FOUR

The Technology-Productivity Paradox

Why Has Productivity Growth Slowed?

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The paradox of seemingly rapid technological change and slow productivity growth has no single, master explanation, but a careful look at some key developments across advanced and major emerging economies reveals some consistent explanations. Many of these same developments are also correlated with high inequalities in many economies, such as those between rich and poor or educated and less educated. We focus specifically on possible reasons behind the productivity slowdown despite rapid technological progress.

Some of the reasons for weak productivity growth are cyclical in nature, but the slowdown has been under way too long to be explained by the short-term ups and downs of an economy. Ultimately, the declining trend in productivity growth is led by factors that do not come and go in cycles but are embedded in an evolving structure of the economy and the incentives that firms face when making decisions on investing, hiring, reorganizing, and, ultimately, producing.

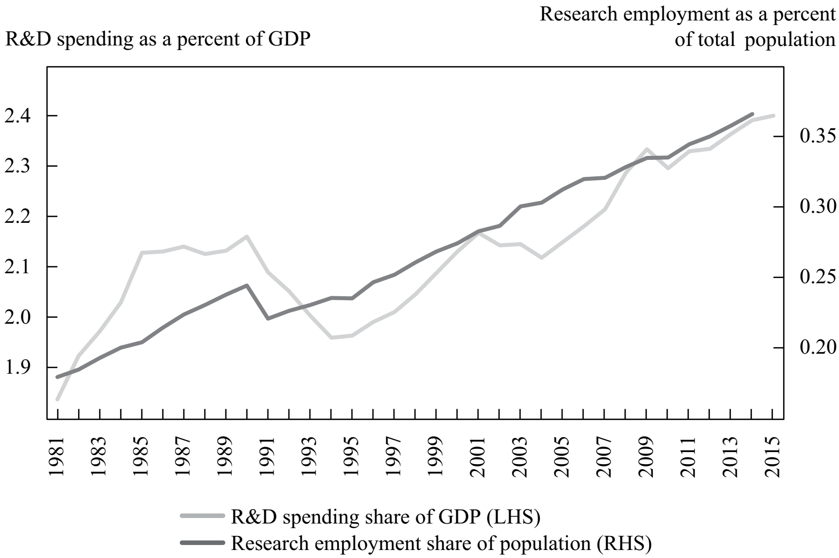
Before wading into the inner workings of the economy, a bigger question looms over the productivity puzzle: Is technological progress as rapid as we think it is? Improvements in productivity depend on the forward march of technological progress and innovation. It is the application of technology to the production process that yields productivity gains, but different ways of thinking about innovation can lead one to believe that the frontier of technology itself has, perhaps, reached its limits. It would follow, then, that the scope for productivity-enhancing innovation may be approaching its limits, too. If that were the case, the productivity slowdown would be with us whether the economy is firing on all cylinders or not. Let us investigate.

Is Innovation Slowing Down?

One does not need to look far to see the impact of innovation on our lives: smartphones with real-time traffic updates, intelligent machines providing investment advice and legal expertise, global digital networks and cloud computing, gene therapy and stem-cell transplants, self-driving cars. The list goes on. Optimism in Silicon Valley is unbounded, and by all appearances we are in a golden age of innovation (Aeppel 2015). But the slowdown in productivity growth has led many to wonder if the seemingly rapid pace of technological progress is just a façade, if today's progress pales in comparison to the transformative technological breakthroughs of the past. Is innovation advancing as rapidly as it appears, or is it actually slowing down and becoming less impactful, as the productivity trends might suggest?

There is some reason to believe that ideas are getting harder to find. The inputs to innovation have been growing, but the outputs do not appear to be keeping pace. In terms of inputs, spending on R&D has trended modestly higher over the last thirty years, and there are more scientists and engineers than ever before (figure 4-1).[1] The outputs are more difficult to measure, however. The number of patents granted is traditionally used as a quantifiable marker of innovation, but this is not always a reliable measure. Some patents may be more valuable in terms of their innovative novelty or in terms of their contribution to a company's output and productivity than others.[2] Anne Marie Knott of Washington University in St. Louis, Missouri, uses firm-level data on R&D investments, patents, revenues, and other characteristics to estimate the value of patents, finding that only 10 percent of patents comprise 85 percent of the total value of all patents in the United States. Knott estimates "R&D productivity" is essentially the ratio of a firm's revenues to its R&D investment, estimating that overall R&D productivity in the United States declined 65 percent over the last three decades (figure 4-2).

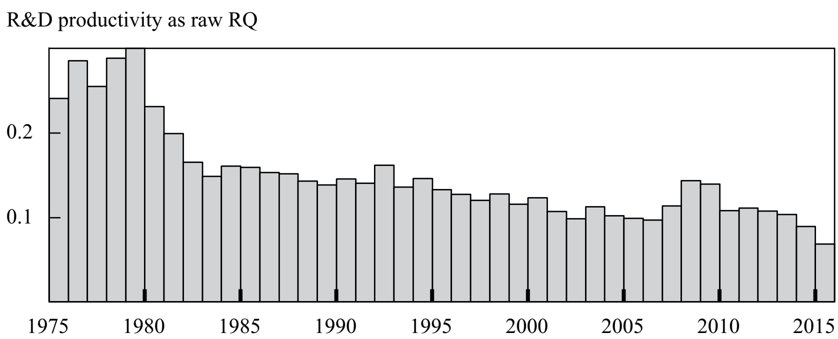
FIGURE 4-1 R&D Spending and Share of Researchers in the OECD, 1981–2015



Source: OECD Main Science and Technology Indicators.

Note: Some variation exists by country. For example, the U.K.'s share of R&D spending in GDP has declined since the early 1980s, but the majority of countries have increased their spending as share of their economies. OECD aggregates include Mexico.

FIGURE 4-2 R&D Productivity in the United States, 1975–2015



Source: Knott (2017).

Note: Raw RQ is a metric developed by Knott (2017) that stands for Research Quotient, which is essentially a ratio of firm revenues to R&D investment. See more detail in Cooper, Knott, and Yang (2015).

In other words, it is requiring more research effort to generate a similar amount of innovation. Consider Moore's Law—the doubling of the computing capacity of a semiconductor chip every two years since 1971. Economists at Stanford and MIT used data on semiconductor R&D from a number of semiconductor firms and equipment manufacturers to find that the research effort needed just to maintain Moore's Law today is around 78 times greater than it was in 1971. They found similar results of declining "ideas productivity" in other areas of the economy, from various agricultural crop yields to mortality and life expectancy (Bloom and others 2017).

There are a number of explanations for why this could be the case. One of them suggests a "burden of knowledge." As ideas accumulate and technology advances, it becomes more costly to innovate, taking longer for new researchers to catch up with the frontier in their area of expertise (Jones 2009). Another suggests that a decline in public spending on basic research has lowered the chances for new discoveries to be widely shared and built upon (box 4-1). A different explanation suggests that increasing environmental or safety regulations are raising barriers to commercializing new ideas. For example, meeting vehicle safety and fuel-emission standards gobbled up extra research effort that once helped make roads safer and the air less polluted, but those benefits do not translate into output (Ip 2016).

The most prominent explanation for why innovation might be slowing down asserts that there are simply no more major innovations to be found. Economic historian Robert Gordon, in his 2016 book *The Rise and Fall of American Growth*, argues that the impact of the transformative technological breakthroughs of the second industrial revolution cannot be repeated or rivaled. After cars and airplanes were introduced, for example, later innovations that improve speed, efficiency, and safety could not be nearly as impactful as the initial transformation from horses and railroads to wheels and wings. When productivity growth slowed in the 1970s, the broad majority of factories in advanced economies had been electrified, households already owned refrigerators and televisions, and medical breakthroughs had increased life expectancy faster than they are likely to in the future. Tyler Cowen of George Mason University (2011) suggests we have plucked the low-hanging fruits of innovation and are now stagnating in a technological plateau. Though the productivity-enhancing spread of ICT in

BOX 4-1 Innovation and Public Investment in Basic Research

Public investment in basic research tends to be positively related with private sector innovative activity and productivity growth. Basic research is experimental work aimed at acquiring new knowledge and discoveries without any specific application necessarily in view. Private firms are more actively engaged in applied research that focuses its efforts on a direct application that can provide a monetary reward. Basic research helps push the frontier of discovery and knowledge, which provides the foundation for applied research by all firms to offer innovative applications and enhance productivity growth. Some of these innovations that spawned from public investment in basic R&D include the Internet, Google's basic research algorithm, and key features of Apple smartphones.

However, public investment in basic R&D has declined in many major economies. In the US, government spending on R&D fell from 1.2 percent of GDP in the early 1980s to half that level in 2015. Furthermore, the share of basic research in the US supported by the federal government has fallen to its lowest level of 44 percent, compared to over 70 percent in the 1960s and 1970s. The overall rise in total R&D spending as a share of GDP shown in figure 4-1 is therefore driven by private investment in R&D. Recent research suggests that the decline in public R&D and its focus on basic research is a contributory factor to the decline in the productivity of overall R&D (Bloom and others 2017).

1996–2004 in the United States made its impact, the wave was short-lived and is now over.

But there is a totally different view of innovation that lends itself to the opposite conclusion—that we are in the midst of rapid technological progress that will only accelerate. It does not see innovation as ideas that "get used up" but rather as blocks of ideas that combine with other blocks to produce even more innovation. This combinatorial or recombinant view of innovation challenges the notion that ideas are getting harder to find by suggesting the opposite—that the number of available ideas only grows over time as they combine and recombine with each other.

MIT economists Erik Brynjolffson and Andrew McAfee (2014, p. 81) argue that the unique properties of digital technology as well as its role as a general-purpose technology—one that can be applied across a broad range of sectors and activities—will result in an exponential rise in ideas. In their book, *The Second Machine Age*, they write:

> Digital innovation is recombinant innovation in its purest form. . . . Moore's Law makes computing devices and sensors exponentially cheaper over time, enabling them to be built economically into more and more gear, from doorknobs to greeting cards. Digitization makes massive bodies of data relevant to almost any situation, and this information can be infinitely reproduced and reused because it is non-rival. As a result of these two forces, the number of potentially valuable building blocks is exploding around the world, and the possibilities are multiplying as never before.

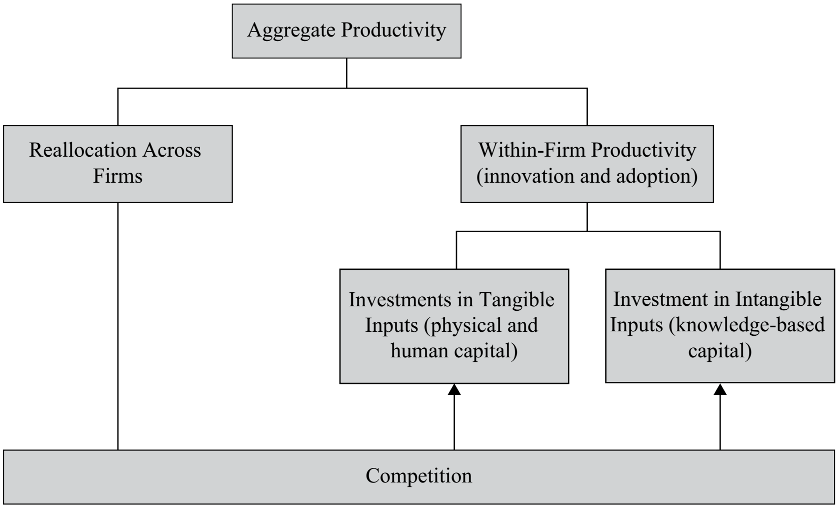
The biggest limit, they say, is to identify which combination of building blocks will be valuable, requiring more eyeballs and even bigger computers to sift through ever-increasing amounts of data.

This is consistent with the fact that some firms in the economy—typically those at the frontier—have become more and more productive relative to the rest, as shown in several studies, including Dan Andrews and others (2016) and Dany Bahar (2018). This is likely the result of innovation at the frontier, which, even if more difficult, is still happening. Yet, for aggregate productivity growth to pick up the pace, it is not enough for some firms to innovate; it requires a broad range of firms to adopt new technologies and best practices. It is this adoption process by laggard firms that appears weak.

The Determinants of Productivity Growth

A 2015 survey by *Fortune* magazine of the CEOs of the biggest 500 companies in the world found that 72 percent of them view the rapid pace of technological innovation as their company's biggest challenge, and 94 percent believe their company will change more in the next five years than it has in

FIGURE 4-3 **A Framework for Explaining Productivity**



the last five years. While these large firms wrestle with the expanding technological frontier, the rest of the economy seems to be lagging behind. As shown in Bahar (2018), firms at the frontier of productivity growth within each narrowly defined sector have continued apace, suggesting continued robustness in innovative activity. The widening productivity gap between frontier firms and lagging firms suggests a weakening of the diffusion of new technologies across the broad landscape of small, medium, and other large firms. For technological progress to have an impact on overall growth and productivity, its adoption by a broad range of firms and industries throughout the economy is critical.

Before diving straight into the reasons behind the weakening diffusion of technological progress, let us first take a step back to ensure we cover all the major bases for what drives productivity growth and what could explain its slowdown. Let us begin with a framework for what determines aggregate productivity to guide us through its key drivers. Figure 4-3 isolates the two key components that affect a country's productivity—the reallocation of resources from low- to high-productivity firms and the productivity growth of the firms themselves. Under each of these two components are key determinants that can ultimately facilitate productivity growth or slow it down.

Reallocation

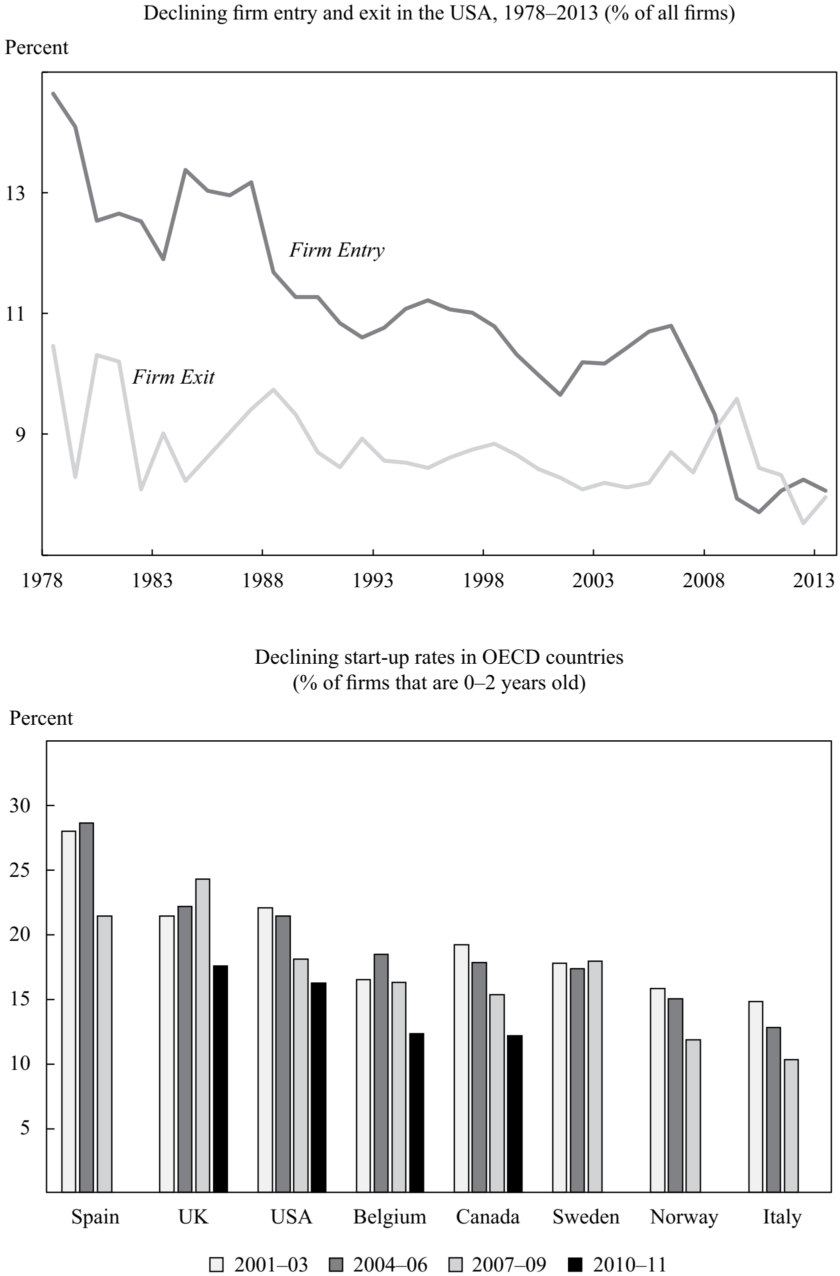
The first component in figure 4-3, reallocation, is directly affected by one subcomponent: competition; that is, the Darwinian selection process that takes place through which less productive firms exit the market and shed resources (labor, capital) that are—ideally—reallocated toward more productive firms. Conceptually, an economy can increase its aggregate productivity without a significant degree of technological progress at all by constantly reshuffling resources to where they can be most productive, as the firms that die are replaced by new, more productive ones.

Over the last two decades, there has been a slowdown in this competitive selection process. The rate of new business formation has been on a declining trend since the late 1970s in the United States and more recently across other OECD economies. In 2013, business start-up rates were around 30 percent lower than the annual average in the 1980s, and the decline has affected nearly all business sectors. The rate at which firms exit the market has also slowed, resulting in a larger share of older firms that face less competitive pressure from fewer new entrants. In the late 1970s, new firms accounted for 16 percent of all firms in the United States. By 2011, that share had been cut in half, to 8 percent. This trend has been most pronounced in the United States but has also been under way in most other OECD countries (figure 4-4).

That there are fewer new entrants suggests there has been a decline in reallocation of resources from less to more productive firms. In a dynamic economy, it is typically young, productive firms that tend to generate new ideas and create jobs. However, in addition to the fact that there are fewer new entrants, post-entry growth of new entrants has also slowed. A 2014 study by Steven Davis of the University of Chicago and Jon Haltiwanger of the University of Maryland (2014) reports that, after 2000, start-up rates in high technology and information-processing firms fell, and those firms that did enter did not experience the same rapid growth as earlier cohorts.

The magnitude of diminished business dynamism and the direct impact of competitive selection processes on aggregate productivity growth is not so clear, however. Critics point out that the acceleration in productivity growth in the United States in the late 1990s and early 2000s is inconsistent with the continued decline in business dynamism over that time period, suggesting that older firms may be just as innovative as newcomers.[3]

FIGURE 4-4 **Declining Business Dynamism**



Source: U.S. Census Bureau (top panel) and Criscuolo, Gal, and Menon (2014) (bottom panel).

A 2017 paper by Chang-Tai Hsieh and Peter Klenow suggests that the decline in dynamism (as defined by job reallocation and the contribution of new entrants to job creation) has contributed as much as 10 percent to the decline in productivity growth in the United States, a notable amount but leaving most unexplained.

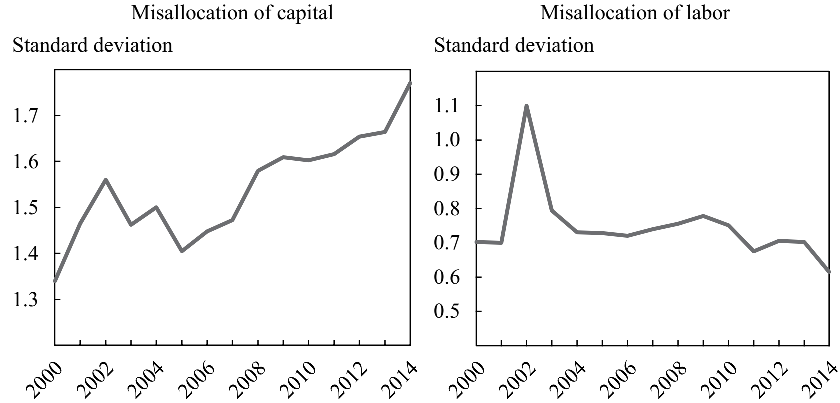
The type of competition that drives Darwinian survival dynamics can come in many forms beyond the pure entry and exit of firms. For instance, unequal access to capital could hinder the allocation of capital to small but highly productive firms in need of more inputs to keep growing. Alternatively, subsidies on inputs that benefit thriving low-productivity firms would tend to drag machinery from firms without subsidies that could use such machinery much more efficiently. For some developing countries, such as China and India, eliminating these inefficiencies could result in increases in aggregate productivity of up to 60 percent (Hsieh and Klenow, 2009).

Misallocation of Capital and Labor

At the heart of the reallocation story stands the ability of all firms to get the optimal allocation of resources. In reality, small and medium-sized enterprises (SMEs)—many of them with high growth potential—typically face stronger financing constraints than larger firms, mostly due to high financing costs and increased perceptions of riskiness by investors. In 2014, the OECD reported that SMEs across OECD countries continued to suffer relative to larger firms from both reduced availability of internal funding after the Great Recession and low credit availability from the banking sector after the Great Recession. In the United States, for example, the share of loans to small firms out of total business loans dropped from 30.1 percent in 2009 to 23.7 percent in 2012. According to the report, bank lending continues to be the most common source of external finance for small firms (OECD 2014). Since 2007, SMEs experienced tougher credit terms than larger firms, in the form of shortened maturities, increased requests for collateral, and higher interest rates. Between 2007 and 2013, the median interest rate spread between loans to SMEs and to large enterprises across twenty-four advanced economies rose from 0.8 to 1.3 (OECD 2016c).[4]

For firms with weaker balance sheets before the financial crisis, tight credit conditions after the financial crisis had a more acute impact on their

FIGURE 4-5 Rising Capital Misallocation in Advanced Economies



Source: IMF (2017); Duval, Hong, and Timmer (2017).

Notes: Standard deviation of factor return, median across countries using the Hsieh and Klenow 2009 approach. An increase in the standard deviation denotes larger misallocation.

productivity than other firms with less overall debt and lower short-term financing needs, especially in countries most affected by the euro area crisis. Research by the IMF finds that, on average across countries, the decline in average post-crisis TFP growth (2008–13) was 1.01 percentage points greater for firms with high financial leverage than for low-leverage firms. In countries where credit conditions deteriorated more (sharper increases in bank credit default swap spreads), the same gap was 1.31 percentage points (IMF 2017; Duval, Hong, and Timmer 2017). This "missing growth" of the low-leverage firms due to credit market frictions is, naturally, reflected in lower aggregate productivity growth.

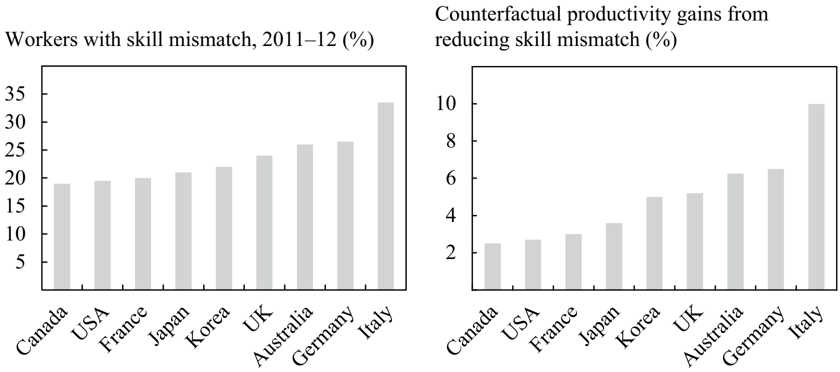
More generally, all market inefficiencies create misallocations that keep the "right" firms from getting the resources they need to compete in the market while, at the same time, allowing low-productivity firms to survive longer than they should.

In advanced economies, there is evidence that the misallocation of capital began to rise before the financial crisis, and rose further in its aftermath (figure 4-5) (IMF 2017). In Europe, the inception of the Eurozone in the late 1990s and the resulting decline in interest rates for many of its members triggered a sharp rise in poorly intermediated capital inflows that drove a notable misallocation of capital across southern Europe (Gopinath and others 2017). Estimates for Italian manufacturing firms suggest that TFP levels would have been 12 percent higher in 2007 if the efficiency of resource allocation had remained at its 1997 level (Calligaris 2015), while estimates for Spain suggest that rising misallocation held down TFP growth by 1.0 to 1.5 percentage points a year between 1995 and 2007 (Garcia-Santana and others 2016). After the financial crisis, capital misallocation worsened more broadly across advanced economies. The productivity growth of financially constrained firms grew more slowly relative to financially healthier firms. Making matters worse, many of these financially constrained firms stayed alive as "zombie firms," as banks may have extended "evergreen" loans to weak firms to delay recognition of losses (IMF 2017). An OECD study estimates that the rise in the share of the industry capital stock stuck in zombie firms can account for around 15 percent of the decline in the efficiency of capital allocation across a set of OECD economies (Adalet McGowan, Andrews, and Millot 2017).

On the other hand, misallocation of labor—conditional on the observed allocation of capital—has remained steady since the mid-2000s in advanced economies, and thus it is not a likely candidate to explain the productivity slowdown. However, when taking skills into the picture, as technological change pushes ahead, the difficulties in matching the right workers with the right jobs is another important source of misallocation.

Areas with tight labor market regulations, like strict rules for hiring and firing in Europe or the rise in the number of licenses and certifications required to do certain jobs in the United States, have contributed to sizable skill mismatches that have helped suppress faster productivity growth. Figure 4-6 shows how sizable productivity gains from reducing skill mismatches and improving the allocative efficiency of skills alone could be. In Europe, a growing body of research finds that lower flexibility in labor markets has limited the ability of firms to reorganize with new business models and skill requirements to take full advantage of productivity-enhancing ICT and digital technologies.[5] In the United States, state-level licensing regulations grew by a factor of five in the second half of the twentieth century with the intention to protect health and safety but in some cases at the expense of increased inefficiency, especially for smaller firms or entrepreneurs. Zoning restrictions in U.S. cities have also heightened housing supply constraints, reducing the efficiency of labor allocation at the state and national levels.

FIGURE 4-6 Skill Mismatches and Productivity, Selected Advanced Economies



Source: Adalet, McGowan and Andrews (2015).

Note: Simulated gain in allocative efficiency by lowering the skill mismatch to the best practice level of mismatch.

Firm Productivity Growth

The second component in figure 4-3 directly links the process of productivity growth to the ability of individual firms to grow mainly by innovating and adopting new technologies or innovations. In addition to entry and exit dynamics, the degree of competition in an industry heavily influences both the ability and the willingness of firms to make productivity-enhancing investments in both tangible and intangible inputs that enable faster technology adoption. When confronted with stiff competition, firms must often invest to raise their productivity to retain their market share, or to survive at all.

Investment in tangible inputs—like equipment, fixed capital, and workers with a range of skills—and intangible inputs—like business processes, organization design, patents, ideas, and copyrights—are critical for all firms to improve their productivity and grow. Over the last two decades, however, private investment rates have been falling, and small to medium-size firms have faced growing credit restrictions, limiting their capacity to invest in themselves.

Figure 4-7 shows the overall decline in private investment since the 1980s in the United States with the exception of the 1990s, when productivity

FIGURE 4-7 Declining Investment by Private Non-Financial Firms, United States 1980–2015

Source: Gutierrez and Philippon (2017).

growth in the United States accelerated, private investment has been on a downward trend. After the shock of the financial crisis, investment rates bounced back to around 10 percent across private non-financial firms, just half of the longer-term average from the 1960s until the turn of the century.

In addition, firms' investment (or lack of it) is also determined by factors other than access to capital. In fact, when we focus only on access to capital as a driver limiting firms' investment, there is a direct link between the reallocation and the within-firm components of aggregate productivity growth. In some sense, one becomes the mirror image of the other. In the presence of financial market inefficiencies, small firms with high potential might not have access to resources that are in the hands of less productive firms (thus generating misallocation), and without such investment their full potential won't be realized (that is, no growth due to no investment).

While access to finance and other critical resources, like skilled workers, for example, mostly determines the ability of firms to invest, there are other factors—competition being a crucial one—that determine the willingness of firms to invest. In this section we focus on the latter, as the former can also be seen from the reallocation lens. First, let's delve into the details of what these tangible and intangible inputs are, how they are a key for a firm's productivity, and what the evidence has to say about why firms are not investing as much as they could.

Investing in Tangible Inputs: Physical and Human Capital

Firms can adopt technologies by accessing tangible inputs, in particular, knowledge-embedded tangible inputs like sophisticated machinery or better managers and trained workers. Yet, evidence consistent across countries suggests there is unequal access to such inputs across firms of different sizes. This generates frictions in the ability of small firms to adopt technologies from the frontier.

Knowledge-Embedded Physical Capital

Upgrading to ICT capital and other forms of modern infrastructure—for example, data servers for storage, devices, networks, and other technology-embedded capital—allows firms to compete in a digital marketplace and to connect with suppliers at home or abroad. The technologies embodied in physical equipment can go a long way in improving productivity of firms, not only by increasing their efficiency in production but also by boosting their ability to adopt best practices and know-how from around the world by connecting them to other firms that otherwise they might not have been exposed to. Investment in the necessary equipment and digital infrastructure is becoming a growing prerequisite for firms to engage digitally and be linked into larger, even global networks. Box 4-2 touches on the importance of public investment in infrastructure at the macro level.

More broadly, there is very little understanding of what keeps many firms from investing in new equipment that could boost their productivity, but it is known that, indeed, the slowdown in capital investment is strongly related to slower productivity growth. According to IMF estimates,

BOX 4-2 The Macro Barriers to Investment and Productivity

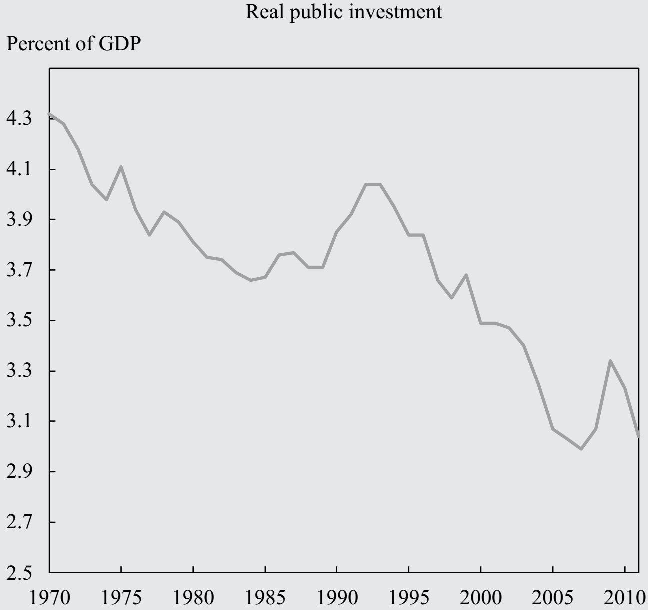
In the short run, investment can stimulate economic activity and demand. In the long run, it can raise potential output by raising productivity. The role of investment in enhancing productivity is structural in nature, though firms' investment decisions are driven by both short- and long-run factors. Weak aggregate demand in the post-crisis period, declining public investment, and heightened levels of policy uncertainty are some major macro-level factors that encourage firms to delay investment decisions.

Weak Aggregate Demand. Several studies by the IMF, OECD, and others have established that weakness in aggregate demand has been a major contributor to weak investment in the post-crisis years. Many economies have been stuck in a low-growth, low-investment equilibrium, generating concerns that the shock of the financial crisis may lead to permanent declines in the productive capacity of the economy. Estimates by researchers at the OECD suggest that the shock to demand after the crisis may have reduced the aggregate capital stock by about 3¼ percent across OECD countries (Ollivaud and others 2016). Reduced capital investment not only reduces the contribution of capital to labor productivity, but it also reduces the diffusion of technological progress embodied in capital.

Declining Public Investment. Public investment, particularly in infrastructure, has generally been linked to faster productivity growth when done effectively. A study by John Fernald of the San Francisco Fed finds that road investment boosted productivity in the United States in the 1950s and 1960s, and a more recent 2014 study in the *Journal of Economic Surveys* finds that public investment, especially by local or regional governments into roads, railways, and utilities, can also stimulate private investment. However, over the last few decades in advanced economies, public investment has been declining as a share of GDP.

Heightened Policy Uncertainty. Economic policy uncertainty in the post-crisis period appears to have played a significant role in delaying investment decisions by firms and generating an adverse

FIGURE B4-2 Declining Real Public Investment in Advanced Economies



Source: IMF (2014).

effect on productivity. The "wait and see" approach by firms led them to cut investment and shift their focus toward shorter-term, lower-risk, and lower-return projects. A 2016 paper in the *Quarterly Journal of Economics* estimated that this effect of increased uncertainty contributed to the post-crisis slowdown in TFP growth by around 0.2 percent a year for Europe, 0.1 for Japan, and 0.07 for the United States compared to pre-crisis years (Baker, Bloom, and Davis 2016).

the impact that declining fixed capital formation has had on total factor productivity has been significant, particularly since the 2008 financial crisis. The evidence is clear that in advanced economies the slowdown in investment began before the crisis, but its contribution in explaining the slowdown in productivity growth has become more important since. Extrapolating from this evidence one can argue that, for firms, investment in capital has become more important in explaining productivity growth over the past decade.

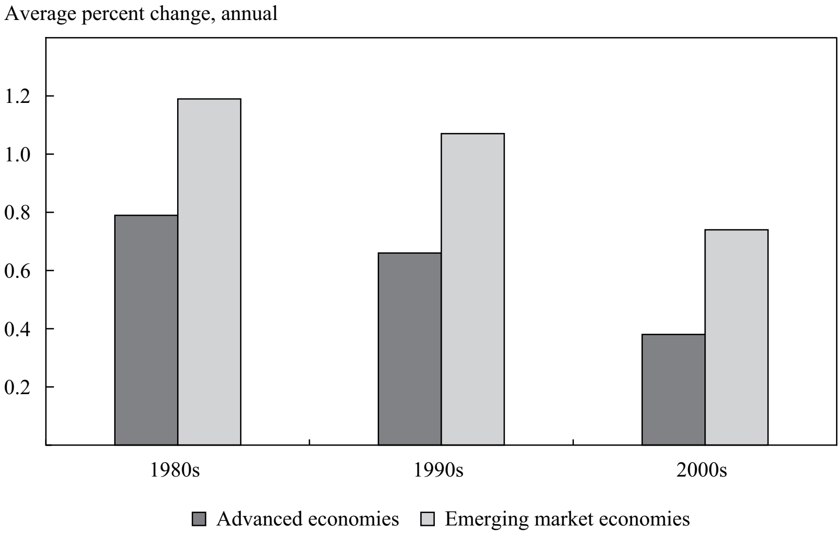
According to the OECD, fewer than 30 percent of SMEs in OECD countries use cloud computing. They are discouraged by both the high costs of upgrading to digital infrastructure and concerns over costly security risks (OECD 2016b). There is an important distinction between the two reasons. The first relates to access to capital, which we have discussed. The second relates to uncertainty on the returns to that investment due to high risks. Clearly, this might be an important component explaining the lack of investment in productivity-enhancing equipment for firms, in particular small ones. The benefits of upgrading to a digital infrastructure could be outweighed by the costs of something going bad, which is not unusual even for firms that invest highly in digital security. For instance, in the early fall of 2017, it became news that Equifax—a firm with over $3 billion in annual revenues and about 10,000 employees—had a serious digital security breach compromising private data of about 143 million U.S. consumers (Gressin 2017). If large and established firms struggle with their digital infrastructure, it is clear that investing in productivity-enhancing equipment of this new era comes with risks that could well outweigh the returns. Gartner Inc., a publicly traded research and advisory company, estimates that worldwide spending on information security reached $90 billion in 2017 and will top $113 billion by 2020 (Gartner Inc. 2017).

Human Capital and Skills

Workers and the skills they bring in are a crucial input of productivity growth. Workers are inherently different in the skills they bring to the workforce, and some—if not most—firms struggle to recruit the best-suited workers.

But even when looking at skill accumulation from a macro perspective, we can understand some of the current trends. Take schooling, for example, which provides a basic set of skills useful across all industries. Given that levels of schooling have increased significantly across the globe, naturally, the rate of human capital accumulation is now slower. The IMF estimates that this slowdown in the accumulation of human capital can explain up to 0.3 percentage points a year of "missing" productivity growth (see

FIGURE 4-8 Contribution of Human Capital to Labor Productivity Growth



Source: IMF (2017).

figure 4-8). In addition, population aging in advanced economies and major emerging economies like China adds more friction to the pace of human capital accumulation and the supply of labor across firms.

When assessing the skill level of workers in a particular firm, an important indicator is wages. When looking at average wages across firms and, in particular, the growing gap between firms that pay more and those that pay less for the same position, it becomes apparent that the most skilled workers are in the firms that pay more. The fact that some firms pay higher wages to their employees might also reflect the fact that these employees are simply more productive, but that would be the case when there is fully fledged competition (more on this later).

On the other hand, if the reason some firms are able to retain workers by paying them more is because these firms' profit margins are much larger than the sector average, then this would reduce labor turnover and, with it, the ability of smaller firms with high potential to attract better workers. A 2018 paper published in *Econometrica* (Eeckhout and Kircher 2018) uses German employer-employee data to find that technological change is helping to drive "assortative matching" at large firms, where skilled workers are joining firms where other skilled workers are, which is, increasingly, in large productive firms, leaving less space for other firms to hire skilled workers with knowledge in the industry. In addition, a 2017 study by economists at Harvard University, the U.S. Census Bureau, and the Institute for Social Research in Norway found that productivity is higher in manufacturing firms with a higher share of scientists and engineers involved in business operations (that is, not in R&D roles), facilitating the adoption of some technologies in the production process. The earnings of these employees tend to be higher than the earnings of their counterparts in other plants with a lower share of scientists and engineers (Barth and others 2017).

A body of economic literature shows that the skill and effectiveness of managers, in particular, has an impact on productivity, with notable variation between high- and low-productivity firms. In a neatly run experiment across Indian textile firms, economists measured the effect of improving management practices on productivity (Bloom and others 2013). Some firms, randomly selected, received five months of customized guidance on how to improve management practices—like factory operations, quality control, inventory management, and human resources management—from a large international management consulting firm, while the other Indian firms, which served as the control group, received one month of diagnostic consulting but no help in implementation.

The results were striking. First, plants that received the most guidance improved their overall productivity by an average of 11 percent (in this example, primarily through improved quality and efficiency and reduced inventory). They also became less decentralized in the decisionmaking process as owners delegated more tasks to middle managers and invested more in computers for data gathering and monitoring day-to-day activities. Among all the plants in the control group who received one month of diagnostic and no help in implementation, only about 10 percent ended up adopting best management practices. Thus, the problem goes beyond information on the existence of the technology. For a firm, possession of such information does not directly translate into adoption.

Research has shown vast differences in managerial skills across firms. A survey of about 700 manufacturing firms across the United States, the United Kingdom, France, and Germany shows strikingly large differences in management scores (Bloom and Van Reenen 2007). The score is based on managers' knowledge of things such as operations; and their practices in terms of monitoring, defining targets, and providing incentives to workers. Better management scores are found in firms exposed to the strongest competition and that have higher-quality workers. They tend to be lower in family firms where management is hereditary from generation to generation. Differences in management practices strongly explain differences in gross output, growth, and the probability of exit from the market. These are all variables that strongly correlate with productivity.

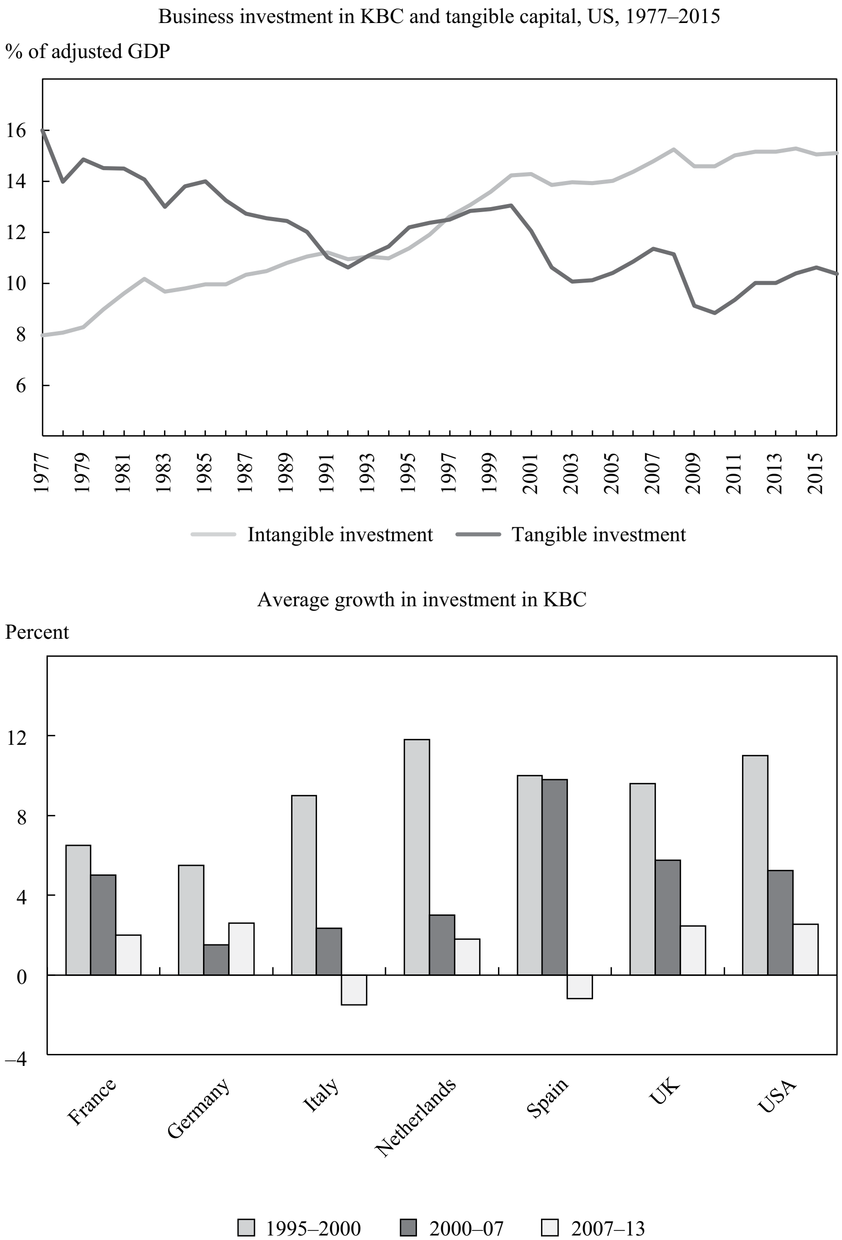
It is not clear, however, why firms—small firms in particular—would decide not to adopt best managerial practices to begin with. There are two possible explanations put forward by experts that seem important: first, the lack of belief by the current management that adopting best practices would actually result in better outcomes; and second, lack of time due to understaffing and other competing demands.

Investing in Intangible Inputs: Knowledge-Based Capital

Since the 1980s, business investment has shifted away from investments in machinery and equipment to investment in knowledge and other intangible knowledge-based capital (KBC) such as organizational capital (for example, internal decisionmaking and business processes), training, branding, supplier and distributor relationships, software, databases, design, and other forms of intellectual property. Even after the investment shock of the 2008 financial crisis, investment in KBC held up better than investment in tangible capital (figure 4-9). Investment in intangibles has emerged as increasingly important to underpin innovative activity and adoption. In a 2002 Brookings paper, Erik Brynjolfsson, Lorin Hitt, and Shinkyu Yang estimated that for every dollar of investment in computer hardware, firms needed to invest an additional $9 in software, training, and business process design.

The process through which firms innovate requires investment in organizational knowledge—like reorganizing production lines, business processes, or organization structures—or even in a firm culture that engages workers and enhances productivity. From the standpoint of an economist, these investments should always be worthwhile as long as the returns raise profits. The challenge to these investments is that there are plenty of

FIGURE 4-9 Intangible Investment in Knowledge-Based Capital



Source: Based on Corrado and Hulten (2010) and OECD (2016a).

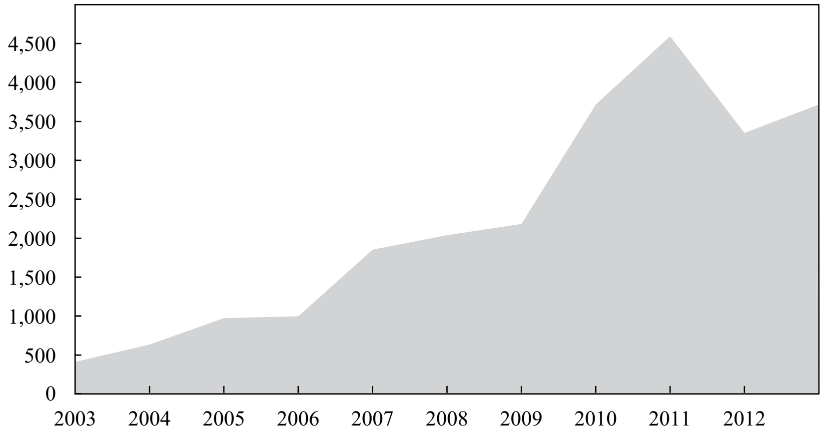
market failures related to investing in knowledge, and the intellectual property system used to address some of these failures has not been working as intended, especially over the last ten to fifteen years.

For example, the returns to investment in R&D, a component of knowledge-based capital, can easily be appropriated by copycat firms that have not made the original investment. Consider a winery that decides to grow a type of grape that no other winery in its geographic area grows. This involves costly research, training, and a lot of trial and error in adapting existing methods implemented by other wineries in remote locations to local conditions, such as quality of land and weather. Even after those expenses, typically more investment in marketing and, if necessary, reinventing ways to deliver the new product to nearby and remote consumers will follow. After all this investment, the winery will be able (if successful) to enjoy the rents of selling its new wine.

Yet, the knowledge generated by the winery in growing this unique grape in the local climate could easily be imitated by competing wineries with similar geographic conditions. In the absence of any patent or intellectual property system, the winery will have no incentive to make such costly investments if its competitors will appropriate the returns. On the other hand, under the current regime, the process of registering and enforcing intellectual property can be quite costly, particularly for smaller firms. The costs associated with globally protecting a patent quickly add up with the number of countries where the patent is to be registered in, and could reach, in some cases, hundreds of thousands of dollars. These costs could be prohibitive for small and medium firms relying on R&D investment to adopt technologies that could then be appropriated by others.

Difficulties associated with adoption of technologies from the frontier can also be associated with too much patent protection, which slows the pace of technological diffusion. Given that large firms are able to protect their intellectual property much more effectively, this would discourage small firms from adopting existing technologies originated by large firms in order to avoid the risks associated with legal battles that may follow. In the United States, the number of firms involved in patent conflicts, being sued by "patent trolls" (companies that are fully devoted to initiating legal battles against firms, mostly small ones, that are, presumably, violating intellectual property laws) grew by a factor of nine in the decade that followed 2004 (figure 4-10). Research suggests that firms that have been sued

FIGURE 4-10 Rise of Patent Trolls: Number of Unique Defendants in Patent Troll Lawsuits



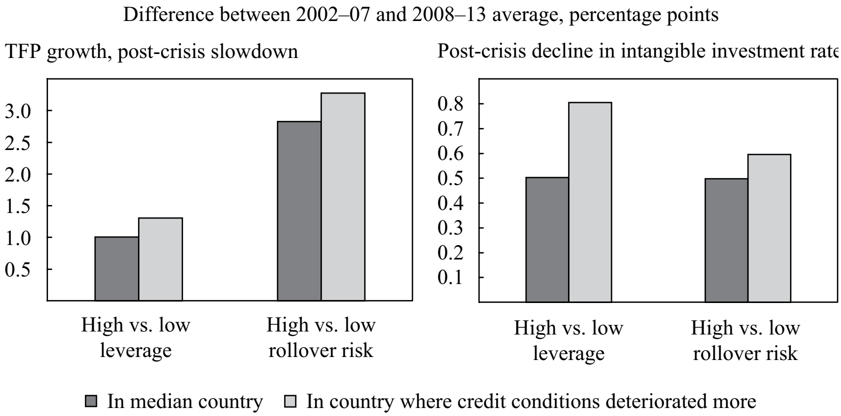
Source: Bessen (2014).

on the basis of intellectual property violation by patent trolls reduce their R&D investment and get less external funding following the episode (Bessen 2014).

It is clear how complicated the system of intellectual property protection can be. Without proper protection of intellectual property, there is underinvestment in R&D, but abuse of the system can make adoption of existing technologies legally problematic and costly. Some authors have suggested rethinking the patenting system to deal with possible frictions faced by small firms when adopting innovations in the industry (Baily and Montalbano 2016). A more efficient patenting system, which allows small firms to adopt technologies without risking losing all their capital in legal battles, could fuel productivity growth.

When it comes to investing in KBC more broadly, credit constraints and access to finance have played a role in slower intangible investment growth and productivity. Firms that face credit crunches tend to respond by cutting nonessential expenses, and R&D investment is typically one of them. In fact, tighter credit conditions after the 2008 financial crisis played a role in reducing financially vulnerable firms' investment in intangible assets. An IMF study found that firms with weaker balance sheets (higher

FIGURE 4-11 Impact of Tight Credit Conditions on Post-Crisis TFP Growth and Intangible Investment



Source: IMF (2017).

leverage and greater short-term external financing needs) reduced their investment rate (as a share of total value added) by 0.5 percentage points more than less financially vulnerable firms. In countries where credit conditions tightened even more, the difference increases to 0.8 percentage points (figure 4-11).

Furthermore, having the ability or incentive to invest in knowledge is one thing, and having the capability and knowledge to effectively use that knowledge is another. A report by the McKinsey Global Institute estimates that, in the United States, lagging sectors are less than 15 percent as digitalized as the leading sectors, but the report finds that this gap has less to do with investment in IT equipment than it does with the ability of firms to engage digitally with their suppliers and customers (McKinsey Global Institute 2015a). This kind of engagement encompasses digital payments, advertising, or interactions on social media and in virtual marketplaces. The gap is, therefore, more a result of know-how in using digital technology than in having digital technology. Developing an effective digital engagement strategy often requires training, new business processes, a branding strategy, new designs, and other forms of knowledge-based capital—the kind that laggard firms could benefit from.

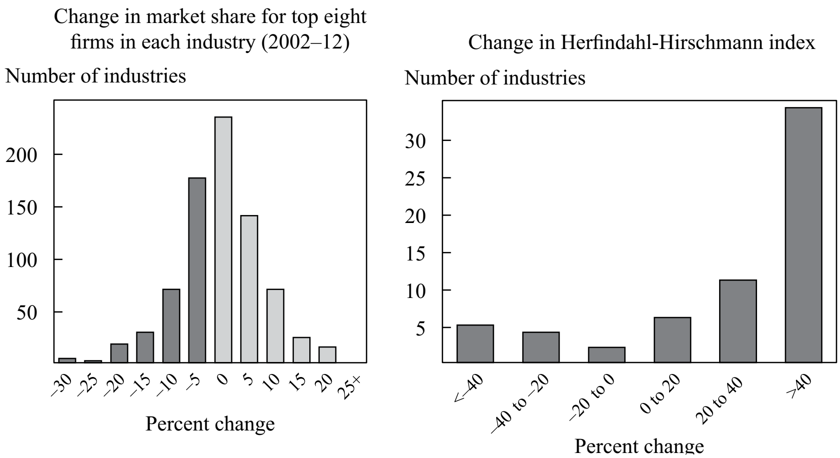
Putting the Focus on Competition

During almost a century since the early 1880s, the iron ore mines of Minnesota were the main supplier of iron ore to the American steel industry located mainly in the Great Lakes area. There was one reason for this: other iron ore producers in other locations, such as Brazil and Australia, could not compete with American miners given the high transportation costs. But this changed in the early 1980s when Brazilian producers began delivering iron ore to steel producers in the United States at lower prices than Minnesota could manage. Unexpectedly for the American iron ore producers, competition had arrived.

In response to increased competition, the iron ore industry in the United States underwent important changes that led it to increase its productivity.[6] After being unchanged for decades, iron ore producers doubled their productivity within five years following the arrival of competitors. Capital and material productivity increased as well (for example, the efficiency with which producers use machines and materials, respectively). These improvements came mostly as a result of a relaxation of work practices that had been in place for decades and had led to overstaffing and the underuse of machinery in significant amounts. These changes, which allowed the American iron ore industry to thrive, were not necessarily innovative on their own, but rather an adoption of best practices from other firms in the industry. It was competition that provided the incentives for these firms to adopt best practices to remain relevant by investing in organizational knowledge.

The link between competition and firm productivity is widely established in the literature. With no competition, even if the firms have the ability to invest, they might not have the willingness to invest if there is little competition that threatens their profitability. Thus, competition incentivizes firms to invest in the adoption of new knowledge, whether by hiring better trained workers, acquiring new and more efficient physical capital like IT systems, or investing in organizational knowledge and best practices. A recent study by researchers at New York University concluded that one of the key forces explaining up to 80 percent of the recent decline in private investment in the United States is less competitive markets (Gutierrez and Philippon 2017).

FIGURE 4-12 U.S. Rising Market Concentration



Sources: OECD (2016); Grullon, Larkin, and Michaely (2017).

Note: HHI index data is based on Compustat data (Grullon, Larkin, and Michaely 2017).

Rising Market Power and Falling Competition

Over the last two to three decades, levels of competition have been declining across a range of industries. First, rising levels of market concentration suggest that monopoly power is rising across industries (figure 4-12). In the United States, the market share of the fifty largest companies increased in three-fourths of broad industry groups between 1997 and 2007. The market share of the top four firms in six broad sectors (manufacturing, finance, services, utilities, retail, and wholesale) increased by 4 percent to 15 percent between 1982 and 2012 (Autor and others 2017).

Rising market concentration by itself, however, is not enough to conclude a decline in competition. For example, consider an industry protected by regulations that block the entry of large, highly productive firms—like some towns blocking Walmart to protect local businesses. Suppose this entry barrier is suddenly removed, and the large firm enters the market and forces the other small, less productive firms to close because they cannot compete with the more productive firm's low prices (a classic example of the Darwinian selection process). We now have a situation where the elimination of an entry barrier made the market more competitive, but the result was an increase in market concentration as the most productive firm began to dominate. Note that the competitiveness of the big firm came from its ability to lower prices, thanks to its scale and higher productivity, enough that smaller firms would be unable to compete and would be forced to exit the market.

Over the last few decades, however, it has not been the case that prices and profit margins have declined as one would expect with stronger competition. In fact, price markups have been growing and corporate profits have been rising at record rates. Price markups, the difference between the price and the cost of a product, have grown while costs have generally declined with lower costs of labor and more globalized supply chains. For the thirty years between 1950 and 1980, U.S. firms' markups of prices over costs had been roughly stable. Since then, however, they increased from 18 percent in 1980 to 67 percent in 2014 (De Loecker and Eeckhout 2017). Across all global corporations, profits have more than tripled, from $2 trillion in 1980 (7.6 percent of world GDP) to $7.2 trillion in 2013 (9.8 percent of world GDP), with companies from advanced economies earning more than two-thirds of the total (McKinsey Global Institute 2015b).[7]

A University of Chicago study finds that rising markups and profits in the United States have been most pronounced in industries with large increases in market concentration (Barkai 2016). The study finds that the declining labor share of income that has been under way in the United States since the early 2000s does not necessarily mean that the capital share has risen. After paying workers their salary, the remainder is usually considered the capital share of national income. The study, however, splits this capital share into two parts. The first is the returns from capital (what it calls the capital share), and the other part is the level of profits. This exercise revealed that the profit share of national income has risen from 2 percent in 1984 to 16 percent in 2014 in the United States, while both the capital and labor shares have fallen. The implication is that firms' profits are not coming from capital accumulation and returns on productive investments but from higher markups, reduced competition, and increased barriers to entry. In those industries that have become most concentrated, the profit share has risen the most.

Higher price markups and record corporate profits suggest that the rise in concentration is indicative of weaker, not stronger, competition. The slowdown in business dynamism described earlier weakens competitive pressure coming from relatively fewer new entrants. Across the OECD, small firms accounted for around 20 percent of all firms in 2002. Over a decade later, that share had fallen to just 12 percent. With less competitive pressure, the incentive for making costly productivity-enhancing investments wanes.

What Could Be Holding Back Competition?

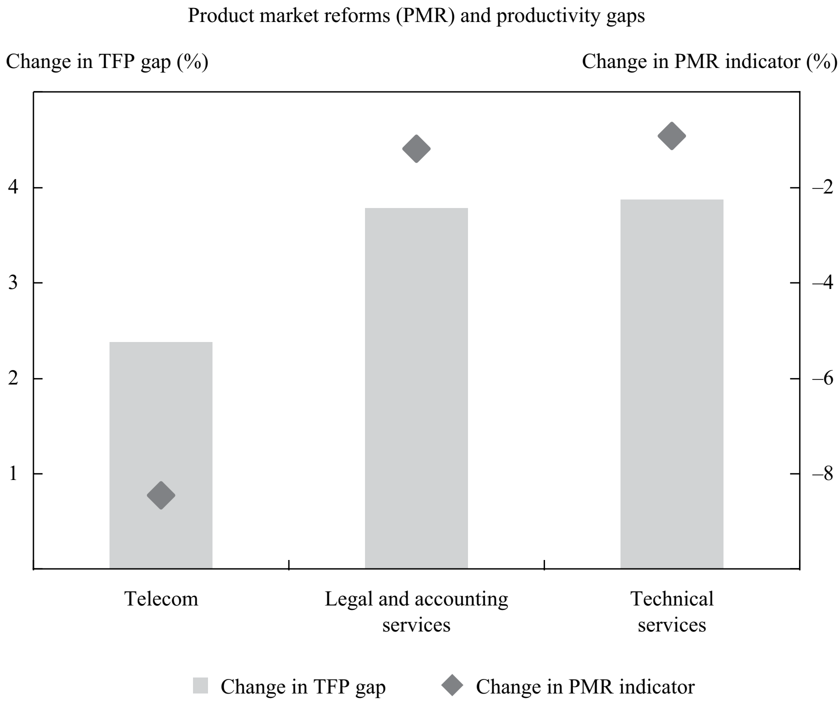
The weakening of competition overall is partly a result of the slow pace of pro-competition national reforms, the slowdown of international trade, winner-take-most dynamics taking hold especially in IT-intensive industries, and a wave of industry consolidation.

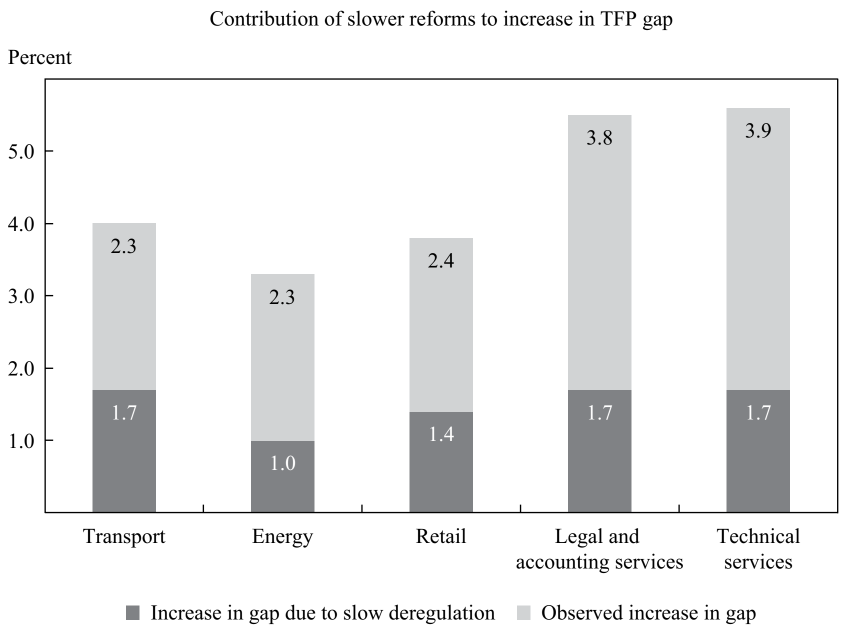
The slow pace of regulatory reforms in product and labor markets has helped weaken the competitive pressures on firms to make productivity-enhancing investments. Empirical studies by researchers at the OECD find that competition-promoting reforms in product markets tend to boost investment and capital intensity, which as we know can be a source of technology adoption through capital-embodied technologies (figure 4-13). Other studies have shown that lower levels of competition resulting from outdated or ineffective regulations has notably slowed down the diffusion of general-purpose IT technologies in continental Europe.

Data on product market reforms (PMR) in service industries reveal that the divergence between high- and low-productivity firms is greater where the pace of reform is slower. Across these sectors, up to half of the increase in the gap between high and low productivity may have been avoided with faster market liberalization in services. The top panel of figure 4-13 shows the relatively faster pace of reforms in the telecommunications industry and the lower dispersion of firm productivity in that industry in comparison to the slower pace of reform and wider productivity gaps in other industries (in the figure, lower value of the PMR indicator denote more reform—reduced restrictiveness of regulation). The bottom panel of the figure estimates by how much the pace of reforms actually contributed to the increased gap between high- and low-productivity firms across services industries.

Another plausible contributor to the overall slowdown in competition and productivity is the slowdown in international trade. Prior to 2012, world trade grew twice as fast as world GDP. Since then, it has barely kept pace. On one hand, higher levels of international trade can add pressure on firms to adopt technologies and best practices by simply promoting more

FIGURE 4-13 Slowing Pace of Product Market Reforms in the OECD, 1998–2013





Source: Andrews, Criscuolo, and Gal (2016).

competition to local firms. But it goes beyond that. Often, intermediate inputs—through global value chains—in the production process play an important role in the ability of firms to produce at lower costs. A growing body of evidence suggests that increased trade in intermediate inputs boosts productivity growth by increasing the variety of inputs or allowing firms to specialize in narrower and more defined tasks in the production process.[8]

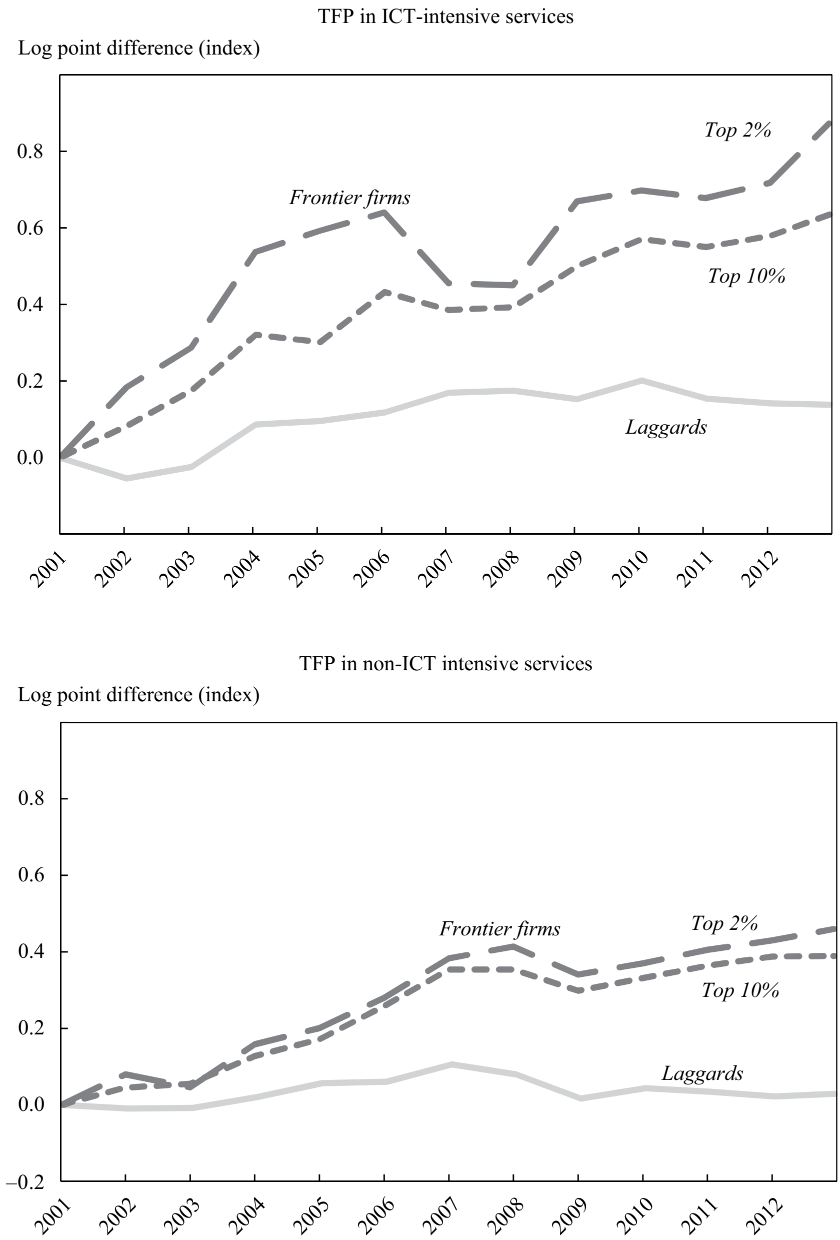
However, the slowdown in international trade since 2012 and the general maturation of global supply chains, or of China's deeper integration into the world trading system, could imply a slowdown in productivity gains from trade going forward. With less competitive pressure from foreign firms, either through import penetration where the pressure grows on domestic firms to innovate or through export penetration where domestic firms are competing at the global level, incentives for firms in tradable sectors to make productivity-enhancing investments chip away.

More fundamentally, the nature of competition itself is changing with fast-growing digital platforms and rising ICT intensity across industries. In services industries with high levels of ICT intensity, there is a significantly larger productivity gap between leading and lagging firms than in other services industries with low levels of ICT intensity (figure 4-14). This could reflect that the winner-take-most dynamics in these markets is changing competition and making it difficult for a broader range of small firms to compete.

In markets with winner-take-most dynamics, massive scale is often required to remain competitive. In an online marketplace, for example, where these properties are strongest, consumer choice is plentiful, and the ease of choosing one product over another often takes little more than a click of a mouse or the lure of a new network whose popularity has gone viral. Indeed, we see natural monopolies most clearly where there are network effects. For example, Facebook owns 77 percent of mobile social traffic, Google has 88 percent of search advertising, and Amazon.com has a 74 percent market share in the e-book market (Foroohar 2017).

More broadly, however, increased digitization has generated an explosion of data on consumer habits and preferences that firms are in a race to collect and own for competitive advantage. The more data a company has on a consumer, the more it can cross-sell customized and personalized services across traditional industry boundaries. Small firms are at an inherent disadvantage when data is owned by the larger firms that have the scale and IT infrastructure to collect it.

FIGURE 4-14 Higher TFP Dispersion in IT-Intensive Services



Source: Andrews, Criscuolo, and Gal (2016).

The large firms that have come to dominate these markets (as of April 2018, Google's parent company Alphabet, Amazon, Apple, Facebook, and Microsoft are the highest-valued publicly traded companies) have also created ecosystems where small firms can operate at lower costs but, ultimately, face high barriers to actually compete at scale. For example, Google and Amazon offer platforms and services like cloud computing and open-source software that small firms can use to start-up at low cost and operate globally with video conferencing, code repositories, and mobile phones. Most large tech firms also offer financing and venture investing for start-ups and promising small firms (Varian 2016). In these ecosystems, however, small firms are reliant on the large providers that may have seats on their boards or acquire them should they develop a capability that would allow them to expand their reach, or if they become a competitive threat.

In fact, a wave of mergers and acquisitions has consolidated a variety of industries and contributed to the rise in market concentration and divergence between high- and low-productivity firms. Some of these acquisitions have been by the large tech firms as they expand their reach, such as Facebook acquiring Instagram for $1 billion in 2012 and WhatsApp for $19 billion just two years later, which gave Facebook immediate scale in the messaging market (Rusli 2012; Kuchler and Bradshaw 2014). Perhaps the most notable example of large tech firms blurring industry boundaries is the entrance of Amazon.com into the grocery market with its acquisition of Whole Foods in 2017 for $14 billion in 2017 (Turner, Wang, and Soper 2017).

The scale of M&A activity in recent years is much larger than the activity of a few firms, however, revealing the growing importance of size in remaining competitive and securing a larger share of profits and stronger market power. In 1990, there were 11,500 M&A deals globally, with a combined value of 2 percent of world GDP. Between 2008 and 2014, there were around 30,000 deals each year, totaling roughly 3 percent of GDP. In 2015 alone the value of M&A deals exceeded $5 trillion, the highest amount in any year on record. Thirty-seven percent of the value of these consolidations surpassed $10 billion, almost double the average of 21 percent in the five preceding years.[9]

Critics in the United States, where about half of the $5 trillion in global M&A deals took place, suggest lax antitrust enforcement due to shifts in political priorities, shrinking fiscal budgets, or insufficient capacity to investigate a rising number of transactions has facilitated the size and frequency of successful mergers. The underlying issue of the changing nature of competition in the digital age looms large over antitrust and competition policy more broadly.

Taking Stock

The wide gap between high- and low-productivity firms points to a central feature of the productivity paradox—small firms' lack of adoption of productivity-enhancing technologies. A broad range of evidence comes together to suggest that this lack of adoption could be the result of underinvestment in the tangible and intangible inputs to adoption. This underinvestment is largely a result of reduced incentives from lower competition and of growing frictions in the supply of the inputs themselves.

It is difficult to decisively point to a single source driving the underinvestment in technology adoption. Declining competitive pressures—as seen by fewer start-ups, rising market concentration, rising markups, and fewer small productive firms growing into large firms—suggest reduced incentives for small firms to make costly productivity-enhancing investments. On one hand, incumbents can focus on protecting their market power and on raising prices. On the other hand, smaller and newer firms are finding it difficult to justify costly investments if their chances to make a decent return or gain market share are low. More competition could, therefore, play an important role in encouraging some firms to invest in their productivity. Some policy levers include public-private risk-sharing efforts in R&D investments and other forms of knowledge (including workforce training), a restructuring of the patenting system, smart antitrust enforcement, faster product market reforms, and a new framework for competition policy in winner-take-most markets.

Frictions in the supply and access to the key inputs of technology adoption also contribute to the observed underinvestment by small firms. While financing constraints after the global financial crisis in 2008 have persisted for many years and constrained the ability of some small firms to raise capital, evidence suggests there are also constraints in what they can actually invest in. Most notable is the slowing growth in the supply of human capital and the observed tendency for highly skilled workers to cluster among high-productivity firms, making it harder for smaller firms to hire and keep these workers. This is especially important given the growing role of intangible and knowledge-based capital in firm productivity. At the national level, greater or more effective investments in infrastructure, education, and R&D could play a significant role in ensuring that access to quality inputs are available to a broad range of firms in an ecosystem of innovation, adoption, and knowledge.

Notes

1. An important caveat, however, is that there is a limitation to R&D data; it only captures some of what economists would consider research. For example, in the United States, 70 percent of measured R&D happens in the manufacturing industry, while some big companies, like Walmart and Goldman Sachs, report doing zero R&D (Jones 2015, Wolfe 2014).

2. A rapid increase in the number of domestic and foreign patents granted by the U.S. Patent and Trade Office began in the 1980s, but a significant portion of that increase can be explained by new legislation that extends patent protection to business models and software as well as changes in the judicial appeals process for patent cases (Jaffe and Lerner 2006).

3. Respondents to this point show that, prior to 2000, declining firm entry rates were predominantly driven by retail and services sectors, where the shift from small establishments to fewer large firms who took advantage of IT and globalization accounts for the rise in U.S. productivity in the late 1990s and the concurrent decline in business dynamism. Meanwhile, the high tech sectors were experiencing an increase in business dynamism until 2000, when start-up rates and the number of initial public offerings (IPOs) began to slow down (Decker and others 2016).

4. Some variation exists across countries. For example, spreads in the United States and United Kingdom have declined since 2007 where credit has tightened through other channels.

5. Cette, Fernald, and Mojon (2016) cite several studies.

6. See Schmitz (2005) for a comprehensive study of this episode.

7. Profits before interest and taxes.

8. Amiti and Konings (2007) use plant level data from Indonesia to find that the productivity effects of a reduction in tariffs on intermediate inputs were twice as large as a reduction in tariffs on final goods. Goldberg and others (2008) find productivity gains in India from reduced tariffs on intermediate goods, which increased input variety, and Ge and others (2011) find similar results for China. From Kowalski and Buge (2013).

9. As pointed out in a report by the U.S. Council of Economic Advisors in 2016, waves of mergers and acquisition tend to occur when stock market valuations are

high, and between 2010 and 2015 the stock market valuation of the S&P 500 index on the New York Stock Exchange increased by almost 60 percent. This suggests that the added intensity of M&A activity in recent years may have been exacerbated by cyclical factors, but nevertheless markets will remain consolidated, all else equal.

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