies and improve managerial performance. The OECD evidence finds that given a 2 percentage point acceleration in frontier growth, annual MFP growth will be around 0.2 percentage points higher in a country with low administrative barriers to entrepreneurship (e.g. Sweden), than in one where such barriers are relatively high (e.g. Greece).

Moreover, it is important to foster a level playing field that does not favour incumbents over entrants. Many policy measures, from environmental to fiscal measures, are designed to favour incumbents. In the area of innovation policies, it is important that R&D tax incentives are designed so as to be equally accessible to incumbent, young and new firms. Indeed, many young innovative firms typically make losses in the early years of an R&D project and thus will not benefit from the program unless it contains provisions for immediate cash refunds for R&D expenditure or allows such firms to carry associated losses forward to deduct against future tax burdens. Leveling the playing field for new firms can facilitate their growth over time, with important impacts on the diffusion of new innovations, and on aggregate productivity growth.

The aggregate benefits of diffusion will be magnified when structural policies foster the growth of the most productive firms. As noted already, the primary reforms that promote firm growth are those that make product markets more competitive. Beyond that, reforms that reduce skill mismatch and the scarcity of risk capital are important, given that weak firm growth often reflects that innovative firms cannot attract the skilled workers and capital they need to expand. Three key channels emerge through which policies can raise productivity via a more efficient allocation of resources and in particular human talent.

- First, policies that promote efficient firm exit – such as bankruptcy legislation that does not excessively penalise business failure – can reduce the likelihood that valuable human resources are trapped in inefficient firms. For example, OECD analysis shows that reducing the stringency of bankruptcy legislation from its most restrictive level in Italy – where skills mismatch and the share of old and small firms are very high – to the median level in Canada is associated with a 10 percentage point decrease in skills mismatch (OECD, 2015a). This in turn facilitates more effective knowledge diffusion. Product market reforms can also contribute to a more efficient allocation of skills and resources in general, via stronger competitive pressures.

- Second, policies that make labour mobility smoother can reduce an inefficient allocation of resources, in particular labour and skills, to underpin the growth of productive firms (ADALET McGOWAN & ANDREWS, 2015). For example, OECD analysis shows that reducing the stringency of employment protection legislation from the maximum levels (in Germany) to the median levels is roughly associated with a 3 percentage point reduction in skill mismatch (OECD, 2015a).

- Finally, adult learning policies that make skills complementary to technical progress can support inclusive productivity growth by better matching skills competencies to jobs. For example, OECD analysis shows that increasing participation in lifelong learning programmes from the low level in Italy to the median level in Estonia is associated with a 6 percentage point decrease in mismatch (OECD, 2015a).

■ Concluding remarks

Economic growth will increasingly depend on improvements in productivity, but the future of productivity is highly uncertain. In this context, countries should look to tap sources of productivity growth where there is potentially large and sure scope for improvement. A key conclusion of this paper is that future growth will depend on re-harnessing the forces of knowledge diffusion, which propelled productivity growth for much of the 20th century. In this regard, framework policies are crucial, but there is also a role for carefully designed innovation policies, including with respect to the funding of public research and the encouragement of science-industry collaboration. Reforms centred on improving the efficiency of resource allocation, which is far from optimal in many OECD countries, may also revive growth by making it easier for productive firms to thrive.

Moreover, and only briefly discussed in this paper, there is much scope to boost productivity and reduce inequality simply by more effectively allocating human talent to jobs. Since the knowledge economy increasingly requires skills that our education systems struggle to provide, the growth and equity benefits of policies that more effectively allocate human talent will rise. Achieving aggregate productivity gains via more efficient resource allocation requires well-designed framework policies accompanied by a range of flanking policies – including adult learning policies, well-designed social safety nets and portable health and pension benefit – to ensure that these gains are distributed more evenly than otherwise.

Finally, while this paper has touched on a number of key issues with respect to long-term productivity growth, our evidence base remains limited and further work will be needed to better understand the drivers of productivity growth and the policies that can help strengthen productivity going forward.

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