THE PRODUCTIVITY PARADOX

Reconciling Rapid Technological Change and Stagnating Productivity

Ian Goldin, Pantelis Koutroumpis, François Lafond, Nils Rochowicz and Julian Winkler

Oxford Martin School Programme
on Technological and Economic Change
In association with Arrowgrass

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Abstract

Productivity growth is an essential component of economic growth and development. The recent slowdown in productivity growth in leading economies has been described as a puzzle or paradox, leading to extensive research into possible explanations. In this paper, we review the relevant literature and identify the reasons underpinning the slowdown, which appear orthogonal to recent technological advances. Our work indicates that mismeasurement, the increasing dependence on intangible assets, the lack of investment in new technologies for the majority of firms and imperfect competition explain much of this slowdown. In this first comprehensive review of the dozens of explanations for the paradox, we describe the economic and institutional mechanisms that contribute to stagnating productivity, weigh their significance, and consider possible policy implications.

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Executive summary

Our contribution

Productivity is a key metric of economic progress and lies at the heart of questions of competitiveness, economic growth and incomes. Defined as the rate at which inputs are turned into outputs, it serves as a benchmark for the performance of firms, wages and over time determines the standard of living within and between countries. Productivity is shaped by organizational and management practices, regional and global market structures, the adoption of new technologies and the skills and competencies of individuals.

This report provides a thorough review of the origins of the ongoing productivity slowdown. Its originality lies in the breadth of its coverage, as we are not aware of any other report as comprehensive. By considering all of the dozens of possible causes of the productivity slowdown we are able to show that many of the explanations which have gained currency in policy and public debates are inadequate and at best provide a small part of the explanation. The causes of the productivity slowdown are more complex than is widely assumed. This means that the solutions are also more complicated. No one action will improve productivity. Rather, a range of actions is required. These need to be undertaken not only by governments, but also firms, universities and other institutions and by society at large. As broad as the explanations for the productivity paradox are, as wide are the set of actions required to resolve it.

Outline

This paper begins by showing that productivity growth is stagnating across the world. The evidence shows that both developed and developing countries have experienced this slowdown. Our aim is to examine the possible reasons for the productivity slowdown.

We first examine the way that national accounting systems measure the inputs and outputs which underlie the productivity statistics in order to understand the shortcomings. We challenge the widely held view that the productivity paradox is simply due to mismeasurement, while recognising the significance of the changing forms of capital and the growing role of intangible capital. Intangible capital has inherently different dynamics compared to material capital, which adds to the complexity of its measurement, depreciation dynamics and investment cycles. We identify the clear failure of the statistics to adequately account for the digital economy and dematerialisation of production. The ongoing digitization across countries and industries and higher dependence on data requires a redesign of the legacy practices used for the measurement of productivity. Nevertheless, mismeasurement is an inadequate explanation for the scale of the slowdown in productivity and only offers a partial explanation.

Second, we examine changes in human capital as a possible explanation for the slowdown, considering in turn education, ageing, migration and individual preferences as candidate factors. We show that these and other changes in the composition of the labour force are unlikely to be important determinants of the slowdown. The "creative destruction" process that turns specific skills into scarce inputs and renders others obsolete is continuing apace, but changes in these factors do not sufficiently explain the productivity slowdown. We argue that the new wave of technologies most likely contributes to an increasing skill mismatch rather than a productivity slowdown. Similarly, the global ageing trends appear to have mixed effects on national accounts. While the elderly population may be less entrepreneurial than the young and have different consumption patterns, not least in that they account for a growing share of care and health services, this impact is to a significant extent offset by higher incentives to increase automation as the younger labour force gets relatively smaller and wages rise.

"The difficulty lies not so much in developing new ideas as in escaping from old ones." **John Maynard Keynes**

Third, we look into the distributional and compositional effects of productivity across firms. A significant divergence in productivity between firms at the frontier and the rest is observed. As concentration, market power, and profits are also increasing across most industries, we discuss the reasons why the factors boosting the productivity of superstar firms are not diffusing as fast as in the past.

Fourth, we examine global trends that affect the performance of firms and nations including the globalization of trade and offshoring of production, as potential reasons for the observed productivity slowdown. While the increase in trade provides cheaper production opportunities, shifts in labour demand towards high-skilled occupations generates competition and produces technology spillovers. We therefore conclude that the muted growth in trade observed globally is unlikely to affect productivity. Protectionism may be a further blow to the recovery of international trade going forward, but the timing of the slowdown in the growth in trade is not associated with the much earlier slowdown in productivity.

Last, we examine the impact of the distribution of new technologies and research as potential key drivers for productivity growth and its slowdown. R&D expenditure has not slowed noticeably on aggregate, although its composition may have changed as a larger share of R&D expenditure is taken up by private businesses, and more is allocated to the funding of basic science. As a result, aggregate levels of patenting have also increased in spite of a declining research productivity.

Our main finding is that the lack of competition across firms drives much of the observed slowdown. The evidence shows that across the OECD fewer new firms enter and exit the market each year while the leading ones tend to dominate across sectors with increasing market shares. This increased concentration leads to reduced competition as incumbents have fewer incentives to keep investing in productivity improvements. Decreasing domestic competition – in the US and elsewhere – is correlated with less investment by the industry leaders, especially for investment into new technologies. In a more competitive landscape – even with identical levels of investment – the development of competing products and services would help increase productivity across firms through the threat of entry from competitors.

In our view, a key reason for the productivity paradox is that it takes time for new technologies to diffuse, for companies and workers to adapt, for complementary investments to take place, for the national accounts to adjust and for regulations and institutions to address changing needs. This process is rarely painless and tends to happen after the new technologies have spread to the broader economy. The productivity slowdown also cannot simply be attributed to the current rate of technological progress, as a range of other economic and demographic factors have contributed. A quick transition to the best available technologies would lead to all key dimensions of our economies becoming out of date at a more rapid pace coupled with significant institutional gaps that would need to be overcome as societies manage this process.

Policy makers should recognize the benefits of faster technological change and act upon its repercussions, by taking into account the unequal distributional consequences for firms, people and places. This implies that greater attention needs to be given to the implications in terms of the need to mobilise higher rates of private and public investment, to increase reskilling and renewal of education and welfare systems, and to improve flexibility and geographical mobility to keep pace with the changing location and needs of firms and society. The impact of these changes has been greater concentration of people and skills in fewer places and firms. This affects housing markets, transport systems and overall mobility, and without countervailing actions reduces the ability of society to share the benefits of frontier firms.

Introduction

Three decades following Solow's famous quip (1987) that 'you can see the computer age everywhere but in the productivity statistics,' this puzzle is as relevant as ever. The slowdown in measured productivity growth over the past fifteen years is evident in the data. Productivity growth rates have generally halved since 2004 across major OECD economies (Figure 1). In the US, productivity growth averaged 2.5% per year from 1996 to 2004. Since then, it has averaged 0.7%. Similar declines have been experienced in Europe, where productivity growth has fallen from around 2% to 0.9%, and in Japan, from 2% to 1.2%.

The productivity slowdown is not only confined to advanced economies; the emerging markets too have seen their productivity reduced, but this started later and from a higher level. For emerging markets as a whole, productivity growth slowed from 4 % in the period 2000-2007 to 3.2% during 2008-2015 and for China from 8.1% to 6.2% respectively[1].

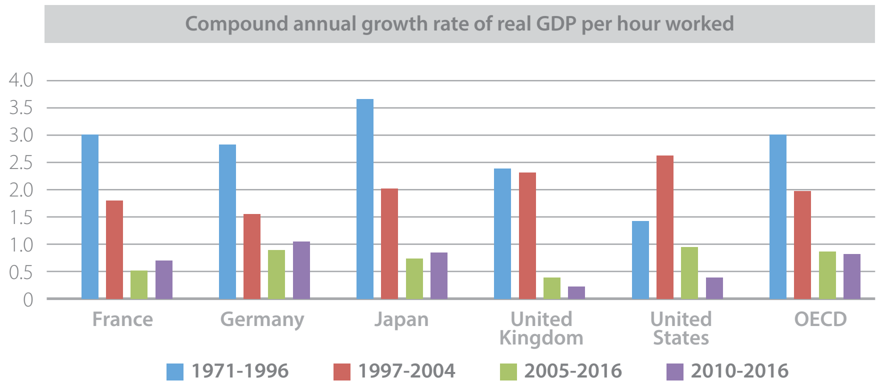


Figure 1: The labour productivity slowdown across countries
Source: OECD

In this report, we look into a range of metrics that measure the rate at which inputs are turned into outputs and which give insights into productivity. At the firm level, productivity is mainly driven by the adoption of new technologies and management practices[2], assuming other inputs are held constant. In theory, market competition gradually replaces inefficient firms with more productive ones in a process Schumpeter identified as being essential for progress. The underlying skills of the labour force and the openness to local and international investment can speed up this "creative destruction" process. So too can new technologies, the acquisition of skills, trade reforms and economic opening, as well as improvements in governance and management practices.

The slowdown in productivity growth has become a subject of wide-ranging analysis, with economists offering varying explanations for this phenomenon. One source of difference is whether slow adoption of powerful new technologies explains the slowdown or whether technological change is slowing down and the capabilities of new technologies have been exaggerated. Some suggest that 'the co-existence of a productivity slowdown and exciting new technologies,' is real but that this only has short-lived impact (which was felt when computers were adopted in the 90s)[3] . Others[4] challenge the usefulness of new technologies and argue that these do not measure up to past industrial revolutions, implying that the reason for the productivity slowdown is slowing technological progress. Technology optimists[5] on the other hand, point to time lags involved in the adoption process to explain

1 The Conference Board (2018)
2 Bloom, Sadun, & Van Reenen, 2012
3 Crafts (2017)
4 Gordon (2015)
5 Brynjolfsson, Rock, and Syverson (2017)

the failure of rapid technological change to be reflected in productivity improvements. They suggest that Artificial Intelligence (AI) can leverage rapid advances in other sectors and that patience and changing business practices are required to ensure widespread diffusion of existing productivity enhancing technologies. Technology optimists also argue that we are not yet seeing productivity improvements because output derived from these new technologies is mismeasured and that the digital economy in particular is inadequately captured in national statistics.

The argument that technological progress is not in fact happening at scale and so slowing technological progress explains the stagnation of productivity, and the counter argument that there are leaps in technological progress but that we haven't seen them impact yet as they take time to be adopted by businesses are both assertions that cannot be tested with evidence. In our view, neither of these popular but polar opposite explanations is satisfactory. Our aim is to go beyond assertions to provide a rigorous evidence-based review of the causes of the productivity slowdown.

We consider a range of factors which can affect productivity, including business cycles, institutions, regulation, education and business dynamism. We consider the views of authors[6] who suggest that slowing productivity is linked to the financial crisis, the resulting regulatory forbearance and quantitative easing having made cheap credit more widely available, thereby reducing competitive pressures and impeding the rate of innovation and diffusion dynamics. Other authors[7] point to the depressed aggregate demand (and thus lower investment), and weakness in markets and institutions (which for example result in zombie firms or labour hoarding) that magnify the effect of the slowdown in technological change. Low productivity growth in core industries (such as oil and gas and financial, health and education services) and changes in factor utilisation, including the retainment of unproductive labour, are also given as an alternative explanation for the productivity slowdown[8]. Another explanation is that slowing business dynamism, stagnating educational attainment and declining returns to research are the cause[9]. Others[10] tie the productivity slowdown to the wider discussion on secular stagnation by pointing out either the divergence in returns on risky capital and safe assets or the lower investment and investor confidence levels. The changes in traditional inputs, including the contraction in both capital formation and intellectual property investment[11] and the misallocation of resources have also been offered as explanations in this process[12].

This wide range of views are unlikely to all be correct. In this report, we review the reasons outlined and weigh their relative importance as contributors to the productivity slowdown. We first look at measurement in national accounts. Secondly, we consider the changes in human and physical capital, including intangibles. Thirdly, we review explanations associated with the distributional effects of productivity across firms before moving to the global effects of trade and offshoring. The fourth set of explanations we consider are those associated with technological progress and research investments. In the final section, we conclude by summarising the evidence and possible policy and other implications.

6 *Haldane (2017)*

7 *Askenazy, Bellmann, Bryson, and Moreno Galbis (2016)*

8 *Goodridge, Haskel, and Wallis (2016)*

9 *Crafts, 2017; Fernald & Jones, 2014*

10 *Caballero, Farhi, & Gourinchas, 2017; Carlin & Soskice, 2018*

11 *Hall, 2017*

12 *Barnett, Batten, Chiu, Franklin, & Sebastia-Barriel, 2014; Pessoa & Van Reenen, 2014*

Mismeasurement

Given the importance of productivity for economic prosperity, the question of whether we are measuring productivity accurately is of fundamental importance. There are many reasons to doubt these estimates, especially in an era when digital services are getting harder to measure as inputs, intermediates or outputs. In particular, national accounts, on which productivity is measured, are built upon the inclusion of what are considered to be "productive" sectors. However, activities which are excluded from economic statistics and not accounted for in productivity statistics may still have a real impact on other measured outputs such as welfare.

In addition to a growing share of activities not being measured, another source of growing mismeasurement could be that price indices do not accurately reflect changes in quality and the value of new goods. Since the value or price of outputs is a key component of the productivity statistics, a failure to account for quality or real value tends to overestimate the impact of inflation and underestimate improvements in real output. A further source of mismeasurement we consider is that of the failure to account for inputs, and in particular intangibles and free goods. Each of these aspects is discussed separately below.

Unmeasured inputs and outputs

A range of outputs are not measured because they are excluded from national accounts, including those associated with the shadow economy and parts of the digital economy. These measurement errors apply to the outputs of the public sector, the household sector and the service sector[13]. Many outputs from these sectors are not captured in the national accounts, with differing accounting rules further complicating the comparability of statistics between countries.

Apart from these exclusions in national accounts, there are other market activities that go unreported and should be included in GDP measurements. These include the shadow economy and the illegal exchanges that are not always reported in the productivity data. The level of this oversight can be large even for those rich OECD economies with an average of 17% of GDP estimated to be underreported as a result of these transactions[14]. In Sub-Saharan Africa the shadow economy represents more than a third of economic activity (an estimated 38%). In Eastern Europe and Central Asia it is similarly around 36% whereas in high income OECD countries it estimated to average around 13%. The shadow economy is invariably mismeasured and also changes over time, as changes in local regulations, taxation or the quality of public and private services and enforcement vary in each country.

The digital economy has facilitated the launch of platforms for transport and rental services (predominantly through Uber and AirBnB) which contributed further towards shifting inputs from the measurable GDP into unmeasured territory. These platforms have turned individuals and households into quasi-producers without a change in the underlying assumptions for national accounting. While this practice is not new – as households have been offering informal services for a long time – its scale and reach to consumers is unprecedented. In 2017, AirBnB had more than 4 million listings worldwide and its capitalization exceeded the combined capitalization of Hilton and Hyatt[15]. These developments have been driven by the

13 Hulten, 2010

14 Shown in a sample of 162 countries during the period 1999 – 2007 (F. Schneider, Buehn, & Montenegro, 2010)

15 Google Finance (2017)

opportunities available to households and the adoption of high capacity computing power connected through fixed or mobile internet services. The resulting level of the GDP and productivity mismeasurement error depends in large part on the ways that household and corporate incomes are declared and appear in the statistics.

Apart from platforms, new technologies can affect economic measurements in other ways. In a recent study,[16] technology was modelled as an "output-saving" rather than input saving moderator for consumer utility. This contradicts the common assumption that better technologies lead to lower use of a certain input to produce more output. Technological change associated with the digital economy has often done the opposite: individuals use less specific goods or services simply because their improvements mean that they can be used more efficiently. For example, we no longer have to spend hours shopping as we can do so online.

Additionally, there is an ongoing academic debate on the effects of free or mismeasured digital goods on consumer surplus. Many new digital goods are free to consumers and so they don't directly appear in household final consumption. Several authors have tried to quantify the contribution of internet access and e-commerce. Their estimates are modest but vary substantially from 0.05% to 3.3% of GDP[17]. Syverson's (2017) update of this number with more generous assumptions leads to $863bn, which implies that even maximising the possible impact would still only explain about a third of the productivity slowdown. More recent estimates by Brynjolfsson, Eggers, and Gannamaneni (2018), using discrete choice experiments, suggest a rather high estimate, with the median consumer requiring $32,000 to willingly give up all digital services (search, email, etc.) for a year. These implied values for the consumer surplus generated by the digital economy are at the higher end of widely varying estimates of the potential errors in measurement[18].

Quality adjustment

When the quality of goods and services improves, it is not necessarily reflected in output statistics as these may remain unchanged. For instance, if a constant number of units is sold but quality increases and price stays constant, we would hope that our measure of real output increases. This will be the case only if our price index is quality-adjusted, so that price per quality-adjusted unit decreases. This issue has become even more relevant today due to the growth of the digital economy and ICT services[19].

A typical example that highlights this effect is the price of a phone bill, which may have only changed a little over the last decade. Meanwhile the volume of text messages, minutes, and data provided in new bundles has grown exponentially. Other examples related to smartphones include digital photos and high accuracy GPS services[20]. In both cases, the number consumed (e.g. number of photos taken) has increased dramatically, but overall measured output and sales in GDP of standalone cameras, photo, music and GPS equipment have gone down. The quality-adjustment for smartphone prices has not nearly kept pace with what the devices provide, and their substitution for a wide range of devices that previously contributed to GDP. On a quality adjusted basis, official prices of telecommunication services should have fallen by up to 90%, instead of the 10% reported between 2010 and 2015[21]. The problem of the mismeasurement of the digital economy has also allegedly become worse

16 *Hulten and Nakamura (2017)*

17 *Byrne, Oliner, and Sichel (2017), Byrne et al. (2017), Syverson (2017), Brynjolfsson and Oh (2012)*

18 *Byrne, Oliner, and Sichel (2017) evaluate the contributions of internet quality and e-commerce, finding that TFP growth in 2004-2014 would be only five basis points higher. Byrne et al. (2017) and Syverson (2017) reviewed recent studies estimating the effects of free digital goods and found generally modest effects, but the numbers vary considerably. One approach is to measure the time consumers spend online. With their valuation of individuals' time, Brynjolfsson and Oh (2012) estimate that the consumer surplus created by these services is around $100b per year, a significant number that still represents only 3.3% of the "missing" $3 trillion.*

19 *Boskin, Dulberger, Gordon, Griliches, & Jorgenson, 1996; Gordon, 1990; Nordhaus, 1996, Abdirahman, Coyle, Heys, & Stewart, 2017*

20 *Varian, 2018*

21 *Abdirahman et al. (2017)*

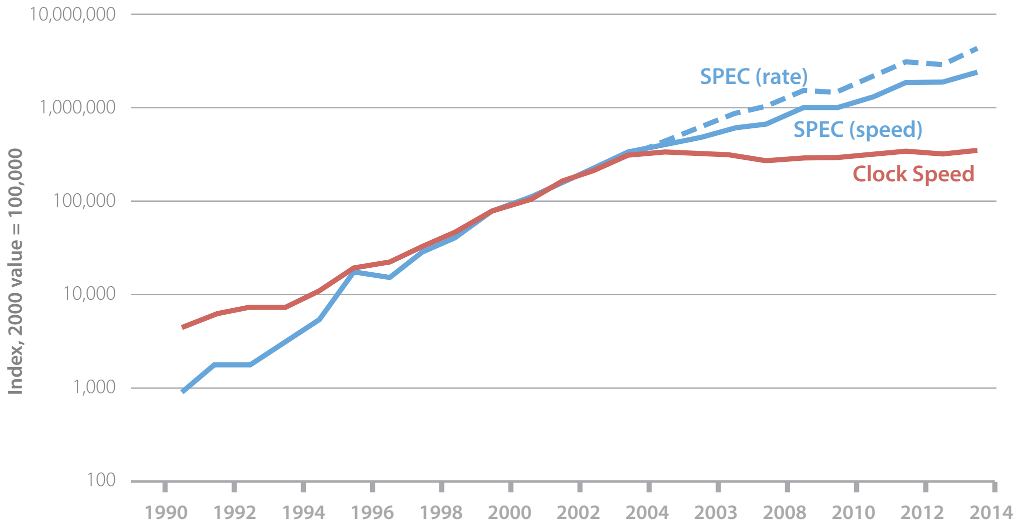


Figure 2: Desktop Computer Performance Measures
Source: Byrne et al. 2016

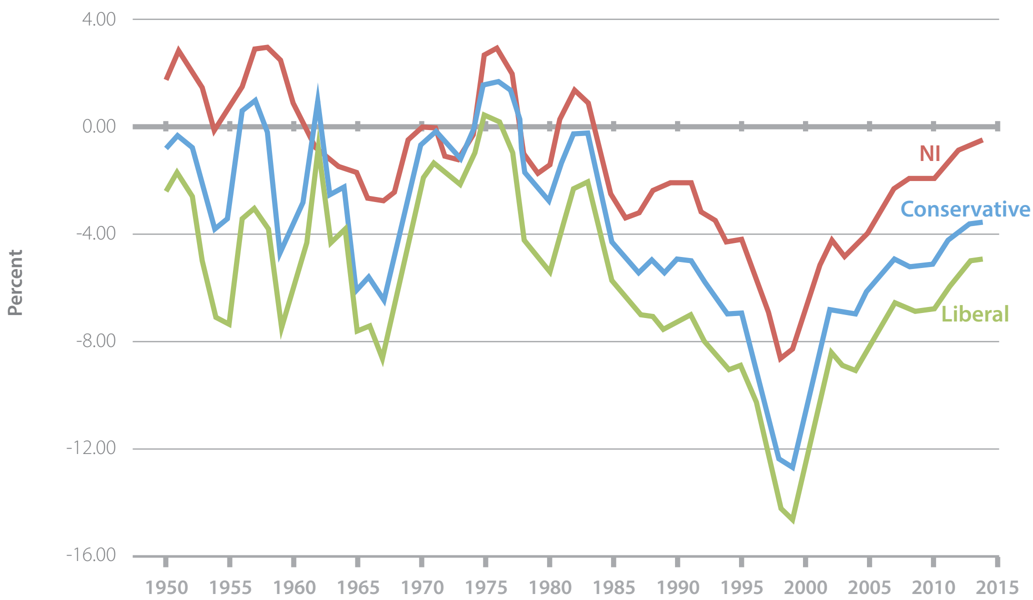


Figure 3: Information Technology Investment Prices Indexes
Source: Byrne et al., 2017; US BEA

as investment has shifted increasingly from major hardware investments toward categories associated with less certainty, notably from hardware to software.

If mismeasurement is to explain the productivity slowdown, the problem must have been getting worse, since if there has always been mismeasurement it would not explain the collapse in productivity. Are these mismeasurement issues new or have they become worse in recent years? Any corrections to the deflators would need to be substantial and if they are to explain the scale of the productivity slowdown, applicable to large parts of the economy. Recent studies evaluating these conditions have concluded that mismeasurement of ICT prices is unlikely to be sufficient to account for the scale of missing productivity.

When corrected PPI and investment deflators are applied (for computers, communications, software, and other IT) to compensate for the improvements in quality, they fail to lead to substantial upward revisions in the productivity numbers[22]. Conversely, some even claim that mismeasurement was in some cases worse before the productivity slowdown so if anything it may be more severe than suggested by the statistics[23]. The fact that the productivity slowdown is no less marked in countries with a much lower IT intensity, is another indicator that mismeasurement of the digital economy does not adequately explain the productivity slowdown.

New and free goods

New goods are hard to measure because they cannot be compared ("matched") with existing goods to construct price indices. Subtler still, if new goods replace existing goods, the procedure followed by statistical agencies to impute price changes from the average of surviving product will overestimate inflation. This is compelling as an explanation for the productivity paradox, as it implies that it is precisely when creative destruction is accelerating that more growth would be mismeasured. Research estimates that the missing growth associated with this mismatching represented 0.5% in the US, with slightly higher numbers post 2006[24].

While the literature on the productivity paradox has focused on semiconductors and digital services, there are other sectors in which mismeasurement is also likely to be applicable, health being chief among them[25]. Both health services and the associated technologies have improved and as people live longer, health has grown substantially and regularly as a share of the total economy over the past 70 years. This source of mismeasurement may have grown more serious in the aggregate, but it is difficult to see how a step-change in this mismeasurement may have been associated with the collapse in productivity over the past fifteen years.

22 *Byrne, Fernald, and Reinsdorf (2016)*

23 *Echoing a theme recurrent in Gordon (2016)*

24 *Aghion, Bergeaud, Boppart, Klenow, and Li (2017)*

25 *Baily & Gordon, 2016*

Intangible Inputs

What are intangible inputs and how mismeasured are they?

In recent decades, it has been recognised that many non-physical assets provide final services, and should therefore be treated as capital, rather than intermediates. There are three broad categories of intangible inputs: computerized information for software and data, innovative property for research and design, and economic competencies for advertising and organisational structures[26]. The latter category alone accounts for 21% of the wage costs of workers in management, marketing, and administration with tertiary education. The importance in accounting for intangibles was recognised in the 2008 revision of the System of National Accounts for the United States, and the 2014 ONS National Accounts Blue Book for the United Kingdom, which included the capitalisation of certain types of R&D investment.

Measuring the stock of such capital and its depreciation rates is inherently difficult. Unlike tangible goods (where units are clearly defined) intangibles such as intellectual property or branding, are difficult to quantify, even before any quality-adjustments are to be considered. The literature offers methods for the calculation of depreciation rates for various types of intangibles through specific R&D surveys or implementing a 'software' model from a traditional industry survey, complemented with an independent account production using data on employment and wages in specific occupations. The rate of R&D depreciation ranges between 1-5%, although this rate can be significantly higher in the first two years and therefore is non-linear[27].

The impact of improper measurement of intangibles on total factor productivity growth adds up to 1 percentage points per annum between 2011-2014 and 2000-2007, of which declining intangible capital services contributed 0.4 percentage points per annum while value added mismeasurement was 0.2 percentage points per annum[28]. The dynamics of general purpose technologies like artificial intelligence on measured total factor productivity have also been linked to the productivity paradox. Initially, investment grows very fast and then slows down, thus investment growth rates are initially higher than capital growth rates, while the reverse is true in later periods. Due to investment being an output and capital an input, this creates a TFP mismeasurement cycle, where TFP growth is initially underestimated (investment and thus total output is underestimated), and then overestimated (capital and thus total input is underestimated)[29].

However, not all intangibles contribute to mismeasurement. The contribution to production of certain intangibles is increasing demand for certain firms while harming others in a zero-sum fashion. For instance, advertising and faster trading algorithms improve one firm's productivity by taking value from competitors[30]. Another aspect of mismeasurement in intangibles appears because of trade and offshoring. Measurement of GDP may be underestimated when firms offshore their profits, which is highlighted for R&D intensive industries producing intangible assets. By tracing differences between gross domestic and national product in the United States, researchers have found that direct investment earnings abroad increased by 2.7% of business sector value added between 1973-1993 and 2012. Using data on labour compensation, the researchers show that 65% of these earnings can be attributed to domestic activity, but are instead shifted to affiliates in low-tax countries.

26 *Corrado and Hulten (2014)*

27 *An updated review of estimates of the depreciation rates can be found in de Rassenfosse and Jaffe (2017)*

28 *See Haskel (2016)*

29 *Brynjolfsson et al. (2017) proposed a simple model to think about the consequences of a General Purpose Technology*

30 *Brynjolfsson et al. (2017), Haskel and Westlake (2017)*

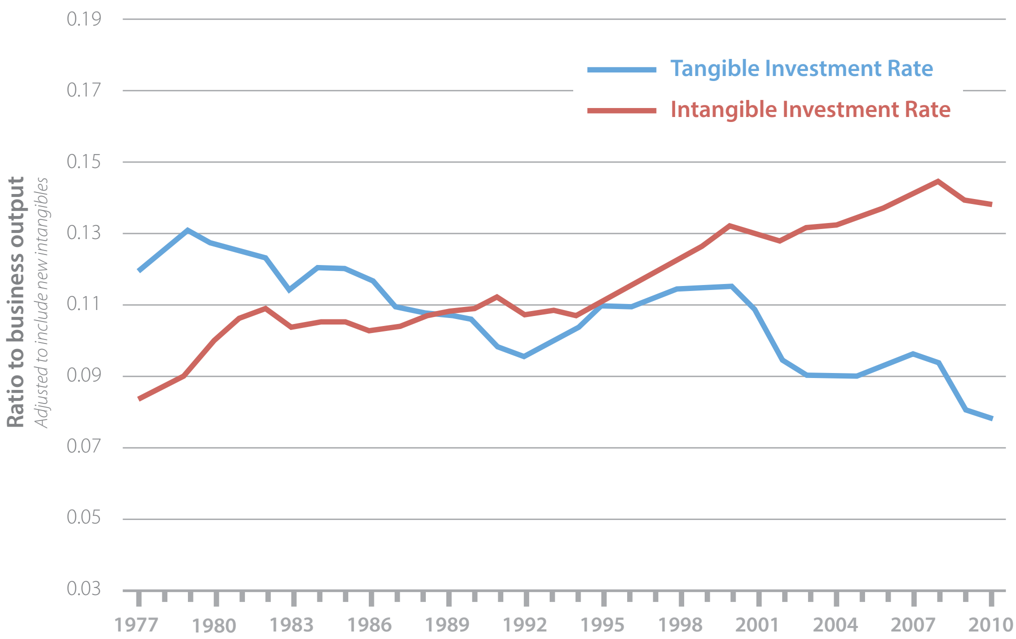


Figure 4: US Business Investment Rates 1977-2010

Source: Corrado and Hulten 2014

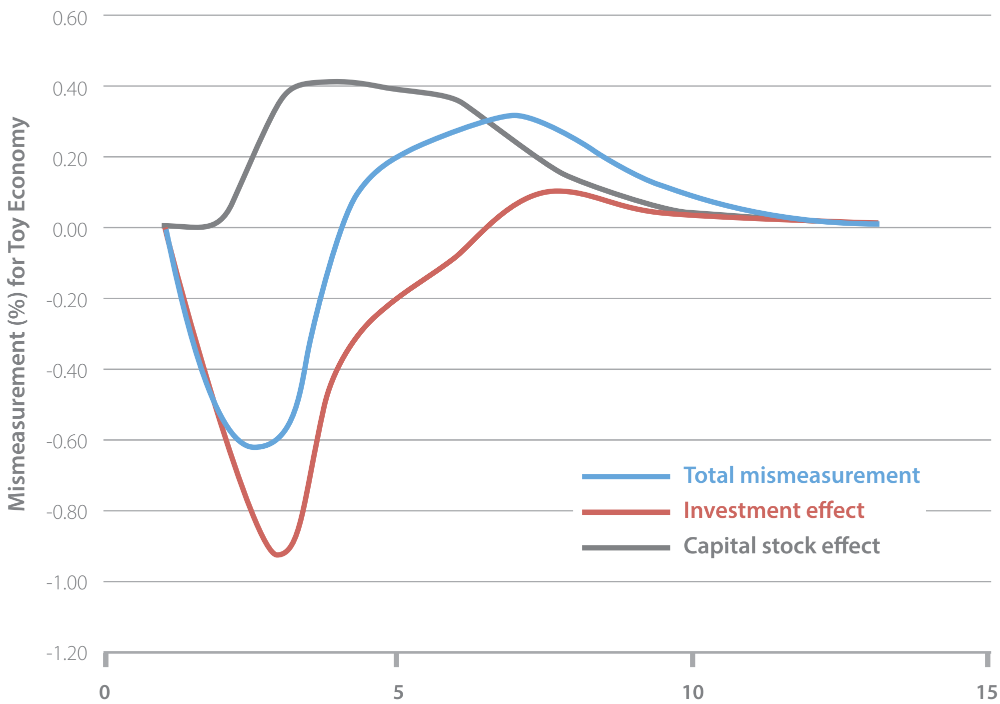


Figure 5: The mismearurement J-curve

Source: Brynjolfsson, Syverson and Rock, 2017

Productivity growth after adjusting value-added between 2004 and 2008 is 0.25% higher than presented in official statistics, although it remains unchanged after 2008. Itthus largely fails to explain a large share of the total slowdown in productivity[31].

31 Guvenen, Mataloni, Rassier, and Ruhl (2017)

Mismeasurement Summary

Recent studies have found that mismeasurement has worsened to the point that it could completely explain the productivity slowdown. However, economies have not seen a dramatic shift towards sectors where real output is underestimated and the extent to which this has happened has been gradual. There are no disruptive breaks in the structure of economies which match the slowdown. There is nevertheless a shift towards sectors and assets that are measured with more uncertainty, such as intangibles, and there is evidence that the digital economy does provide large unmeasured benefits. We conclude that mismeasurement is therefore part of the explanation, legitimately emphasizing that technological transitions are challenging for measurement systems and that more work is necessary in this area. Nevertheless, it is unlikely that a major part of the observed productivity slowdown is due to mismeasurement as this has been prevalent for far longer than the slowdown and we cannot associate significant changes in errors associated with measurement with the slowdown.

Human capital

In this section, we discuss potential explanations linked to the characteristics of the population. We first show that aggregate measures of improvements in human capital like educational attainment have not slowed down, but the skill mismatch may have increased. We then discuss demographic factors, finding that migration is unlikely to have had an important effect while ageing is instead affecting productivity through direct channels (age-productivity relationship), but also indirect channels (savings or shifting consumption preferences). We discuss an emerging literature on the role of technology in lowering labour supply, and conclude the section by reviewing the discussion surrounding labour market institutions, and in particular their role during the financial crisis and more recently with respect to the rise of the gig economy.

Educational attainment

A key determinant of labour productivity is human capital itself, so an explanation for the productivity slowdown could be a slowdown in educational attainment or a growing skill mismatch. The importance of education for labour productivity and wages is one of the most established relationships in the economic literature[32]. In a traditional framework, wages are equal to the marginal product of labour and subsequent wage premia imply higher output[33].

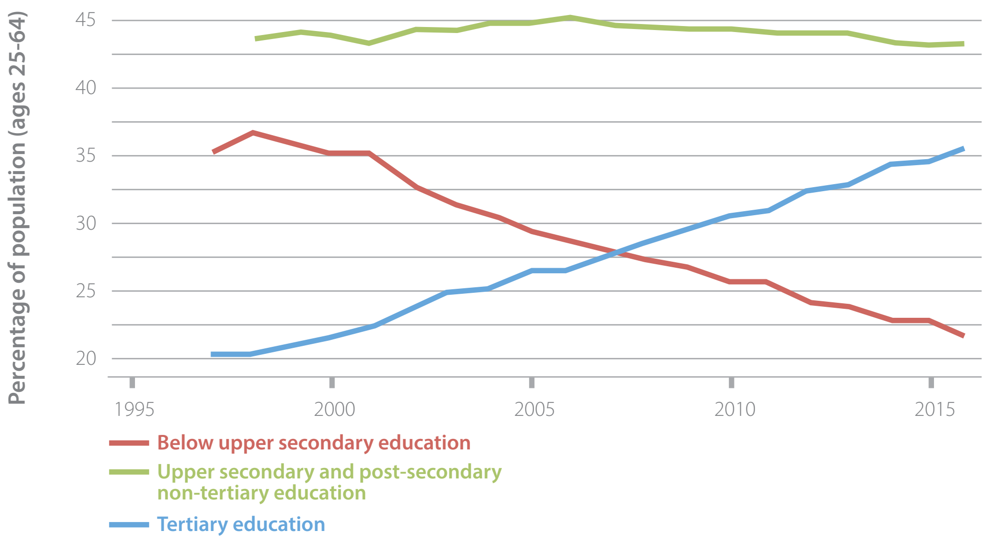


Figure 6: The evolution of educational attainment in the OECD
Source: OECD

In this context, a slowdown in productivity could be caused by a general slowdown in educational attainment in the advanced economies, which is not apparent. The OECD provides data that differentiates between different levels of education. Notably, attainment of below secondary education appears to drop steadily for the OECD countries as a whole and notably for France and the UK and for some countries asymptotes at zero (US and Germany). This plateauing of average years of schooling is also consistent with the literature[34]. Moreover, the share of population with tertiary education has been increasing in a stable, linear fashion for every country observed. As a result, a secular decline in educational attainment is not an explanation of the recent global productivity slowdown.

Whether this trend will be sustained going forward is unclear, and concerns have been raised

32 Mincer, 1958
33 Heckman, Lochner, & Todd, 2006
34 C. Goldin & Katz, 2008

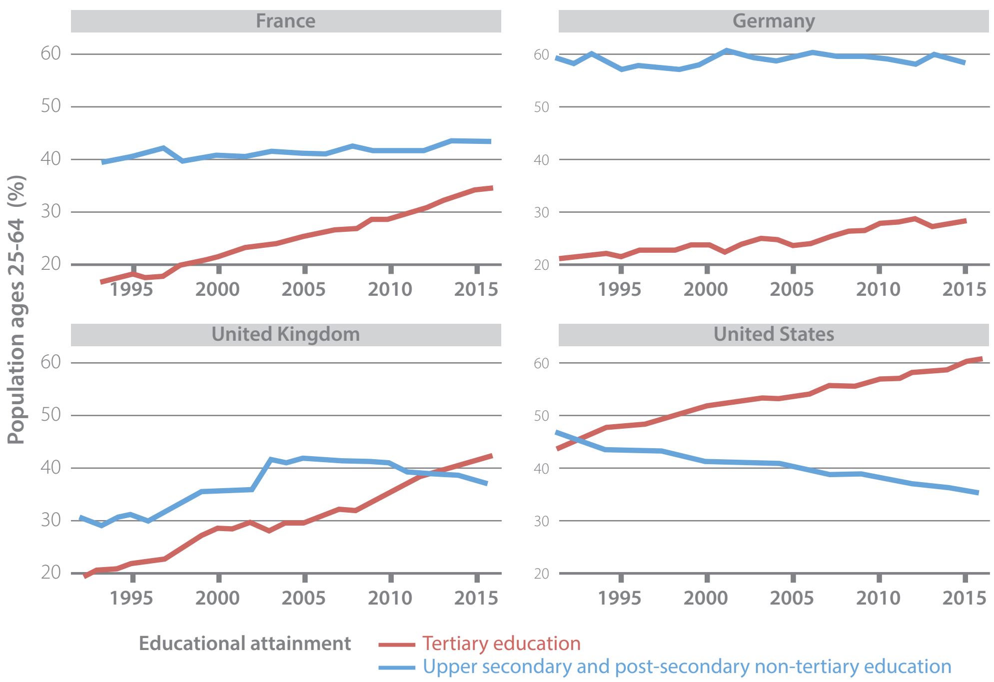


Figure 7: The evolution of educational attainment in the OECD countries

Source: OECD, authors' calculations

about rising student debt[35]. So far, it should be noted that tuition fee increases do not seem to have lowered the demand for education services; though it may be the case that the evidence is not yet available due to the long lags between investments in human capital and changes in productivity. For example, the impact of the 2012 tuition fee hike in the United Kingdom, at a glance, does not seem to have severely disrupted the growth in tertiary education. The trend is similar in the US, where fees have experienced one of the largest price increases in the economy. Given the high returns to education compared to the real interest rates faced by young scholars, credit constraints seem to have played a less significant role in this process[36].

Skill mismatch

Given that educational attainment has risen, a potential explanation for the productivity slowdown is that there is mismatch between the supply and demand of specific skills. For instance, in the case of fast technological change, we should expect the skills associated with new technologies to be in too short supply, but also that different occupations will be affected differently by the biased technological change[37].

There is a consensus that skill biased technological change led to the hollowing out of the wage distribution in the 2000s, when middle wage cognitive routine occupations were automated[38]. This may have led to some extent to deskilling technological change, contributing to the skills mismatch and pushing workers with intermediate levels of education to take low productivity jobs. In combination with the emergence of digital platforms, a larger share of such workers now participate in the gig economy . Recent research on changes in the allocation of workers in the context of the productivity slowdown is inconclusive and often conflicting[40]. A low skill mismatch however, (i.e. when existing skills are almost perfectly matched to demand) is correlated with good policies on bankruptcy laws, residential mobility, and the flexibility of wage negotiations, among others[41].

35 *Gordon, 2016*
36 *Heckman et al., 2006*
37 *Acemoglu & Autor, 2011*
38 *Goos, Manning, & Salomons, 2014*
39 *The Department for Business, Energy & Industrial Strategy, 2018*
40 *On the one hand, Goodridge et al. (2016) find that employment was re-allocated towards high-productivity industries in the United Kingdom, yet Patterson, Şahin, Topa, and Violante (2016) calculate that most labour was reallocated to low productivity occupations, accounting for up to two-thirds of the slowdown. These findings can be reconciled by the fact that the latter considers sectoral differences in matching frictions, yet the extent to which the effect is from reallocation from sectors with high productivity levels or growth is unclear.*
41 *McGowan & Andrews, 2017*

Migration

Net migration has increased in the OECD countries since the 1960s with significant fluctuations as a response to business cycles and geopolitical events. This change was manifested with significant variation across countries and the different migration categories[42]. In practice, migration increases labour supply and subsequently affects productivity.

One approach to identifying the effects of migration on productivity is to evaluate the impact of refugee waves on local economies. Studying the impact of events like the Mariel boatlift of Cuban refugees in the US has not led to a wide consensus on the employment, wage or productivity impacts[43]. There are several reasons for this outcome: firstly, refugees often differ from other labour supply inflows like students entering employment and therefore these surges can be hard to predict and secondly, the changes in migration policies can directly affect the observed economic outcomes. A typical case is the gradual integration of European Union members, where the impact of immigration (as workers move freely between countries) on productivity remains unclear .

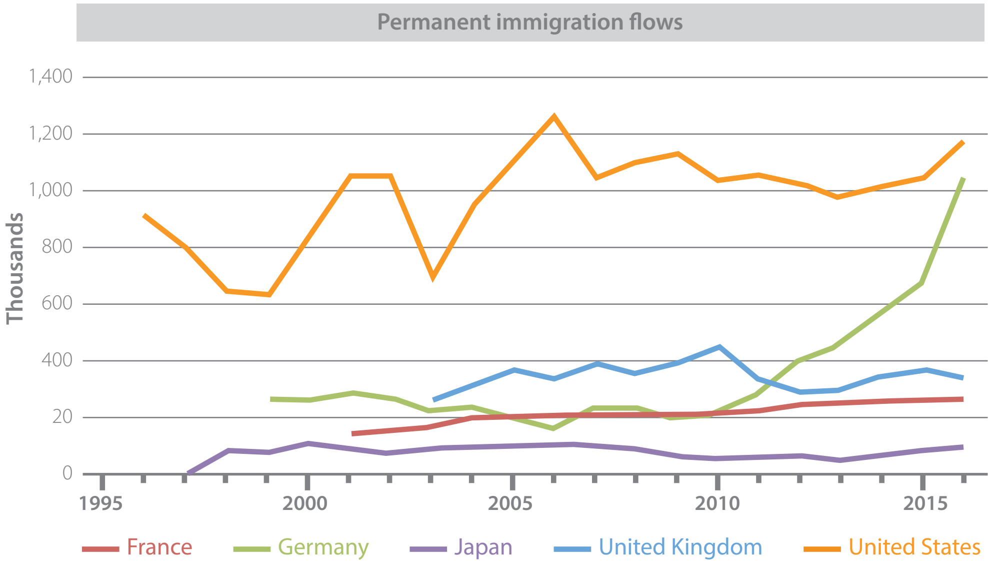


Figure 8: Annual migration flows across countries 1975-2015

Source: OECD, authors' calculations

Aside from the volumes of migration, its impact can be traced to the provision of new skills and entrepreneurial activity[45]. Immigration is positively correlated with total factor productivity growth in the USA, with the efficiency gains larger for unskilled workers than skilled[46]. Comparing migration flows in OECD economies against their impacts on labour markets[47], researchers found that the US and Germany exhibit productivity changes close to zero or even negative while the UK and France benefited from these flows[48]. The effects on entrepreneurship are also significant: 40% of all Fortune 500 companies were founded by first- or second-generation immigrants and more than half of US startups valued at $1 billion or more before going public (often referred to as unicorns) have at least one immigrant co-founder[49]. Immigrants accounted for 28.5% of all new US businesses formed in 2015 despite accounting for just 14.5% of the overall US population. In addition, they are almost twice as likely as the native-born population to start their own business (in the US and the UK).

42 OECD, 2014.
43 Borjas & Monras, 2017; Card, 1990; Peri & Yasenov, 2015
44 Beerli & Peri, 2017
45 Borjas & Doran, 2012; Mitaritonna, Orefice, & Peri, 2017
46 Peri (2012)
47 controlling for the skills of immigrants
48 Boubtane, Dumont, and Rault (2016)
49 Goldin, Cameron, & Balarajan, 2011

Ageing

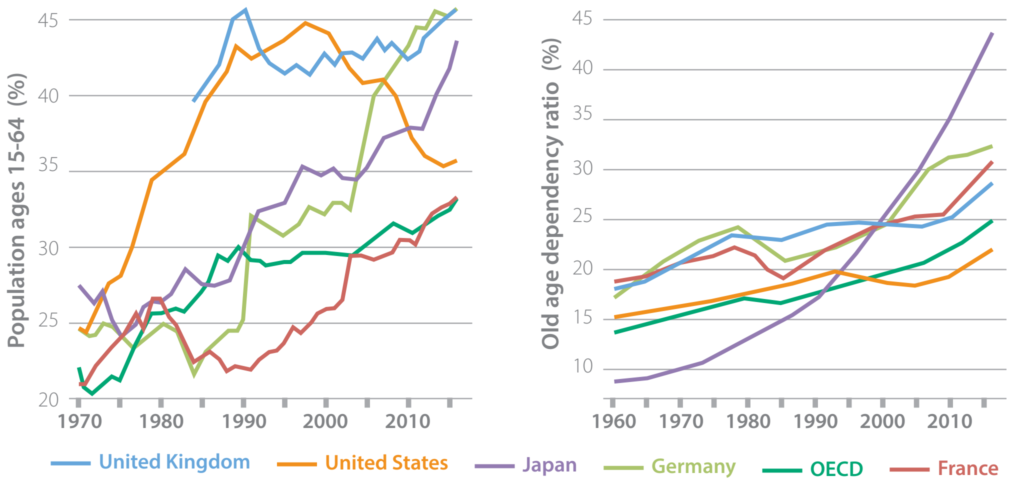


Figure 9a: Population ageing across OECD countries 1975-2015

Source: World Bank, authors' calculations

Figure 9b: Elderly dependency ratio across OECD countries 1960-2015

Source: World Bank, authors' calculations

Two demographic trends are responsible for a global ageing population: increases in longevity and decreases in birth rates. Research for the United States documents a persistent decline of ill health across all age groups, with the notable exception being middle-aged white males.[50] These trends are already well under way in advanced economies globally, and the resulting surge in the number of people aged over 65 as a compared to those aged 16-64 is evidenced across the globe.[51] Here we discuss three potential effects of ageing on productivity: a direct effect due to a link between age and productivity, a macroeconomic effect of ageing on saving rates, and a structural change effect due to changing patterns of demand.

Understanding how productivity changes with age is often problematic. The sample of employed older workers may not be representative (selected due to good health) as there can be omitted variables in determining wages (seniority and anti-ageism laws), along with other generational effects[52]. Nevertheless, the concerns regarding the lower productivity of the older population are largely dismissed in recent studies.[53]

Population ageing affects the availability and rates of returns of both labour and capital inputs but there is no consensus on the nature and extent of the effect on productivity[54]. Lower and negative population growth rates would increase the supply of savings, to the extent that individuals need to save for retirement. At the same time, a higher saving rate would lead to lower demand for consumption goods, reducing investment opportunities for firms[55]. Both shifts lead to a lower equilibrium rate of interest. An ageing labour force combined with the low cost of capital also leads to a stronger incentive towards capital-biased technical change, leading to higher productivity. Acemoglu and Restrepo (2017) observed a faster rate of adoption of automation in countries with older populations, which more than offsets any effects on output by labour scarcity.

Consumption baskets may change drastically as individuals age. Specifically, consumption by the elderly focuses more on services, in particular healthcare and leisure activities, in which productivity and productivity growth is generally lower. Using country-level data, researchers found that an older population was associated to a shift of employment shares away from agriculture and industry towards personal services and the financial sector[56]. This further helps explain job polarization due to ageing, as the growth in demand for personal services increases the demand for low wage services[57].

50 Case & Deaton, 2015; Freedman et al., 2013

51 United Nations, 2017

52 Lee, 2016

53 National Research Council (2012), Mahlberg, Freund, Crespo Cuaresma, and Prskawetz (2013) and Börsch-Supan (2013). Maestas, Mullen, and Power (2016), exploiting variation across US states, find that a higher share of population above 60 is associated with slower labour force growth and slower labour productivity growth. Liu and Westelius (2016) found that the share of mid-age population at the prefecture level in Japan was associated with higher productivity growth. Finally, recent research has investigated the link between ageing and entrepreneurship, with Liang, Wang, and Lazear (2014) finding that countries with an older population exhibit lower rates of business formation.

54 Lee, 2016

55 Lee (2016), Eggertsson, Mehrotra, and Summers (2016) and Teulings and Baldwin (2014) argue that ageing may have an indirect effect in causing secular stagnation by driving interest rates to the zero lower bound. However, Eichengreen (2015) found that empirically increases in dependency ratios have actually roughly equally negative effects on both the demand and supply of savings. An ageing labour force combined with low cost of capital also leads to a stronger incentive towards capital-biased technical change, leading to higher productivity. Acemoglu and Restrepo (2017) observed a faster rate of adoption of automation in countries with older populations, which more than offsets any effects on output by labour scarcity.

56 Siliverstovs, Kholodilin, and Thiessen (2011)

57 Moreno-Galbis and Sopraseuth (2014)

Leisure technology and labour supply

New leisure technologies could be impacting on labour force participation rates. Between 2007 and 2014, an additional 1.6 hours/week for men (from 38.36 hours to 39.97 hours per week) and 1.2 hours/week for women (from 33.32 to 34. 51 hours per week) were spent on leisure activities (watching TV or video games), but this consumption of digital goods is not large enough to have a significant impact on the value of leisure[58].

In fact, the productivity growth of leisure time has slowed down in the digital era. A more direct channel is that digital technologies may disrupt productivity directly, for example because of working hours spent on social media and indirectly, by forming new habits of distraction that reduce capacity to work[59] . Some early findings show that the impact of social media could be significant[60]. On the other hand, the increased engagement of people during what is defined as leisure time on work emails or activities is also not measured as an input. The dual impact of individuals at work using digital technology to do non-work activities and during non-work time to do work activities means traditional measures of hours worked are unlikely to reflect actual work hours. The overall impact of this on productivity is however unclear, as while hours at work may be overestimated leisure hours may also be overestimated.

58 Hall (2017), Bridgman (2018)
59 Mark, 2015; Nixon, 2017; Terranova, 2012
60 Knight, 2005

Labour Market Institutions

Aside from the quantities and qualities of inputs, labour market institutions can influence productivity too. Studies regarding the extent of unionisation have not yielded clear conclusions. While unions may introduce rigidities to a system that would otherwise work more efficiently, they also may lead to higher levels of investment in workers and greater loyalty of workers to employers, as well as improved health and safety and less disruptive activity, all of which undermine productivity.

Stringent hiring and firing regulations however do tend to reduce the pace of job reallocation[61]. Researchers[62] have also looked into the productivity effects from anticompetitive regulations in product and labour markets through their impacts on production prices and wages. The existence of these regulations across countries and industries results in rent-seeking behaviour by firms which impedes productivity. Countries could expect sizeable gains in productivity from the implementation of pro-competitive regulation practices.

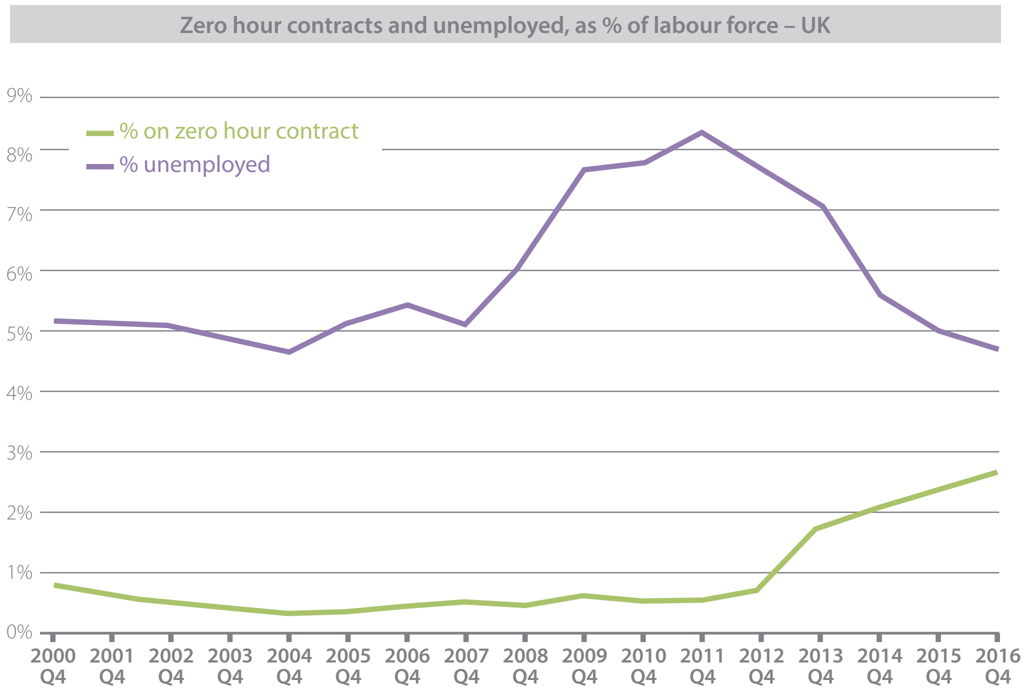


Figure 10: Zero hour contracts and unemployed as % of the UK labour 2000-2016

Source: ONS, authors' calculations

In the UK, a persistent increase in self-employment, zero-hour contracts, and the rise of the 'gig economy' may be responsible for a recent increase in the deskilling of the workforce and the increase in unskilled labour[63]. The gig economy may be detrimental to overall labour productivity, as it is associated with lower rates of investment in skills accumulation and experience in jobs than in the case of long- term contracts. As a result, a higher share of workers in gig employment have lower long- term commitment to their jobs and are over-qualified.

61 *See Haltiwanger et al (2014) who used harmonized measures of job creation and destruction in a sample of industrial and emerging economies.*

62 *Cette et al (2016)*

63 *for the political debate in action see Taylor et al. (2018)*

Human capital

Changes in the composition of the labour force are unlikely to be an important determinant of the slowdown. However, while the growth in attainment of college degrees kept pace with its pre-crisis trend, there is a growing literature pointing out that the new wave of technological change is making specific skills scarce and others obsolete, possibly increasing the skill mismatch. Ageing has mixed effects. On the one hand, there are concerns that an older population may be less entrepreneurial, and may also shift consumption towards services, such as care, which have low productivity growth. On the other hand, ageing increases incentives for automation as the labour force gets smaller and wages rise. The argument that new leisure technologies may decrease labour supply by allowing people at work to do social media and other activities has not yet been shown empirically and neither has the countervailing suggestion that working hours have increased due to a growing share of leisure time purportedly taken up with work activities. Labour market institutions play a role in explaining the experiences of different countries post-crisis. However, changes in labour market institutions do not correspond with the slowdown in productivity and none of the individual factors outlined above could account for the scale of the slowdown. Labour market factors are therefore not significant in explaining the overall productivity slowdown.

Physical and intangible capital

Contribution of capital growth to productivity

Labour productivity is affected both by total factor productivity (TFP)[64] as well as by capital deepening.[65] Recent evidence shows that total factor productivity and capital deepening contributed only half a percentage point each to labour productivity growth in the post 2004 period, against 1.7 for TFP and 1.2 for capital in 1995-2004[66]. For the OECD, labour productivity growth fell from about 1.8% to 1% between 2000 to 2008, with most of the decline being due to the slowdown of total factor productivity growth from about 1% to 0.4%. In contrast, the post-crisis period was marked by a further decrease of labour productivity growth which can be entirely attributed to a slower growth of capital deepening – a finding that is supported by individual country experiences[67].

Several explanations for the slowdown of capital deepening have been proposed. First, the composition of capital is shifting towards assets with shorter lifetime, such as ICT, which implies a higher aggregate scrapping rate. However, this increase of the scrapping rate has taken place since at least 1990, rising from 3% to 5%. A second, more plausible explanation for the weak post-crisis investment is simply the fall in aggregate demand. Countries with lower pre-crisis interest rates, which may have built up more capital misallocation, had a stronger slowdown in capital growth following the crisis. Finally, government investment also fell post-crisis, contributing around a fifth of the fall of investment as a share of GDP. Besides the direct effect, a lack of investment in infrastructure and public capital may have longer-run (and harder to measure) consequences on productivity.

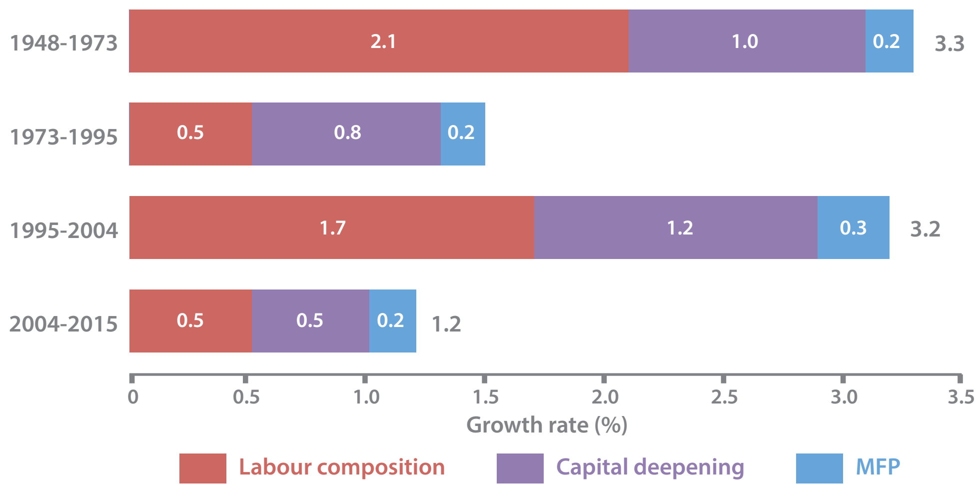


Figure 11: Multifactor productivity in the US 1948-2015

Source: Baily and Montalbano, 2016

Looking at publicly traded firms in the US, researchers[68] found that the slowdown of investment relative to fundamentals started in the early 2000s. This slowdown is explained by two factors: firstly, the slowdown did not take place in industries in which capital cannot be easily relocated, such as energy production or telecommunication transmission and secondly, high tech firms shifted their investment towards intangibles.

64 This refers to the part of the change in output that cannot be attributed to changes in labour or capital inputs.

65 The increase in capital per worker in an economy.

66 Baily and Montalbano (2016)

67 Ollivaud, Guillemette, and Turner (2016)

68 Alexander and Eberly (2018)

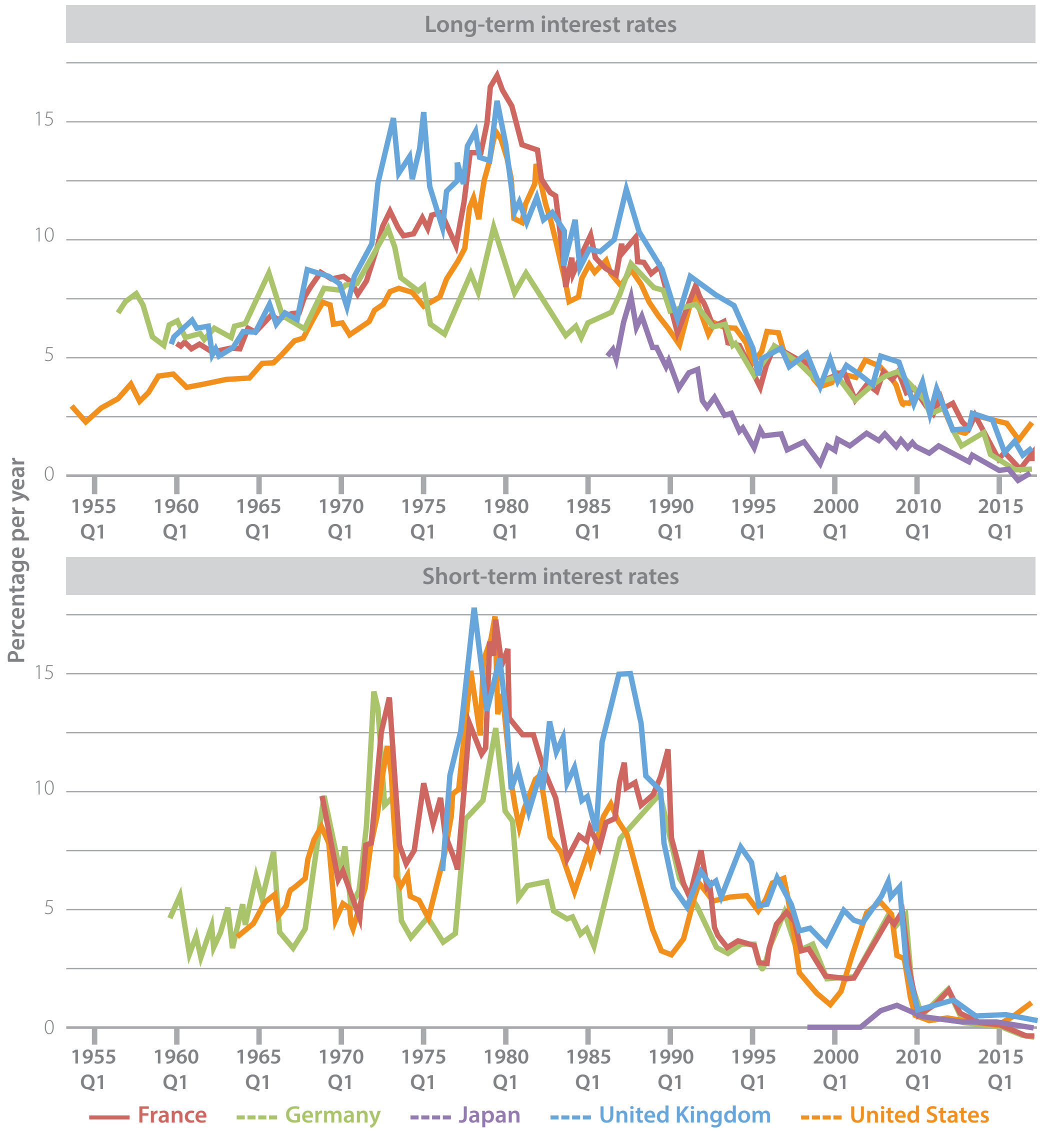


Figure 12: Long and Short-term interest rates across OECD countries 1955-2015

Source: OECD

Intangible capital

While physical capital is often at the forefront of productivity discussions, intangibles have been the largest systematic driver of growth over the last 50 years[69]. In fact, there is evidence that intangible assets are a growing share of investment and this has been higher than investment into tangible capital since the late 1980s[70]. Accounting for the stock of intangibles, capital deepening in revised accounts is responsible for half of labour productivity growth in the United States, and total factor productivity contributions decrease accordingly[71]. Tangible capital deepening explains no productivity gains whatsoever[72]. Intangibles alone explain up to 25% of productivity growth, and nearly one-third since 2001.

Haskel and Westlake (2017) argue that the fundamental nature of intangible capital allows established firms to accumulate market power. Several forms of intangible capital benefit from synergies, such as knowledge capital that can be recombined into new

69 *Corrado and Hulten (2010)*

70 *Haskel and Westlake (2017), Corrado, Hulten, and Sichel (2009) for the United States, Marrano, Haskel, and Wallis (2009) for the United Kingdom, and Fukao, Miyagawa, Mukai, Shinoda, and Tonogi (2009) for Japan*

71 *Corrado and Hulten (2014)*

72 *C. I. Jones (2002) and Fernald and Jones (2014)*

forms. Additionally, intangible capital is often easy to scale at near zero marginal cost, thus generating increasing returns for incumbents. Meanwhile, startups may face barriers to entry in the form of funding opportunities, since the difficulties related to valuing such capital make it hard to list as collateral. On the other hand, the effect of spillovers may enable smaller firms to benefit from intangible investments of larger firms, for example through the diffusion of new technology.

Since intangible capital probably has higher spillover effects than tangible capital, a slowdown in intangible investment is worse than a slowdown in physical capital deepening. As a result, while there is evidence that investment into intangibles is stagnating in the same fashion as it is for tangible investment, its adverse impact on TFP might be worse[73].

Besides R&D, intangibles also include economic competencies and good management practices. Management practices are indeed a good predictor for productivity at the firm level, and slower diffusion of best practices could help explain the productivity gap between frontier and laggard firms[74]. To translate into productivity improvement, technological change often requires a change in companies' internal processes and organization. During the "first" productivity paradox of the 90s, insufficient organizational change was identified as one of the key points holding back technology diffusion[75]. Similar arguments can be made today, where organizational change complementary to the development of AI are just starting and will take time to take place fully[76].

Declining investment rates could be due to an increase in short-termism amongst top managers. In firms where the pay of top management is linked to firm performance on the stock market, an increasing amount of resources are spent on stock buybacks instead of long-term investment which would in turn improve productivity[77]. This change in corporate governance within a large number of firms led to lower investment rates in long-term projects . In spite of the importance of these incentives, reduced competition is likely the more important factor[79].

Financial market frictions

Why is investment slowing down? There are several explanations for this finding: Firstly, due to an increase in risk premia, cost of capital did not fall as much as safe assets rates might suggest. Secondly, the credit crunch following the financial crisis appears to have been important and may have relatively affected intangible investment more. Thirdly, capital reallocation has been weaker since the crisis.

Returns on productive capital

The returns on productive capital (including intangibles) have remained more or less stable at around 6.5%, while the returns on safe assets have decreased[80]. There has been a substantial increase in the risk premia since 2000, and even more after 2008. Additionally, a shift of capital in the economy towards the intangible kind could also dampen risk appetites. Investment in intangibles is generally sunk and thus riskier. As economies shift to higher shares of intangibles in production the risk profile of the capital stock is deteriorating.[81]

73 This point is also made in Goodridge et al. (2016), who suggested that part of TFP growth slowdown might be due to missing lagged spillovers due to the slowdown of R&D investment in the 90's and 2000's.

74 Haldane (2017)

75 Brynjolfsson, 1993; Brynjolfsson & Hitt, 1996; Brynjolfsson & Hitt, 2000

76 Brynjolfsson et al. (2017)

77 Lazonick (2014) and Haskel and Westlake (2017)

78 Gutiérrez and Philippon (2017)

79 Gutiérrez and Philippon (2016, 2017)

80 Caballero et al. (2017)

81 Haskel and Westlake (2017)

Credit frictions

The Global Financial Crisis (GFC) cannot be a stand-alone explanation of the productivity slowdown, simply because the slowdown started before the crisis. However, there are reasons to believe that the forces driving down productivity growth may have been different pre- and post- crisis, with the post-crisis period being relatively more marked by a lack of investment.[82] Indeed, more financially vulnerable firms had a higher decline in total factor productivity growth after the GFC[83]. This effect was stronger in countries with a higher credit supply shock, while credit constraints may have affected productivity by reducing intangible investment, which is more difficult to use as collateral than physical investment. Proxying credit frictions with a 'probability of default model', researchers[84] have found that these frictions may have already depressed output in the United Kingdom before the crisis. While they were understandably large during the crisis itself, the effects lingered after the crisis, accounting for up to 23% of the slowdown in productivity growth relative to its pre-crisis trend.

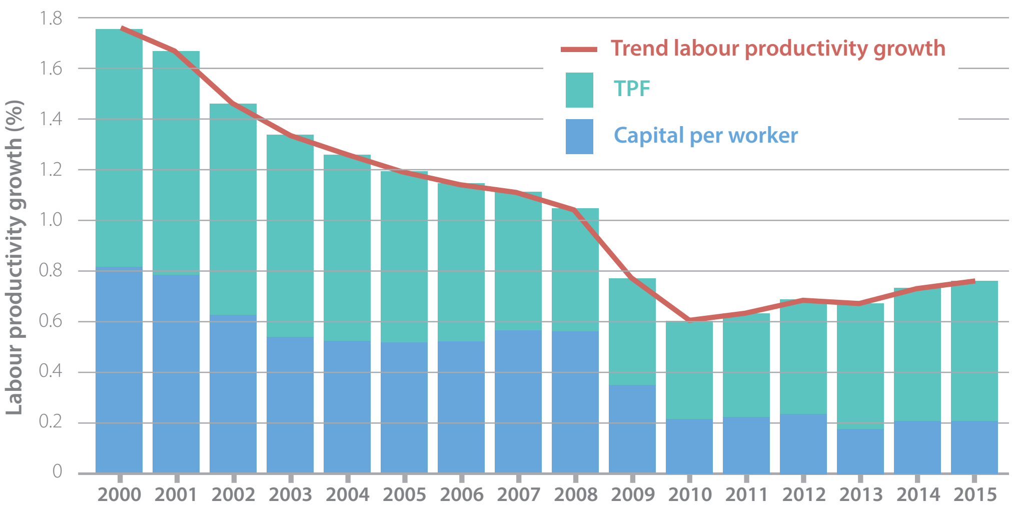


Figure 13: Labour productivity, TFP and capital deepening in the OECD 2000-2015

Source: Ollivaud, Guillemette, and Turner, 2016

Capital misallocation

The GFC had a negative impact on capital reallocation in the UK. Specifically, the positive relationship between investment incentives (capital rates of returns) and actual investment (capital growth rates) disappeared after the financial crisis, suggesting that firms are less responsive and that as a result, capital misallocation has increased.[85] Rising capital misallocation can also be found in Spain, Italy and Portugal since the 90s, which is attributed to low interest rates leading to misallocated capital inflows.[86]

82 *Ollivaud & Turner, 2016*

83 *Duval, Hong, and Timmer (2017)*

84 *Besley, Roland, and van Reenen (2017)*

85 *Barnett et al. (2014)*

86 *Gopinath, Kalemli-Özcan, Karabarbounis, and Villegas-Sanchez (2017) and Cette, Fernald, and Mojon (2016)*

Productivity dispersion

A natural approach to understanding the evolution of productivity is to disaggregate. In this section, we first discuss the idea that productivity can be slowing down because low productivity growth sectors become more important. We then review the recent work on the distribution of firm productivity, which points to the simultaneous rise of superstar firms co-existing with zombie firms and suggests that misallocation has increased and knowledge diffusion from frontier to laggard firms is too slow. Finally, we discuss one of the major explanations put forward for this trend, namely the rise in market concentration and markups.

Sector-level productivity growth and structural change

Are some sectors becoming smaller or larger? Is this effect linked to productivity growth? William Baumol famously pointed out that aggregate productivity growth would asymptotically equal the rate of progress of the slowest industry[87] under certain conditions. In the context of the productivity slowdown, it may well be that those sectors which are rapidly innovating are capturing a declining share of total output, or are not systemically important.[88]

Industry Multifactor Productivity by Timeframe

Annual growth rate (%)	1997-1995		1995-2004		2004-2014		1987-2014	
Agriculture, Foresty, & Fishery	-0.1	0.1	3.3	3.3	0.5	0.5	1.3	1.3
Mining	1.8	1.8	-0.4	0.4	2.7	2.7	1.4	1.4
Manufacturing Sector	0.8	0.8	2.0	2.0	0.0	0.0	0.9	0.9
Utilities	2.4	2.4	-0.4	0.4	0.3	0.3	0.7	0.7
Construction	0.1	0.1	-0.5	0.5	-1.1	1.1	-0.6	0.6
Wholesale Trade	1.3	1.3	2.8	2.8	-0.1	1.1	1.3	1.3
Retail Trade	1.7	1.7	2.3	2.3	-0.2	0.2	1.2	1.2
Transportation & Warehousing	1.0	1.0	1.4	1.4	0.3	0.3	0.9	0.9
Information	0.3	0.3	1.0	1.0	1.5	1.5	1.0	1.0
Finance, Insurance, & Real Estate	-0.3	0.3	0.1	0.1	0.9	0.9	0.3	0.3
Services	-0.8	0.8	0.3	0.3	0.0	0.0	-0.2	0.2
Private Business Sector	0.6	0.6	1.7	1.7	0.5	0.5	1.7	1.7

Figure 14: Annual change of productivity across sectors in the USA 1987-2014

Source: Baily and Montalbano, 2016

In the US researchers found that manufacturing, wholesale, retail trade, services and agriculture were responsible for a large fraction of both the acceleration of aggregate MFP growth between the 1995-2004 compared to 1987-1995, and its slowdown in 2004-2015 compared to 1995-2004. This highlights that productivity growth can be thought of as an adjustment of the levels, with an innovation leading to a new normal level of productivity growth; that is, a transitory period of productivity growth. This is linked to the experience of the retail sector with the rise of big box retailers driving out small shops, until they reached overcapacity in the post 2004 period.[89] In the UK 35% of the slowdown can be explained by weak total factor productivity growth in oil and gas, as well as financial service industries[90]. In particular, financial services account for almost a third (0.5 out of 1.7%) of the pre- vs post-financial crisis difference in UK labour productivity.[91]

87 Baumol, 1967
88 see Oulton (2001)
89 Gordon (2016)
90 Goodridge et al. (2016)
91 Haldane (2017)

In the US most of the 1990's productivity surge was due to ICT producing industries.[92] In line with previous arguments, others have found that almost all the slowdown in average labour productivity growth between 1995-2004 and 2005-2015 can be explained by a within sector slowdown, with reallocation playing no role .

In contrast to the previous views, Haldane (2017) examined productivity growth trends at the sectoral level pre and post the financial crisis, and found that all sectors have been affected by the recent slowdown in productivity growth.[94] This suggests that compositional effects – i.e. the relative impacts of each sector – are not responsible for the lion's share of the slowdown. In the US, using new total factor productivity growth rates while keeping industry shares fixed to 1987, there is no evidence that growth of low TFP growth industries as a share of output resolve much of the productivity slowdown.[95] If anything, it complicates the puzzle.

92 *Cette et al. (2016)*
93 *Murray (2017)*
94 *Billet & Schneider, 2017*
95 *Byrne et al. (2016)*

Widening productivity distributions

There is a broad consensus that there are strikingly large productivity differences between frontier and laggard firms within industries.[96] These differences tend to be persistent over time, indicating the presence of firm characteristics that make them productive over longer time horizons, but also that low productivity firms are not necessarily eliminated quickly.

Superstar firms

Looking across firms in the OECD countries, researchers documented a substantial divergence between firms at the "frontier" (defined as the top 5% most productive firms in the distribution) and the rest in a sample of 23 OECD countries. Those at the frontier have increased their productivity by around 40% on average since 2010, while the rest experience slow, if any, productivity growth. Looking at some determinants of higher productivity growth, researchers[98] find that firms with high productivity growth tend to be (i) exporters, (ii) foreign-owned, (iii) located in productive regions (London in this case), (iv) concentrated in some sectors, (v) relatively larger, and (vi) invest substantially in R&D. Superstar firms tend to arise mostly in sectors that are characterized by high patent intensity[99] and firms that make the most of intangible capital.[100]

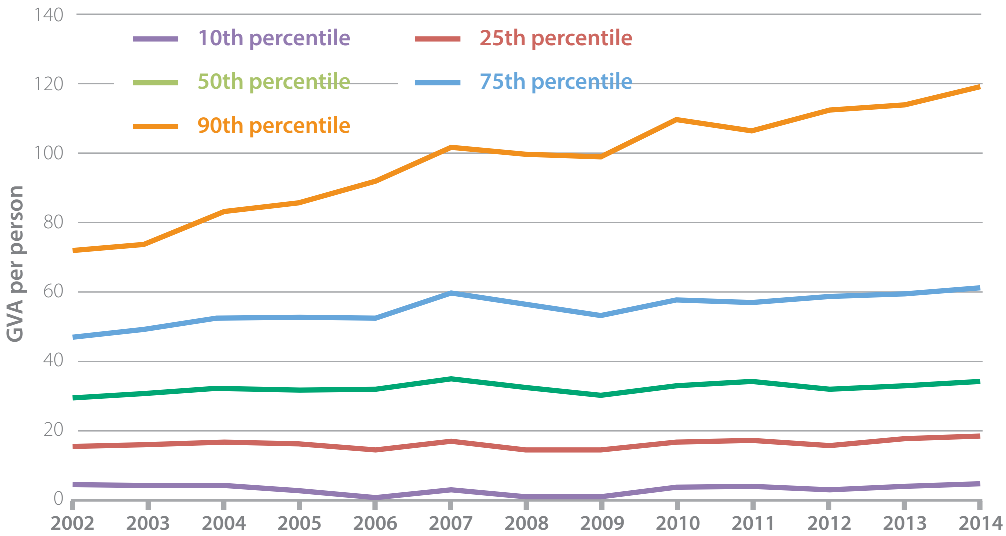


Figure 15: Gross Value Added per person in the UK by income 2002-2014

Source: Haldane, 2017; ONS

Still there is an observed decline in turnover at the productivity frontier. Out of the firms that make up the top 5% of the productivity distribution, there are now significantly more firms that were already at or near the frontier two years prior compared to a period at the beginning of the 2000s.[101] The skew in the distribution means that changes in the productivity growth rate at the top tail have a large impact on aggregate productivity growth, yet it is still unclear why productivity growth slowed down in the first place.

One hypothesis is that the reduced entry of new firms relieves pressure on incumbents to innovate, leading to the observed reduction in turnover of firms at the productivity frontier.[102] The ageing of frontier firms, while still younger than the average firm, may be another indication of lower dynamism at the productivity frontier.[103]

96 *Andrews, Criscuolo, & Gal, 2016; Syverson, 2011*

97 *Andrews et al., 2016*

98 *Haldane (2017)*

99 *Autor, Dorn, Katz, Patterson, and Van Reenen (2017b)*

100 *Haskel and Westlake (2017)*

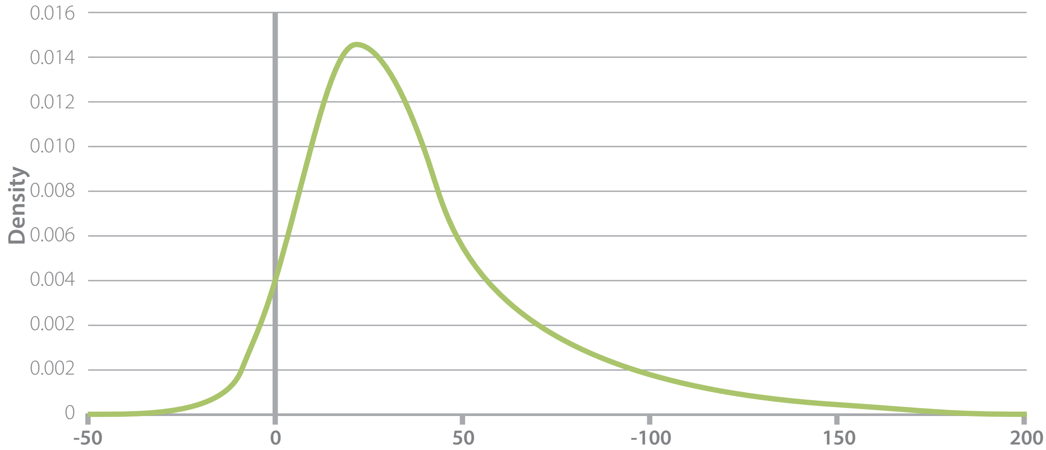
101 *Apart from the OECD sample P. Schneider (2018) explicitly outlines that the productivity slowdown in the United Kingdom emerges from the slowdown in productivity growth for the already-productive firms at the frontier*

102 *Foster, Haltiwanger, & Syverson, 2008*

103 *Andrews, Criscuolo, & Gal, 2015*

Zombie firms

Zombie firms can be thought of as firms that manage to survive despite negative productivity. While the evidence shows that many unproductive firms failed during the financial crisis, it also documents that a significant fraction of them are still in operation. Among the reasons for this lack of exit is the lack of competitive pressure[104] and bank forbearance[105] as well as historically low interest rates and the availability of cheap credit, due to quantitative easing.



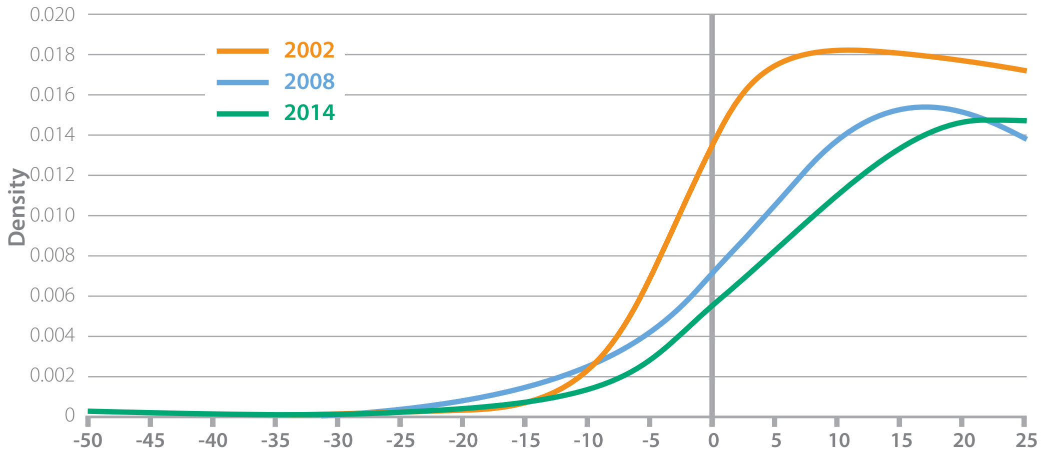


Figure 16: Distributions of Gross Value Added per worker in the UK

Source: Haldane, 2017; ONS

These zombie firms hold labour and capital that could otherwise be employed productively. They also hamper productivity growth rates in healthy firms by appropriating not just labour inputs, but also bank lending.[106] However, researchers have estimated that the effects on aggregate productivity of the exit of those zombie firms would be relatively marginal, so they are unlikely to account for a large proportion of the missing productivity growth.[107]

104 Andrews et al. (2016)

105 Andrews, McGowan, and Millot (2017)

106 Caballero, Hoshi, and Kashyap (2008) giving evidence from Japan,

107 Haldane (2017) and Arrowsmith et al. (2013)

Increasing market concentration and profits

Rise in markups and industry concentration

Average markups in the United States have more than tripled since 1980 across almost all industries, whilst the largest markups are set by a small number of firms and the distribution of markups has widened substantially.[108] In particular, the top decile of firms has seen their markups almost double from an already high starting point, whereas the median firm experienced no noticeable change. Based on profit rates and share dividends this rise in markups reflects a rise in market power, and not an increase in fixed costs that necessitates higher markups.[109] Across OECD countries the rise in markups is particularly pronounced in industries which are intensive in their use of intangible capital.[110]

Prescribing the optimal pace of business dynamism resulting in direct reallocation of resources to the most productive sectors is not straightforward and might be sensitive to

Figure 17: Average industry markups across the world 1950-2015

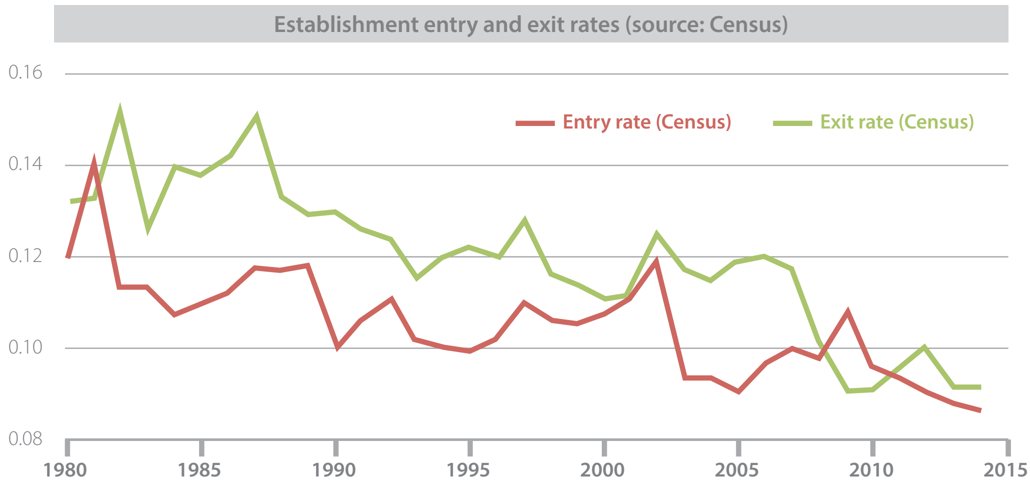
Source: DeLoecker and Eeckhout, 2017

geographical and temporal variations. However, there is evidence that the rate of business startups, the role of young businesses and the pace of employment dynamism in the US economy have fallen in the most recent decades and this trend has accelerated after 2000, suggesting that incentives for entrepreneurs to start new firms in the United States have diminished over time.[111] The reasons for this trend are attributed to declining investment and competition over time with some evidence that there is a link between market regulations and increased concentration.[112] Stricter controls on immigration may be another factor, as we show below that immigrants account for a disproportionate share of innovation and startups.[113]

Firms in less regulated markets tend to be more productive, and deregulation could help boost productivity growth in overprotected sectors.[114] Similarly, more flexible input markets allow faster reallocation of resources from low-productivity to high-productivity firms, and can thus have positive impacts on aggregate productivity in other sectors.

108 De Loecker & Eeckhout, 2017
109 De Loecker and Eeckhout (2017)
110 Haskel and Westlake (2017)
111 Decker et al., 2014
112 Gutierrez and Philippon, 2017
113 Goldin, I., Cameron, G., & Balarajan, M. (2011). Exceptional people. How Migration Shaped Our World and Will Define Our Future, Princeton and Oxford.
114 Andrews et al. (2016) and Syverson (2011)

Consequences on productivity, the labour share and inequalities



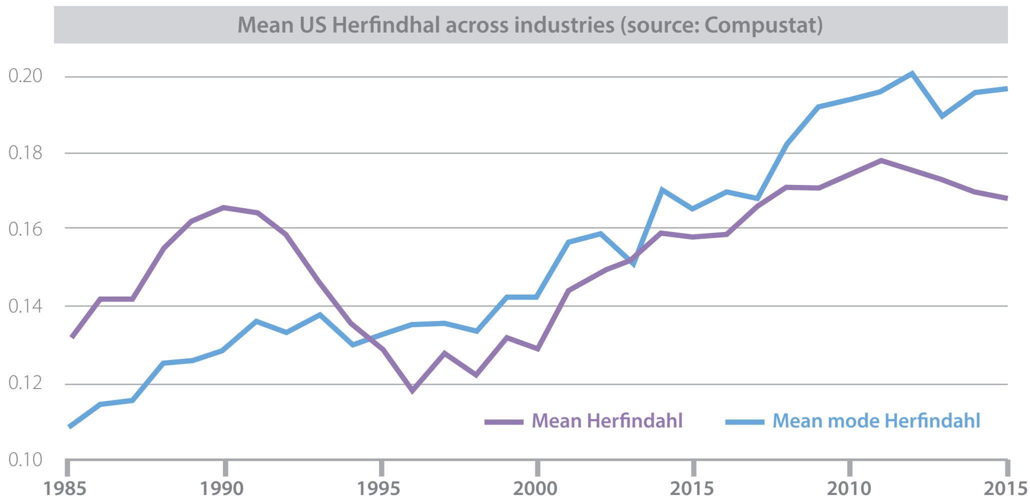


Figure 18: Entry and Exit rates and industry concentration (HHI) in the USA for 1985-2015

Source: Gutierez and Philippon, 2017

While the increase in concentration took place in almost all industries for major OECD countries, those industries with the biggest increase in concentration coincide with those with the fastest fall in the labour share.[115] This effect is reported to have been taking place between firms in respective industries, not within firms. In other words, this trend is not secular, and rather reflects a tendency for revenues to be shifted towards firms with lower labour shares. In terms of productivity, this need not necessarily be bad news: a lower labour share for the superstar firms should translate into higher labour productivity.

Increased concentration is seen to lead to reduced competition, and incumbents will have fewer incentives to keep investing in productivity improvements. In the United States, decreasing domestic competition is correlated with less investment by the industry leader,

115 Autor, Dorn, Katz, Patterson, and Van Reenen (2017a)

especially for investment into intangible assets.[116] Despite this, industry leaders are able to maintain their profit levels. There is in fact no significant relationship between the productivity of an industry and its concentration after 2000, so a dispersion in the firm productivity distribution may not cause a dispersion in the size distribution, or vice versa.[117] Investment would increase significantly with higher competition, even if it were only through the threat of entry of competitors. The scope for additional investment would be quite significant due to high profit margins and high Tobin's Q.[118] This has been the case since the early 2000s, so it is unlikely to be a direct consequence of the Financial Crisis.

Together, the combined forces of divergent firm productivity and profitability also contribute to a worrying trend of increasing inequality in advanced economies. In fact, most of the increase in wage inequality is due to greater divergence in average wages between firms, and not within.[119] Between-firm wage inequality is consistent with the evidence on firm productivity and profitability divergence, as average wages have grown faster at the top end of the firm distribution.[120]

Summary

While most sectors are affected by a slowdown in productivity growth, sectoral productivity decompositions have shown, at least in the US, that ICT-creating and even more ICT-using sectors have benefited from a period of high productivity growth that came to an end, with this contributing to the observed slowdown.

At the firm level, there is a divergence in productivity between firms at the frontier and the rest. Simultaneously, concentration, market power, and profits are also increasing across most industries. This begs the question of why the factors boosting the productivity of superstar firms are not diffusing, or not as quickly as in the past. One hypothesis is that superstar firms increasingly are able to erect barriers to entry. Another hypothesis is that diffusion takes a long time, and we should expect long lags between an initial innovation and its full impact on aggregate productivity, a point emphasized by the optimists in the productivity paradox debate. On the pessimist front, Haskel and Westlake (2017) point to the innate ability of superstar firms to appropriate intangible capital and keep it from diffusing.

116 Gutiérrez and Philippon (2017)

117 Gutiérrez and Philippon (2017)

118 Tobin's Q is the ratio of a company's market value (plus liabilities) divided by its asset value (plus liabilities).

119 Song, Price, Guvenen, Bloom, and Wachter (2015) looking at United States wage inequality

120 Berlingieri, Blanchenay, and Criscuolo (2017) using a multi-country micro-aggregated dataset confirmed the relation between the two "great divergences" of wages and productivity

Globalization, trade and offshoring

Globalisation has been a main driver for productivity growth in the last decades. The ability for firms to access foreign markets, both for production and final good export, has increased through a number of factors, reflecting directly in the growth of trade in goods and services. The first part of this section discusses these factors, drawing from the literature to explain why growth in trade has slowed down. The second part of this section demonstrates several channels through which trade increases productivity, thus in part pinning the slowdown in the growth of labour productivity to the slowdown in the growth of trade.

Slowdown in global trade

Trade has been an important driver of economic growth for much of the past century, but its growth has stagnated, as the export-to-GDP ratio for the world has not changed since the crisis.[121] Causes for the slowdown include cyclical factors related to the financial crisis, as trade is historically highly responsive to changes in output. Structural components might also keep growth in trade suppressed permanently, such as the one-off integration of China and ex-communist countries or technological advancements that enabled the spread of large Global Value Chains (GVCs).

Weakness in demand in the aftermath of the Great Recession may be a primary cause of the slowdown in trade, as the slowdown has been notably more pronounced in countries hit hardest by the crisis.[122] Import volumes for the United States and the Eurozone are 20% below their pre-crisis trend, as GDP levels are 8% and 13% lower, respectively. The collapse of investment accounts for a significant share of the slowdown in trade growth for the G7 countries, as imports are much more responsive to investment than changes in private consumption .

Structural components have played a significant role as weakness in aggregate demand accounts for roughly half the gap between trend and realised import growth. The rate of increase in trade between the mid-1980s and mid-2000s may itself have been an outlier, largely due to the emergence of China as an exporter, as well as the collapse of communism. In addition to these geopolitical factors, technological advancements, notably in communications and transportation, have fuelled an expansion in the use of GVCs[124]. Thus, the slowdown in trade can be linked to the slowdown either in the development of new technologies, or in the adoption of new technologies. Protectionist policies have not been found to explain much of the slowdown in trade, but may pose a significant headwind going forward.[125] In all, these structural components would indicate that trade has become less responsive to output growth, and the slowdown in the growth of trade may be permanent.

121 Baldwin, 2009; Hoekman, 2015

122 Constantinescu, Mattoo, & Ruta, 2016

123 Bussière, Callegari, Ghironi, Sestieri, and Yamano (2013)

124 Baldwin, 2016

125 Hoekman, 2015

Reorganization of Global Value Chains and importance for productivity

The emergence of GVCs has enabled cheaper production, specialisation, competition, and the diffusion of technologies and knowledge. The strong complementarity between the rise of services in developed countries and the diffusion of GVCs highlights the importance of trade for productivity.[126]

Offshoring and Outsourcing

Offshoring is not only a way to exploit efficiencies abroad, usually through cheaper labour costs in developing countries, but also increases a firm's access to foreign markets. The dual decision of supplier and production locations highlights the tendency for highly productive firms to offshore. This is contingent on their reliance on 'headquarter' inputs.[127]

Firms choosing to export are highly productive prior to exporting, and among firms choosing to engage in foreign trade the most productive will commit to offshoring.[128] In all, productivity gains from offshoring are significant, and are usually captured by already productive firms.[129]

Specialisation in high skilled work

The overall impact on domestic human capital is debatable. Exposure to Chinese import competition in the United States has contributed to a 25% decline in manufacturing employment within commuting zones,[130] with similar findings for local labour markets in Europe.[131] However, using evidence on the expansion in export activity in the United States, researchers have estimated that the net effect of access to foreign markets on employment is near zero within commuting zones. This results from the reallocation of labour into other occupations, notably high skilled occupations that are harder to offshore. Indeed, offshoring increased employment of high skilled workers within industries in the United States, increasing the skill premium by 15%[132].

Competition spillovers

Aggregate productive industry rises through the exit of the least productive firms and the extra exports generated by the most productive firms . Exporting alone has been shown to have significantly boosted firm productivity by up to 19%[134].

Foreign competition could also affect the rate of domestic innovation, but the evidence here is limited. By observing patenting behaviour, researchers showed that Chinese import competition led to higher technological innovation within firms in Europe.[135] Despite similar impacts for local labour markets, the United States experienced a lower issuance of patents following increased exposure to Chinese imports.[136]

126 Criscuolo and Timmis (2017), Baldwin (2016)

127 The model receives empirical support in numerous studies, such as Helpman, Melitz, and Yeaple (2004) for the United States, and Delgado, Fariñas, and Ruano (2002) for Spain.

128 Schwörer, 2013

129 Antràs and Helpman (2004)

130 A commuting zone is a geographic area used in population and economic analysis. In addition to the major use of urban areas, it may be used to define rural areas which share a common market

131 Autor, Dorn, & Hanson, 2013; Bloom, Draca, & Van Reenen, 2016

132 Feenstra, Ma, and Xu (2017)

133 Melitz (2003)

134 Bernard & Jensen, 1999

135 Bloom et al. (2016)

136 Autor, Dorn, Hanson, Pisano, & Shu, 2016

Offshoring of services and knowledge spillovers

Traditionally, services are exported through foreign investment since they are often supplied at the location of production. Recent innovations in ICT technologies have changed that paradigm, whereby a growing number of service inputs are offshored, and outputs are sold to suppliers and consumers abroad.[137] The offshoring of services has grown at an annual rate of 6.3% in the United States between 1992 and 2000.[138] They find that service offshoring within industry has accounted for 10% of the average growth in labour productivity in those years, arguing that this is largely due to a re-allocation of labour to performing more productive tasks.

The offshoring of services is also shown to contribute significant knowledge spillovers. Research demonstrates that a 4% increase in the share of foreign-owned firms increases output of domestic firms by 15% in a sample of Lithuanian firms.[139] In some instances, FDI inflows come in the form of acquisitions with the intent to acquire skilled workers and technological expertise.[140]

The importance of strong property rights is crucial in enabling the outsourcing of 'headquarter services,' including R&D. The protection of intellectual property rights abroad leads to faster offshoring of R&D and higher aggregate rates of innovation, especially for high-tech industries.[141] Therefore, investment protection, particularly in intellectual property rights, plays an important role in the productivity growth for services.

Summary

The global increase in trade has benefited domestic productivity by providing cheaper production opportunities, shifting labour demand towards high-skilled occupations, generating competition, and producing technology spillovers. These channels are not expected to generate productivity growth as long as growth in global trade remains muted. While some reasons for the slowdown are cyclical effects from the recession, structural components have also emerged in the form of the integration of developing countries and fewer developments in communication and transportation technologies. Protectionism may be a further blow to the recovery of international trade going forward.

137 *Freund & Weinhold, 2002*
138 *Amiti and Wei (2009)*
139 *Javorcik (2004)*
140 *Griffith, Redding, & Van Reenen, 2004; OECD, 2008*
141 *Antràs and Helpman (2004), Canals & Şener, 2014; Şener & Zhao, 2009*

Technological factors

The debate around the productivity slowdown is often presented as an argument between techno-optimists and techno-pessimists. On the one hand, Gordon (2016) argues that past waves of technological change, such as steam power, electricity, or the internal combustion engine had a highly significant but one-off impact on productivity. Current new technologies, in particular digital, he argues, are unlikely to have a similarly significant impact as they affect only specific aspects of human life, such as communication and entertainment.

In contrast, Brynjolfsson and McAfee (2012, 2014) and Brynjolfsson et al. (2017) argue that the ICT revolution and artificial intelligence are still in their infancy, and that it will take a long time to reveal their full potential. The technologies are still being developed, and extensive complementary investment, complementary innovation, organizational changes and diffusion are needed before the full productivity potential of the ICT industrial revolution will be realised. Mokyr's (2014) analysis is similar to Gordon's in that it is founded in historical analysis. He suggests that there are new technologies being currently developed that have the potential to become General Purpose Technologies (GPTs) and enable sustained productivity growth, such as in the case of genomics. Pratt (2015) takes a hybrid view and argues that the fusion of ICT with other new technological areas, in particular robotics, will generate spectacular new gains in living standards.

In this section, we investigate four sources of a potential decline in innovation and its effects on the real economy:

(i) a lower investment in R&D and inventive activities,

(ii) lags in the diffusion of innovations,

(iii) a faster depreciation of existing capital and infrastructures due to current innovation, and

(iv) an increasing difficulty in innovating.

Research and innovation efforts

The OECD (2017) reports that aggregate R&D expenditure has not slowed across OECD nations following the recession, but the level of funding by governments has plateaued since 2010. This decline has been offset in the increase of business R&D spending, accounting for 70% of total R&D expenditure. While all types of research grew steadily in the OECD area both before and after the crisis, funding into basic science grew faster relative to applied and experimental research. This changing composition stems from a larger contribution from universities to R&D funding, although large variations persist between countries. Notably, basic science research performed by businesses in the United States has more than doubled between 2005 and 2015.

Besides differentiating between applied and basic science research, using data from the National Science Foundation researchers[142] show that medical research funding by the United States government has experienced the largest increase. A shift of funding towards the health sector is expected to have a negative impact on productivity, because health and pharmaceutical research is known to result in lower productivity growth.[143] Additionally,

142 *Mervis (2017)*
143 *DiMasi, Grabowski, & Hansen, 2016*

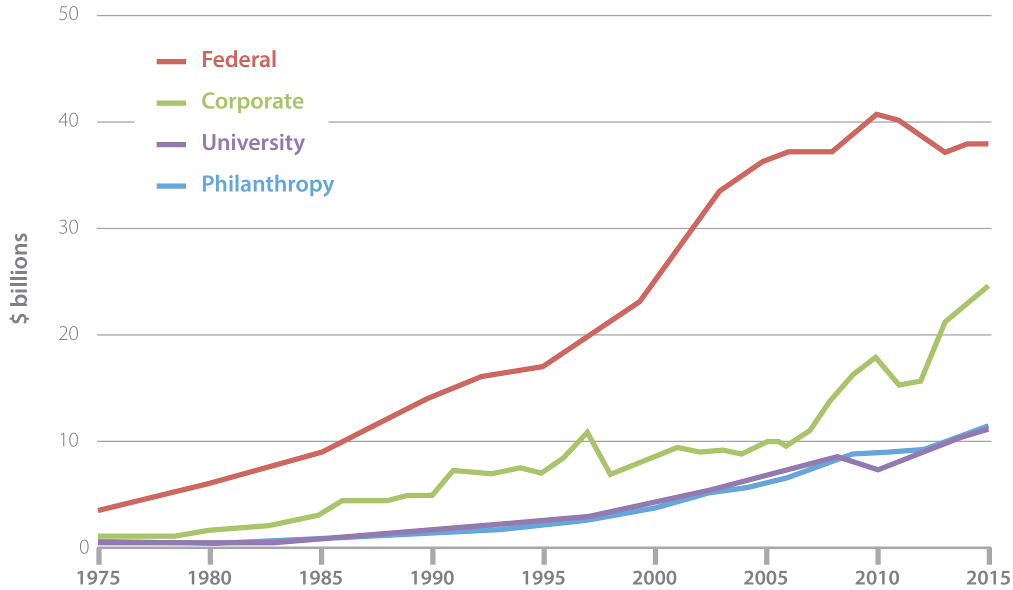


Figure 19: R&D investment by source for 1975-2015

Source: AAAS, National Science Foundation

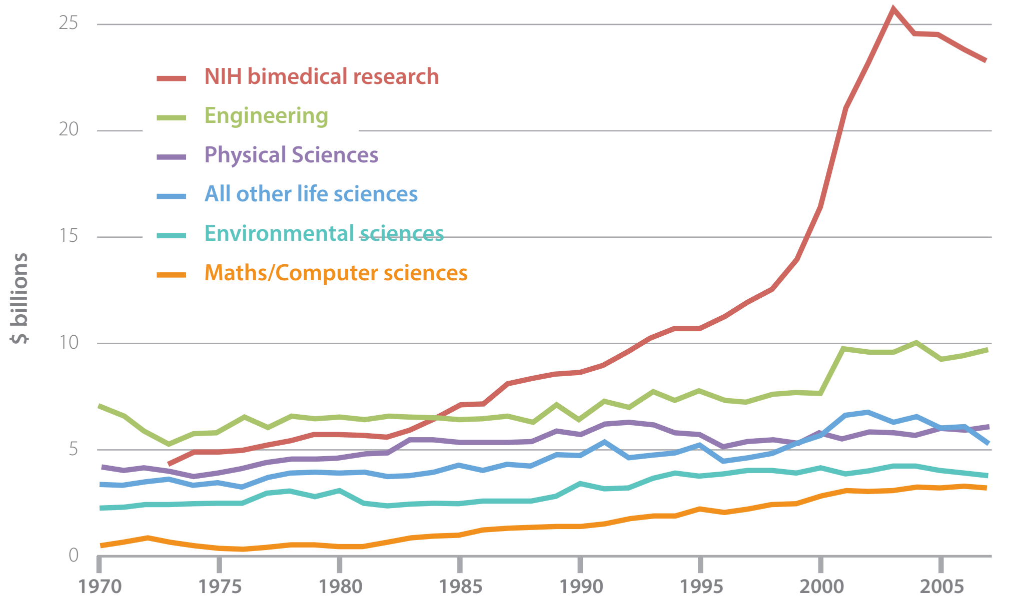


Figure 20: R&D investment in the US (billions $) by research area for 1970-2008

Source: AAAS, National Science Foundation

health services are consumed directly by households, so productivity improvements in this sector do not benefit the entire economy as much as productivity improvements in intermediate sectors, such as energy or capital goods.

The availability of skills and R&D labour force is unlikely to explain the productivity slowdown. Although the supply of doctorates in science and engineering show "some signs of slowdown"[144], excluding Japan, the number of PhDs awarded continued to grow between 2002 and 2012. According to data from the OECD, the number of FTE researchers in OECD countries has kept rising, from 3.2 million in 2000 to 4.8 million in 2015.

144 OECD, 2016

Policy measures can have different effects on the relative rate of radical versus incremental innovation, while some strategies like standardization and the introduction of production norms could have altogether negative effects on innovation despite boosting productivity growth.[146] There is substantial heterogeneity in the levels of tax incentives for R&D in different OECD countries, yet the most innovative countries are not those with the highest tax incentives. This suggests that while innovation policy matters, it is unlikely that a dramatic change in policy is responsible for a large part of the current productivity slowdown.[147]

Additionally, commercial research and development is a highly concentrated activity, both across firms and across countries. Across countries, most of the high impact research papers and patents are produced in only four or five countries. Within advanced economies, the 50 businesses with the largest R&D expenditures account for around half of the total business R&D spending on average.[148] However, inequality in R&D expenditure has not increased in Europe, and may have even have slightly decreased before 2012. The churn among the R&D leaders is low, yet whether this phenomenon is new is unclear without more data.[149]

Overall, growth in R&D expenditure has not slowed noticeably on aggregate, although its composition may have changed. In particular, a larger share of R&D expenditure is taken up by private businesses, and more is allocated to the funding of basic science. There is also some evidence of government research efforts being reallocated to the healthcare sector, which could be one potential source of a slowdown in aggregate productivity.

Diffusion and lags

A major hypothesis to explain the productivity paradox is simply that it takes time for new technologies to diffuse, for companies and workers to adapt, and for complementary investments to take place.[150] A historical parallel can be found between the diffusion of the computer and the electrical dynamo during the electrification of the United States. For both the dynamo and the computer, there were significant time lags between the first key inventions in a General Purpose technology (GPT) and its impact on aggregate productivity.

The key explanation is the prevalence of old technologies in the existing capital stock.[151] Old methods and the old capital remain more efficient during the initial phases of the GPT development, so firms have no financial incentive to switch early to the new technology. Thus, investments to improve the GPT as well as complementary innovations are needed before the new GPT becomes superior. Such investments require time and are lumpy, and the larger and lumpier the investment costs, the longer the lag.

The improvement in the GPT itself can take decades, as was the case for the dynamo, which only superseded steam four decades after the first major inventions. The dynamo only started to have major productivity effects for the firms when a complete reorganization of factories was realized. Even then, not all firms switched to the superior technology immediately, but waited until old capital had depreciated before introducing large-scale changes to their production process. In all, old and new technologies and capital vintages may be expected to coexist for a long time before diffusion becomes widespread.

The historical observations are complemented empirically with research showing that measured aggregate productivity growth first slows down for extended periods, before it

146 *Edler, Cunningham, Gök, and Shapira (2013)*
147 *OECD (2017)*
148 *OECD (2017)*
149 *Veugelers (2018)*
150 *This argument was put forward by David (1990) at the time of the first productivity paradox.*
151 *David (1990)*
152 *Jovanovic and Rousseau (2005)*

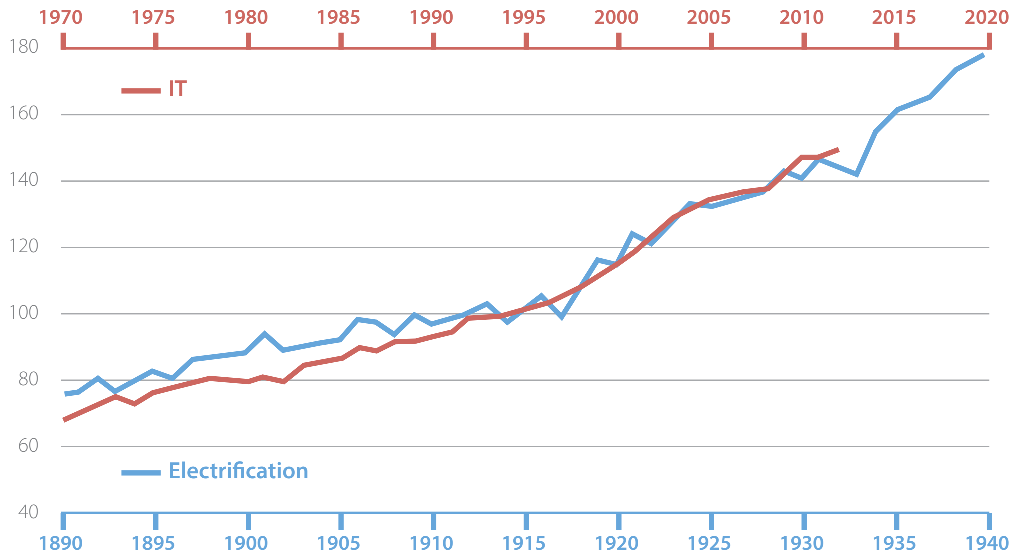


Figure 21: Adoption of Electricity compared to IT (bottom y-axis and top y-axis)

Source: Syverson, 2017

picks up significantly.[152] However, even during the productivity slowdown, the economy shows signs of restructuring and innovative activity. As firm dynamism increases, the number of patented inventions grows, initial public offerings are launched for progressively younger firms and investment into young firms increases relative to investment in old firms. Other effects observed across waves include: (i) the skill premium rises, since demand for skilled workers to enable firms to transition increases, (ii) TFP growth slows at the beginning of the wave, (iii) entries, exits, and mergers of firms increases, (iv) stock prices fall initially as old capital depreciates in value, (v) younger and smaller firms do better than larger and older firms in terms of stock market performance and investment, and (vi) interest rates rise while the trade deficit worsens because of higher consumption. There is no empirical support for IT technologies diffusing faster than electricity, so there is no great reason why we should expect current innovations to manifest themselves immediately.

Along these lines, an updated survey on the literature on GPTs emphasizes the importance of diffusion lags and the need for complementary innovation and investment.[153] The literature suggests that periods of fast TFP growth are actually the exception rather than the norm. Without new technologies, arguably total factor productivity growth comes from improved allocative efficiency, which by itself cannot sustain these growth rates indefinitely. The widely cited supporters of the "lag explanation", Brynjolfsson et al. (2017) review existing explanations for the current productivity paradox, and conclude that lags in implementation are the most important explanation for this paradox. In a similar approach, other researchers argue that the digital economy is still in its "installation phase" and productivity effects will occur once the technology enters the "deployment phase".[154] .

153 Bresnahan (2010)
154 Van Ark (2016)

Creative destruction and faster depreciation

There are theoretical reasons to believe that once a new technology has been introduced, older capital depreciates faster. If this is the case, it provides a good explanation to the productivity paradox: **it is precisely because innovation accelerates that productivity goes down**. For instance, based on a few examples such as Amazon replacing brick-and-mortar bookshops, researchers[155] argue that creative destruction has accelerated. This suggests that one should try to compute time varying scrapping rates, both for tangible and intangible capital.

Research[156] has produced R&D capital depreciation rates ranging from 6% to 88%, underlining a large degree of uncertainty regarding the stock of R&D capital and a potential for mismeasurement on total factor productivity growth. Using alternative depreciation rates for the UK, researchers found that a premature scrapping might explain up to 15% of the missing 12 percentage points of productivity growth.[157]

While these arguments are often motivated by the financial crisis, there is a more general theoretical argument: during phases of profound technological transformation, society as a whole has to adapt. During the previous industrial revolution and the last productivity paradox, it took a lot of time for firms as well as workers to adapt and complementary innovations to develop.[158] As an example, consider AI and autonomous vehicles: not only does the education system need to be reformed to train people with the right skills, but other institutions such as contracts and the judiciary system need to be re-invented, for instance to deal with the responsibility of autonomous non-human entities. Creative destruction makes entire sets of institutions and branches of knowledge obsolete, which is extremely hard to capture in the data.

Research Productivity

Here we discuss theoretical arguments on why research productivity is expected to increase or decrease, and then turn to empirical evidence. One of the simplest arguments about research productivity is the fishing out hypothesis: there exists a fixed pond of ideas, and we are fishing for the easiest first. In other words, the low hanging fruits may have already been picked.[159] For instance, Gordon (2016) argues that many of the drivers of productivity in previous industrial revolutions (steam, electricity) were innovations that could only be made once (such as urbanisation and the hygiene revolution) and that these have a level effect, not a growth effect on productivity.

On the other hand, knowledge should become easier to find as knowledge progresses because new ideas arise out of existing ideas. The more ideas there are, the more can be found.[160] However, as the space of ideas expands and multiplies, it may become increasingly harder to explore. In fact, some researchers have proposed that an increasing scientific frontier also creates a "Burden of Knowledge", as every researcher needs to acquire greater knowledge before making a novel contribution.[161] In support of this theory, empirical evidence suggests that the age at which scientists and inventors make their most significant contributions has been increasing and that the share of scientific papers and patents that are written by a team of several authors is increasing. This suggests that researchers cope with the increasing burden of knowledge by being more specialized and working in teams. As well

155 Komlos (2016)
156 Li and Hall (2016)
157 Goodridge et al. (2016)
158 David, 1990
159 Cowen, 2011
160 Arthur, 2009; Weitzman, 1998
161 B. F. Jones, 2009

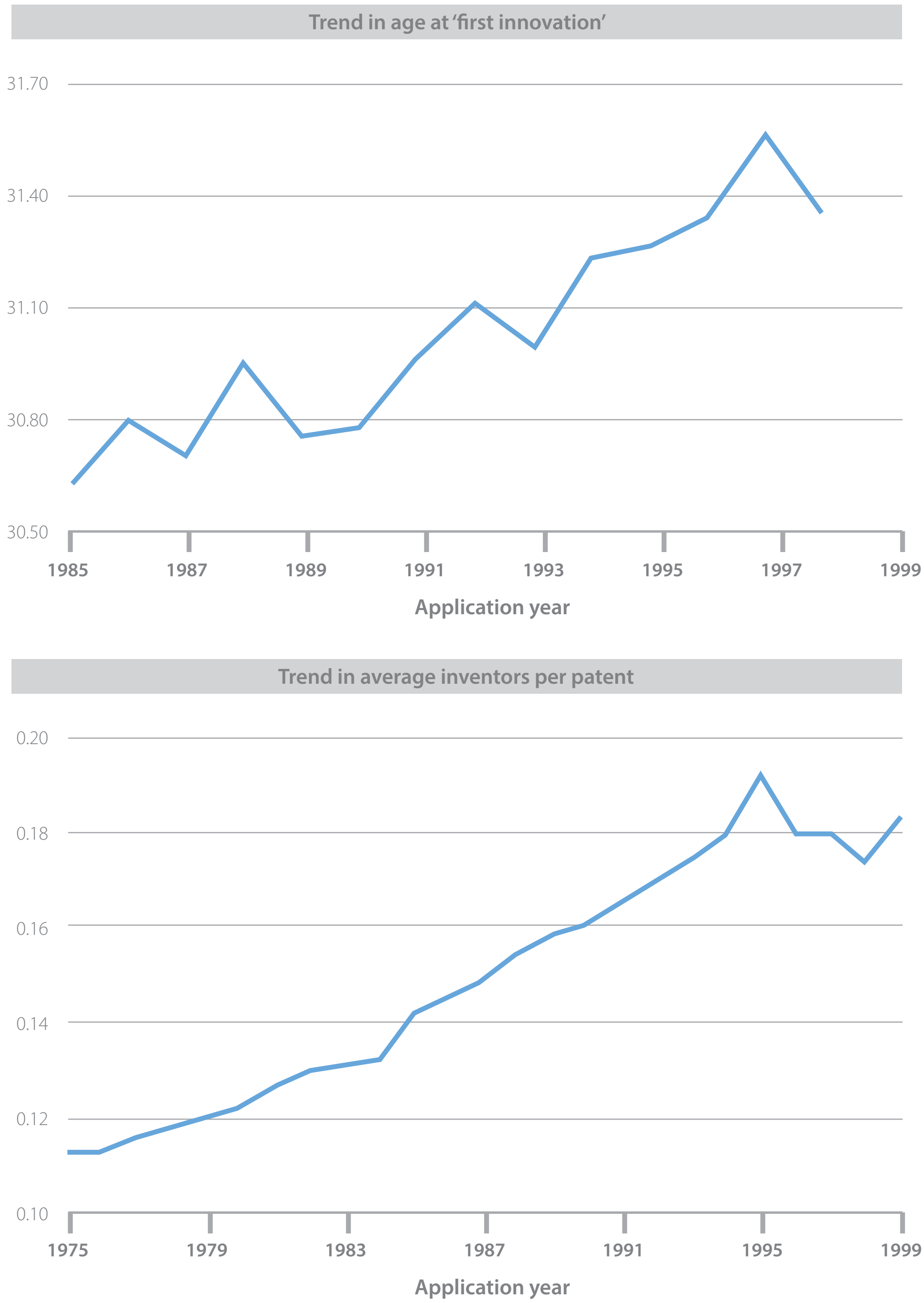


Figure 22: Age at first invention and inventor team sizes over

Source: Jones, 2009

as this, the likelihood of switching field is decreasing, again suggesting that the burden of knowledge is creating a higher barrier of entry into fields.[162]

This poses the question of whether ICTs, by making knowledge more accessible or by making science more automatable,[163] could make research more productive. If we push the argument to the extreme, in the future artificial intelligence could lead to a rising research productivity and an intelligence explosion.[164] Researchers have not however found evidence for this hypothesis in the data so far.[165]

162 B. F. Jones, Wuchty, & Uzzi, 2008; Wuchty, Jones, & Uzzi, 2007

164 Bostrom, 2014

165 Nordhaus (2015)

An important indicator that researchers use to determine research productivity has been measures of research inputs per patent. There is evidence that the number of patents per researcher in the US economy has been on a continuously declining trend for several decades.[166] However, research spending per patent is extremely heterogeneous across countries. This suggests that as well as the different sectors that countries innovate in, heterogeneity in the propensity to patent may explain parts of the differences across countries. An interesting fact is that for ICT, research spending per R&D is significantly lower than the average.[167]

Does a constant level of research effort lead to a constant rate of productivity growth? Under this assumption, if research inputs stay constant, total factor productivity should keep growing at the same rate. This hypothesis is overwhelmingly rejected, as is observable by looking at raw numbers: total factor productivity growth in the US has been at best stable or even declining since 1930, whereas measured research input has increased by a factor of 23. In other words, while productivity keeps growing at a constant rate or even slowing down, the efforts made to achieve this have been increasing.[168]

The decline at the aggregate level could mask important differences in research productivity trends at the micro level. One area where declining productivity of research activity has been noted in particular is the pharmaceutical sector. The research spending per drug has gone up continuously and substantially, so much so that it has been termed "Eroom's law", a letter

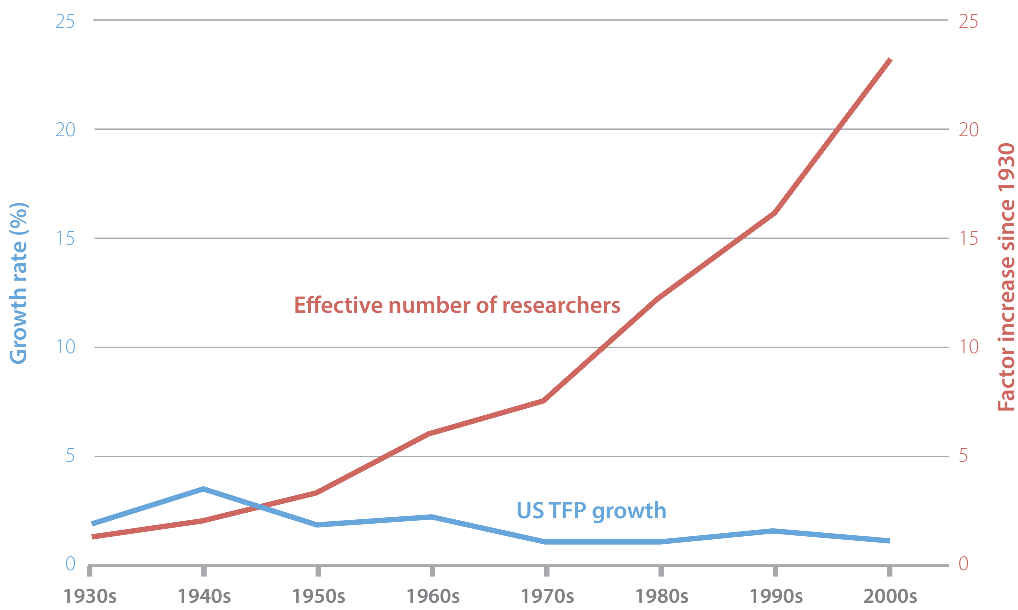


Figure 23: Number of researchers and US TFP for the period 1930-2000

Source: Bloom et al., 2017

play which reverses the seemingly steady increase in computing power associated with Moore's law. However, researchers have shown that even Moore's law was only upheld by a significant expansion in research effort, so research productivity has declined substantially even there, though not as much as in other areas.[169] Repeating the exercise at the firm level and measuring research output as increase in sales, suggests that research productivity only increased for a small fraction of firms, whereas a large majority have seen their research productivity decline, in some cases substantially.

166 Griliches (1994)
167 OECD (2017)
168 Bloom, Jones, Van Reenen, and Webb (2017)
169 Bloom et al. (2017)

Conclusion

Possible reasons for an observed slowdown in productivity are wide and varied. Failures to properly measure growth form part of the explanation. This is both with respect to inadequate measurement of current output and to the increasing significance of intangible capital, which leads to growing mismeasurement of inputs. A broader examination of the changes taking place within and across economies is required in order to establish the size of the shadow economy and the relative merits and behaviour of the mismeasured sectors. Taken together, the evidence we have assembled suggests that although it needs to be addressed, mismeasurement is unlikely to explain the productivity paradox, not least, as there has not been a major rise in mismeasurement that coincides with the collapse in productivity.

Going beyond mismeasurement is therefore necessary. This paper has identified changes in different market sectors as potential sources of the productivity slowdown. In labour markets, the key causes of the slowdown have been driven by the gradual automation process of cognitive routine occupations that led middle wage workers to low skilled jobs. This effect was combined with other major factors including the declining returns to skilled labour, lower migration flows, and new labour market institutions, such as the increased use of gig workers and temporary contracts which are associated with lower commitment and training by employers and workers. For firms, changes in the productivity and profitability distributions, growing reliance on intangible capital, faster depreciation, and production network considerations, stand out. The slowdown in trade may have also damaged the rate at which domestic productivity accrued benefits from foreign competition and export markets. The hoarding of profits and apparent reduction in the rates of investment in R&D, mean that faster depreciation has not been countered by faster renewal of intellectual and physical assets. While all of these factors contribute to the slowdown, the precise nature and ranking of these contributing factors is different in different circumstances, with geographical and sector specificity reflecting a wide range of culprits.

Amongst the factors that have not been adequately addressed is the role of institutions. Faster technological change can challenge the responses of existing institutional controls. Institutions are of primary importance in economic development and growth. However, the extent to which institutions have a one-off level effect, or if they indeed influence trend growth rates remains unclear. Besides accelerating technological change, the Great Recession may have contributed to a further deterioration in institutions. A spread in mistrust in government and the financial sector, while not necessarily misplaced, undermines their legitimacy. Indeed, these aftershocks are just now being felt through waves of populism.

This paper has focused on large, advanced economies. While some of the mechanisms presented above are relevant for developing and emerging economies, they may be exposed to different dynamics. For example, it is questionable how long a reliance on cheap labour to attract foreign investment is a sustainable growth model for a developing nation, when an increasing amount of repetitive and rule-based employment in manufacturing and also services (including in call centres and administrative back offices) is likely to be automated.

Our comprehensive review of the explanations for the productivity slowdown is not exhaustive. It draws on existing sector, industry and country studies. It shows that all the main explanations that have been offered are inadequate and that none alone could account for the productivity slowdown. We demonstrate that an intersecting set of factors best explains the observed slowdown in productivity across countries. Our review offers an agenda to evaluate both the microeconomic and macroeconomic mechanisms that undermine productivity growth and to evaluate their relative importance. By assessing these factors, the policy implications will become clearer. More research is needed to solve the productivity puzzle. However, we have shown that a great deal is already known. The evidence points to a wide range of interventions that need to be undertaken by governments and firms to address stagnating productivity. Raising productivity is vital to restore growth and to address the pressing distributional and other economic challenges which our countries face. This issue is too important to be left to the future and requires urgent and wide ranging actions. It is our hope that the factors we have identified will be addressed and that productivity growth may be restored.

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