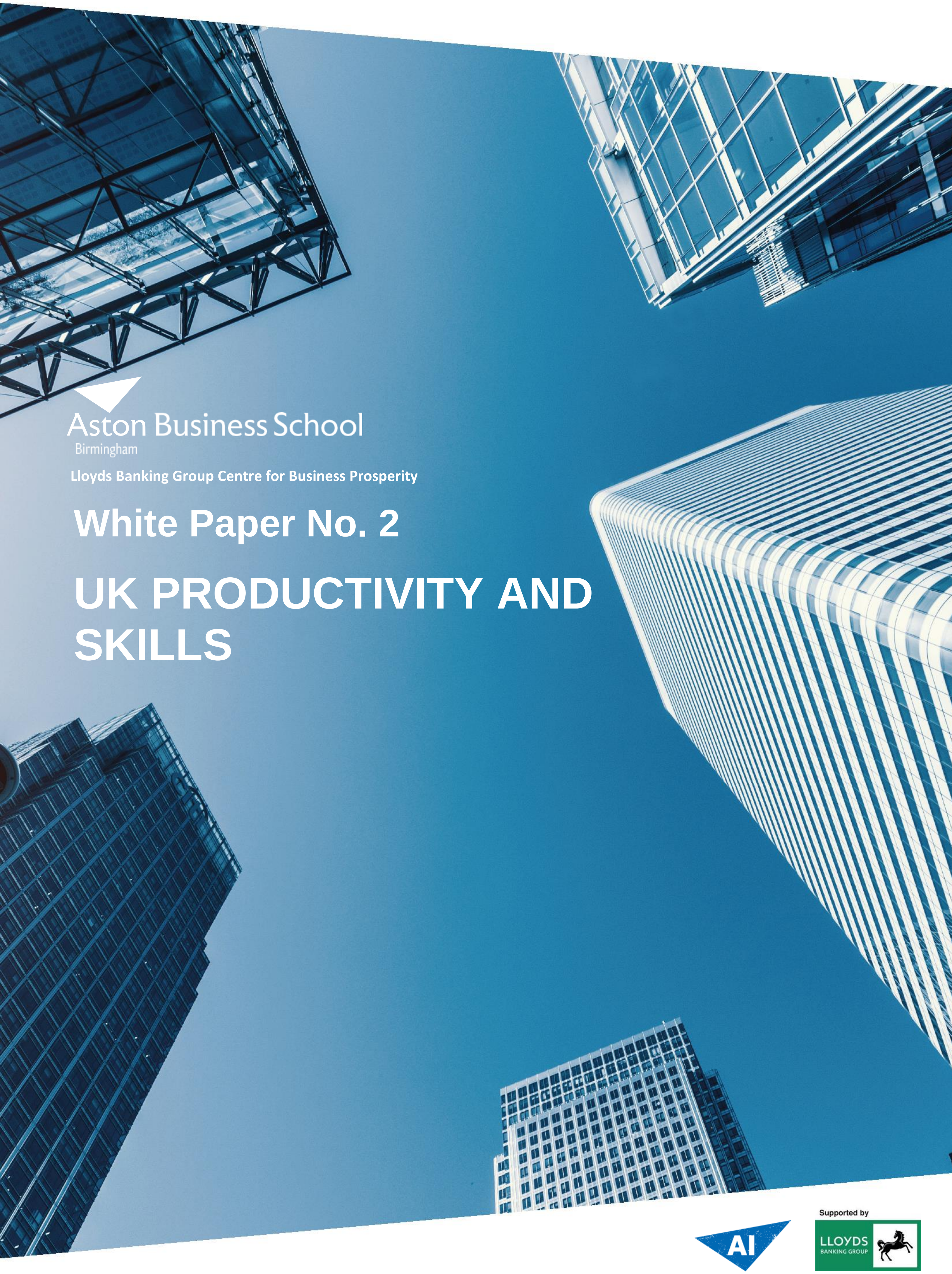

Aston Business School
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Lloyds Banking Group Centre for Business Prosperity

White Paper No. 2

UK PRODUCTIVITY AND SKILLS

Supported by

UK Productivity and Skills

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Context of the White Paper

This is the second White Paper in the series on skill challenges, productivity and prosperity in the UK, forming part of a series of research outputs of the Lloyds Banking Group Centre for Business Prosperity (LBGCBP). These will be presented under two broad themes, each headed by a white paper and with associated research papers; each white paper will be also accompanied by a briefing paper:

- **Theme 1 – Making the UK a more effective trader**
  - White Paper 1: UK Trade in the New Globalised World
  - Research Paper 1: On the Determination of Sectoral UK Exports
  - Research Paper 3: Defying Gravity? Policy Uncertainty and Trade Diversion
  - Research Paper 4: An Export Strategy for High Growth

    (More to follow)

- **Theme 2 – Skill challenges, productivity and prosperity in the UK**
  - White Paper 2: UK Productivity and Skills
  - Research Paper 2: Individual Ownership, Age of Firm and Productivity
  - Research Paper 5: Path-breaking to Innovate: The Internet of Things (IoT) technologies

    (More to follow)

The purpose of this white paper is to take stock of the existing literature, and as a result to identify the knowledge gaps we currently face around the issues of UK skills and productivity growth. Filling these important gaps will shape the research agenda for the LBGCBP.

Executive Summary

The productivity slowdown across the developed economies begs both an explanation and policy solutions since the financial crisis in 2008, and continue to stimulate lively debates today. In the UK where the problem seems particularly acute, one of the key areas of the productivity debates relates to skills problems. This White Paper offers a perspective on this long term problem, and more generally takes stock of the existing understandings of the UK productivity challenges, and the evidence on the links between skills and productivity, at national, regional and firm levels.

The global and national economic forces since 2008 compounded the long-term factors that restricted productivity growth in the previous decades. The overview of the key factors of production (labour and capital) and other factors affecting productivity (such as innovation) help us to understand the rationales given behind the UK's weak productivity. What has become clear is that no single factor has caused the UK's productivity problems. In the short-run, the acute decline of global demand and the slow recovery have been partly responsible, but this accompanied by other concerns, not all global crisis related, such as curbed business dynamisms across regions and industries.

More concerningly, the long-term productivity growth slowdown is real and we argue in this review that to explain it we need to turn to technology and skills focus. Conceptually, skills are part of human capital, and determine productivity and long-run growth. On the positive side, in recent years, the UK has improved at each skill level and is expected to continue to improve. However, the cross-country comparative statistics show that the UK is lagging behind on vocational education and training. The job prospects of many adults are restricted by their poor literacy and numeracy skills, while the chance of further learning and education is limited. Overall, the UK performs comparatively well on high skills, while facing challenges on intermediate skills and low skills, compared to international peers.

Technology is fundamental to productivity growth yet its adoption and diffusion requires skills. Not only the right level of skills, but also the right characteristics of skills, placed where and when they are needed impact on if and how evolving technology drives growth. Hence the problems of mismatch of skill demand and supply, namely skill shortages and gaps, matter. Regardless of skill levels, the evidence consistently narrates a story of skill shortages, skill gaps and skill mismatches in UK workplaces. Skills gaps and skill mismatches are hardly surprising phenomena for an economy experiencing technological advancement. Yet dealing with skills problems requires forward-looking policies and instruments to reshape education and training to meet the new demands.

There is consensus that the creation of new technologies (that is innovation) and their subsequent adoption (that is diffusion) require different types of skills. It is argued that the impact of technology leads to rising relative demand both for highest-paid skilled jobs, which require non-routine cognitive skills; and for low-paid least-skilled jobs, which require non-routine manual skills. Nevertheless, demand will fall for ‘middling’ jobs, which have required routine manual and cognitive skills. This trend implies that for the UK, where competitiveness hinges on innovation, high levels of education and skills are needed to sustain growth.

In practice there are empirical difficulties in assessing skill gaps. Skill levels are often proxied by educational attainment, which is an imperfect measure, as formal education ends for most individuals in their early twenties, and yet they may (or may not) acquire skills subsequently. While the formal education measures used for skill levels raise measurement problems, so do the self-reported measures of skill gaps, often with reporting bias by employers. Another challenge is to ensure that the link found between skills and productivity is causal, i.e. that skills do have an impact on productivity, rather than that productivity drives skill acquisition.

At national level, earlier work that considered skill gaps found a strong link between skill shortages and productivity growth. In 1993 it was estimated that if Britain’s skill shortages grew by the European Communities average, UK productivity growth in the period would have been 5.1% per annum, 0.4% better than that which occurred. This study also found that skill shortages are more influential in reducing productivity in industries where there is a greater concentration of skilled labour. The evidence also suggests that reported skill shortages lead to decreased short-term R&D expenditure and decreased long-term fixed capital investment.

Furthermore, the regional perspective acknowledges the presence of knowledge exchange between workers within an area. Tacit, practical knowledge is found to be particularly transferable through human interactions and depends upon the firms’ existing absorptive capacity. Following this logic, high skill levels may play a role in creating even higher skill levels in the area. Or vice versa, skill gaps may reduce the exchange of knowledge within a region and create less opportunity for learning effects, slowing productivity further. However, little evidence is available to directly test the concept of skill mismatch and these virtuous and viscous circle effects. Moreover, a study of high growth firms showed that in an industry-region where there were more fast-growth incidents in terms of employment, the average employment growth of the rest of the cluster seemed to dwindle, in the UK's peripheral regions in particular. This suggest that there was potential competition for skills and talents, and that in the regions with a weak skill basis isolated cases of fast-growing firms may actually make things worse not better.

Related to this, there is research showing that more of the variation in labour productivity between regions came from unproductive sectors in certain regions than from allocation of sectors to regions or to specialization in the regions. In turn, these sectoral productivity differences between regions partly resulted from the skills and occupations composition of the employees in the region.

On the still lower level, empirical work linking firm level skill problems and productivity is scant. Routine data are not associated with skills information, and skill surveys do not have measures of productivity. One plant level analysis estimated the relationship between total factor productivity, including the percentage of skill gaps within the firm, showing that plants experiencing skill shortages were less productive than those which did not have skill gaps.

The majority of skill shortages are expected to be found in relation to experienced professionals. This signals that expanding higher education will not provide the necessary skills to improve performance, and training may be more appropriate. Similarly, a move away from education levels as the key variable, and towards skills composition analysis, is important, with exploration of skill gaps providing a valuable alternative to the current skill levels evidence about productivity.

In conclusion, skills gaps and skill mismatches are hardly surprising phenomena for an economy experiencing technological advancement. Skill gaps, however, are detrimental to productivity, and reduce R&D spending and capital investment, which in turn restrict productivity growth. This means that skill gaps are the most constraining, be they of high, medium or low skills levels. Evidence seems to suggest that both skills levels and skills gaps hamper firms' performance, both directly, and indirectly through their effects on innovation.

While focusing on the complex relationship between technology, skills and productivity, we also acknowledge the importance of other aspects of the long-term productivity challenge, such as the inter-connection between technology, market structure and market power, and its implications for productivity. Other relevant aspects are the conditions of international trade and global value chains. The microstructure of the industries of a nation determine the job opportunities and hence the required skills set. But this microstructure within industries is not permanent, for it depends on what others do in the global marketplace. Hence, it is too narrow to focus on the UK's productivity issues within a sector and in a specific place. A global view is essential for productive analysis.

Figures

1. Introduction

Raising productivity is crucial to economic prosperity. At the macroeconomic level, productivity, measured by total factor productivity (TFP), is a well-understood source of long-run economic growth (Hall and Jones, 1999; Bartelsman and Doms, 2000), and therefore its distribution is the main driver of global inequality in economic outcomes (Hall and Jones, 1999; Hsieh and Klenow, 2009). The differences in productivity of comparable countries explain a large degree of the differences in those nations' economic growth.[1]

At the microeconomic level, productivity is an unfailing predictor of firms' survival and post-entry growth (Fariñãs and Ruano, 2005), the likelihood of successful exports and firms' international expansion (see more in LBGCBP White Paper 1). More productive firms are also those that tend to stay ahead through innovation (see Syverson 2011 for a review). As Paul Krugman asserts, "productivity isn't everything, but in the long run it is almost everything" (Krugman, 1997).

However, the UK's productivity has long been seen as sluggish. To understand the UK's productivity challenges, we may think of two separate problems. There is a long-term productivity problem – the longstanding productivity gap compared with the major international peers since the 1970s (Figure 1.1). The UK has experienced a steady growth at a rate of 2.3% in labour productivity, yet by 2016 the output per hour worked in the UK was 16.3% below the average for the rest of the G7 advanced economies (ONS 2018).[2] Although this gap turns out to have been reduced with the recent adjustment of the statistical measure, the UK level is still below those of many other productive nations (OECD, 2019).[3]

The UK's second, more recent productivity problem, known as the productivity puzzle, refers to the zero-productivity growth in labour productivity following the financial

[1] For example, it is noted that the UK's overall productivity is lower than Germany and France (ONS, 2014), and some attribute the differences to the size of the medium-sized enterprises sector (Grant Thorton, 2012). Another example is the debate on productivity and middle-income trap (Eichengreen et al., 2011) among fast growing emerging economies.

[2] ONS (2018), International comparisons of UK productivity (ICP), final estimates: 2016.

[3] According to the OECD's adjusted estimates, the UK's gap in labour productivity levels with the United States, is estimated around 8 percentage points smaller than was previously estimated – closing from 24% to 16%. The gap with Germany shrinks from 22% to 14% and with France from 20% to 11% (OECD, 2018).

crisis in 2007-2008, a growth level which has failed to recover ever since. While the focus is on the slow recovery in productivity since 2008, we seem to overlook the fact that the UK has experienced an extraordinary flat period for productivity change over a very long time (Haldane, 2014). The pessimistic view suggests that the decline and slow recovery of productivity growth is not just a short-term question, and that long run patterns in the labour productivity trajectory may persist, even if productivity growth returns to the pre-crisis level (Oulton and Sebastiá-Barriel, 2013).

The explanations of these two productivity problems differ. While productivity measurement issues may obscure the whole picture about the comparative productivity records, the weakened demand, from global and at home, may have acted as a restraining factor for the post-2008 stalled productivity growth. The declining business dynamism may underline the UK's short-term productivity problem, but to understand the UK's long-term productivity challenge, we must take a long-term perspective and examine the fundamental factors that determine productivity growth, such as technology and the implications for skills. Over the past decades, technology has changed the way firms and industries operate, with enormous, but unequal impacts. In this White Paper, we review the UK's skills and productivity links which are often influenced by technology changes.

The UK traditionally held the belief of a free market in training, like the USA. It assumes that market incentives are sufficient to encourage people to acquire skills. This differed from countries like Germany, France, Australia, Japan and Sweden, where institutions were created to address the market failures resulting from insufficient investment in skills when financed only by private companies and individuals. Nevertheless, opinions in the UK have shifted in recent years towards positive interventions through tax relief on vocational training costs.

This review aims to take stock of the existing understanding of the UK productivity puzzle and of the evidence on the links between skills and productivity, at national, regional and firm levels. We also consider a special case – entrepreneurial skills – and try to understand how they impact on productivity.

The intelligence on skills compiled in this review illustrates an increasingly clear picture of the UK skills mix in the context of the UK's productivity challenges. However, the statistical patterns of the productivity and skills characteristics do not prove causal relationships between them. Based on the theories and empirical evidence we review in this report, we may say that while the causal links between skills levels, skill mismatch and productive performance are established at national level, the emerging theories and evidence only start to suggest some regional productivity consequence of certain skills distributions. The weakest link in our established understanding of these processes remains at the micro, establishment level, where much more research is needed to help understand the mechanisms through which skills, technology and productivity are tightly intertwined.

Another purpose of this review is also to identify what we need to know about the elements of UK productivity, but do not know as yet. Filling these important gaps in our knowledge will guide the prioritisation of our future research agenda. This White Paper is structured as follows. Section 2 begins by sketching a picture of the UK's skills, using available statistics. Section 3 takes a short-term perspective in reviewing the UK's productivity problems. Section 4 takes a long-run view and reviews in more depth the links between technology, skills and productivity. Conclusions are drawn in the final section.

2. The UK Productivity and Skills

This section is a snapshot of the UK's skills in the context of the UK's most significant economic problem, the productivity conundrum. We do so by positioning the UK alongside its international peers in terms of its productive performance and the skills development, utilising available comparative statistics.

We start by portraying the key productivity indicators, illustrating the UK's productivity problems, which will feature in more detail in the next two sections. Inquiring into the fundamental factors of production (labour and capital) and other factors affecting productivity, such as inputs for innovation, we show the patterns of some known factors that explain the UK's weak productivity. In particular, we focus on the skills factors that are embedded in human capital and that determine productivity and long-run growth. The fallen real wages and hence the reduced capital-to-labour ratio explain the fall in labour productivity and TFP (Pressoa and Reenen 2014), yet the issues around skills are complex and the cost leading to reduced productivity growth is non-permanent. The UK has record high employment levels compared to most OECD countries, and evidence suggest that the weakened labour quality is not mainly driven by the UK's flexible labour market (Blundell et al., 2013).

In what will emerge from the statistical pictures, the UK performs comparatively well on high skills, while facing challenges on intermediate skills and low skills compared to international peers. The comparative statistics also show that the UK is lagging behind on vocational education and training, although in recent years more emphasis has been put into the government's policy agenda on the aspect of skills development. There is emerging evidence, albeit limited, to suggest that cognitive skills are greatly demanded in the age of the digital economy. The job prospects of many adults are restricted by their poor literacy and numeracy skills, while the chance of further learning and education is limited.

While the workplace skill mismatch statistics are scanty, the existing evidence consistently narrates a story of skill shortages, skill gaps and skill mismatches in the UK workplace. The existing statistics suggest that to boost growth, productivity and earnings, the UK should accordingly encourage lifelong learning among adults and promote better skills utilisation.

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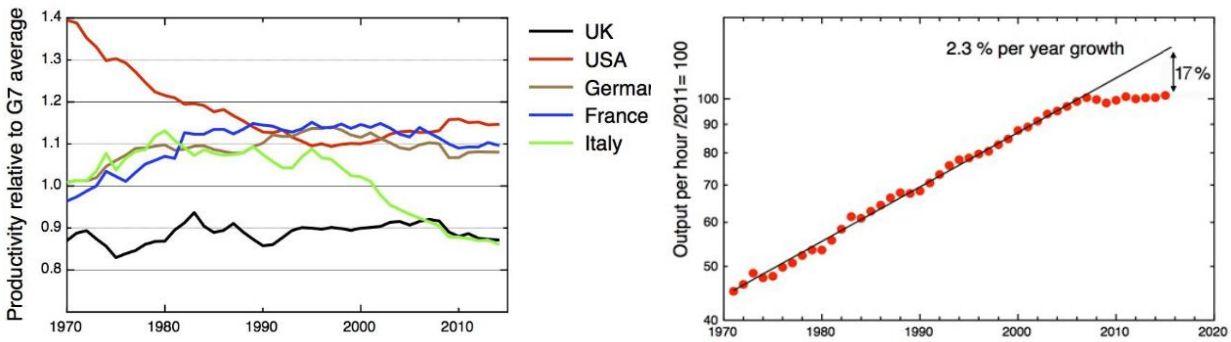
2.1 The UK productivity and factor inputs

The UK has a longstanding productivity gap vis-a-vis its major international peers (ONS 2018).[4] It is estimated that by 2016, the output per hour worked in the UK was 16.3% below the average for the rest of the G7 advanced economies. Although this gap has been reduced with the adjustment of how labour input is measured, the UK is still behind many more productive nations (OECD, 2019).[5]

In addition, while the UK economy has experienced steady growth at a rate of 2.3% in labour productivity since the 1970s (Jones, 2016), following the financial crisis of 2007-2008 it slowed down considerably and has failed to recover since. This has been dubbed the UK productivity puzzle (Barnett et al., 2014). In addition, some economists think that the decline and slow recovery of productivity growth is not just in the short term, but may have affected the long run labour productivity growth trajectory, even if it returns to the pre-crisis level (Oulton and Sebastiá-Barriel, 2013).

Figure 2.1: The UK's labour productivity records and the productivity puzzle



Source: Jones (2016).

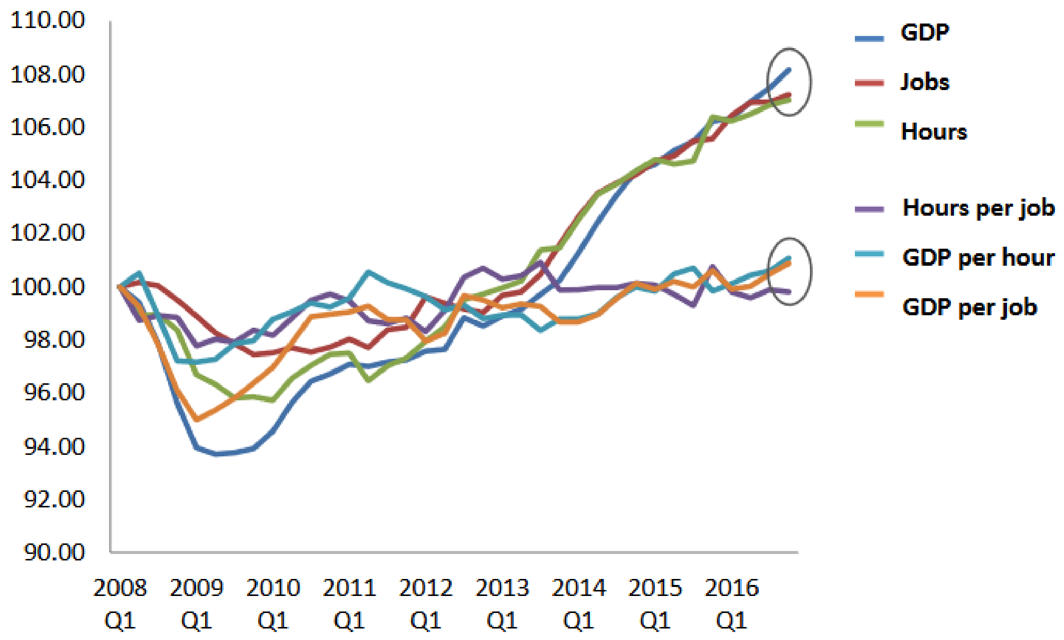
Productivity defines efficiency in production. Hence the more output is produced from a given amount of inputs, the higher the productivity of the producer. Even though what affects the UK's slow productivity growth since the recession and what affects it over the long-term may differ, we can approach the issues by considering the accumulation of the factor inputs of

[4] ONS (2018), International comparisons of UK productivity (ICP), final estimates: 2016.
[5] According to the OECD's adjusted estimates, the UK's gap in labour productivity levels with the United States, is estimated around 8 percentage points smaller than was previously estimated – closing from 24% to 16%. The gap with Germany shrinks from 22% to 14% and with France from 20% to 11% (OECD, 2018).

production (labour and capital) and innovation (the new ways in which labour and capital are combined).

First, it is notable that during the recession since 2008, what followed the sharp fall in aggregate demand was the much milder decline of labour inputs. Figure 2.2 shows the trends of output, hours worked and jobs in the UK since 2008. In fact, soon after 2008 a continuing improvement in employment combined with sluggish output would almost inevitably lead to recorded lower labour productivity. This emphasises a clear gain post-crisis of at least 7-8% in labour market outcomes (Chadha, 2017), while the labour productivity indicators stayed at lower levels. This was the curious pattern interpreted as labour hoarding and attributed to the UK's flexible labour market institutions (Oulton, 2018).

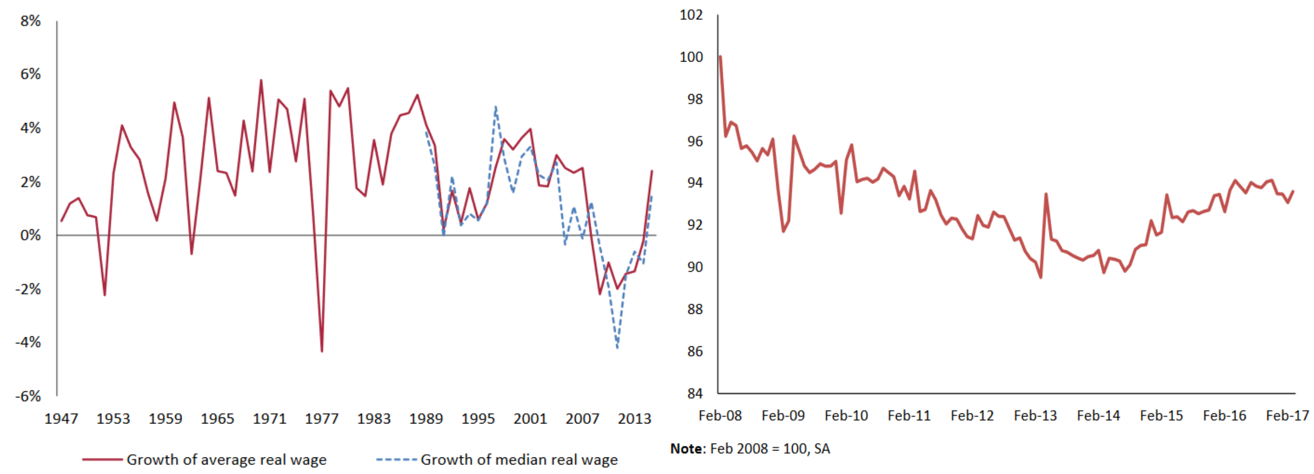
Figure 2.2: UK skills and productivity in an international context



Note: Output is measured as real GVA; 2008Q1 = 100
Source: ONS & NIESR

Not surprisingly, rising employment and stalled output led to lower productivity and hence lower real wages. Figure 2.3 (left) highlights the overall trend in both the mean and median growth of real wages in the last seven decades. What emerges is that wages tend to follow the trend of labour productivity, although some temporary deviations might occur (Chadha, 2017). Nevertheless, by the 1980s the average growth rate in real wages was around 4%, and remained positive up to 2008, yet since then this figure has drastically fallen. Moreover, as **Error! Reference source not found.** (right) shows, by February 2017 weekly earnings were about 7% below pre-crisis levels.

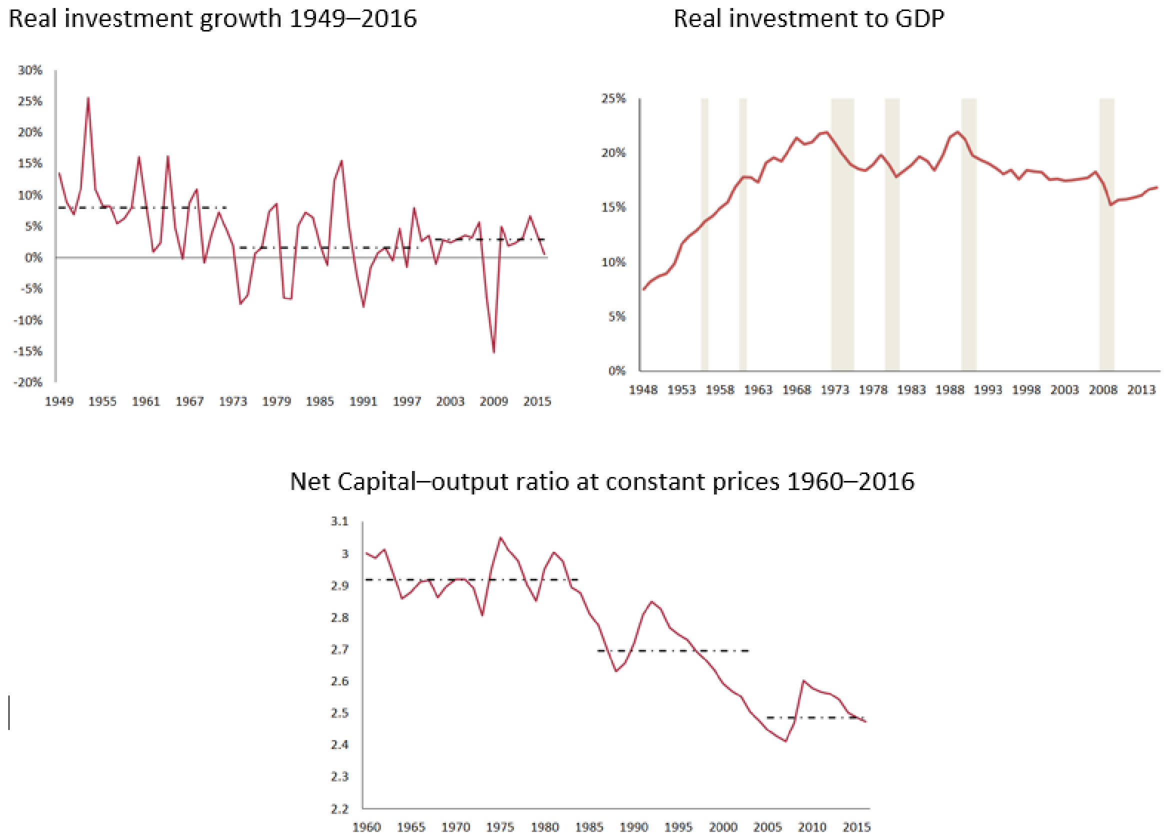
Figure 2.3: Growth of real wages and Real Average Weekly Earnings



Source: Chadha, 2017, Figure 5,6 on page 9, 10

Turning to capital investment, the UK also experienced an overall decline of capital investment since 1949, which resulted in low capital stock (Figure 2.4) (Chadha, 2017). Indeed, this has contributed to an overall reduction of capital employed per employee. As Figure 2.4 highlights, the investment to GDP ratio has remained drastically below its pre-crisis levels. The decline in new investment translates into a lower capital to output ratio since the late 1980s. Low capital investment is recognized in the literature as a reason for weak productivity (Syverson, 2011). In addition, some evidence suggests that Britain's low productivity in relation specifically to Germany and France is in large part due to lower levels of investment (Crafts and O'Mahoney, 2001; Broadberry and O'Mahoney, 2004).

Figure 2.4: Real investment and net-capital-output ratio trends



Source: Chadha, 2017, Figure 7,11, 13 on page 10,16 and 17

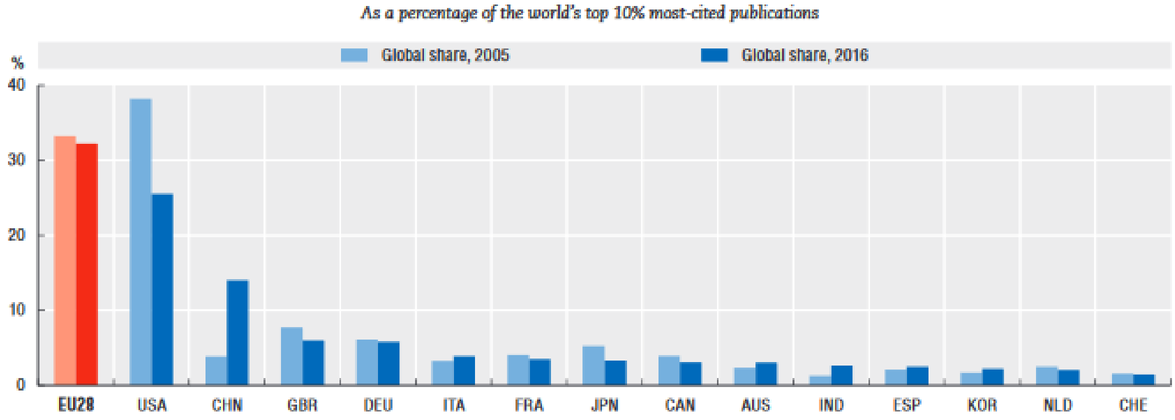
2.2 Innovation and technology

Innovation is an essential driver for productivity. We next examine the UK's R&D efforts and the resulting outcomes. The overall picture suggests that the UK is one of the leaders in knowledge creation, specifically leading on research excellence. However, the UK's R&D investment has been low and seems lagging in the fields of Industry 4.0 domains.

Research excellence

The UK is among the leading countries in terms of scientific publication citations and scientific excellence. As shown in Figure 2.5, the United States remains the largest single country for top publications (around 25%), while the UK is ranked fourth, accounting for about 5% of the total (OECD STI Scoreboard, 2017). The EU28-based authors have a leading position in 2016 and they account for about 33% of the world's most cited articles. Further, in terms of scientific excellence, measured by the percentage of publications produced within each country that attain a top 10% world cited status, the EU's average is about 10%. The UK is above it, with an average of about 15%, behind only the USA.

Figure 2.5: Economies with the largest volume of top-cited scientific publications

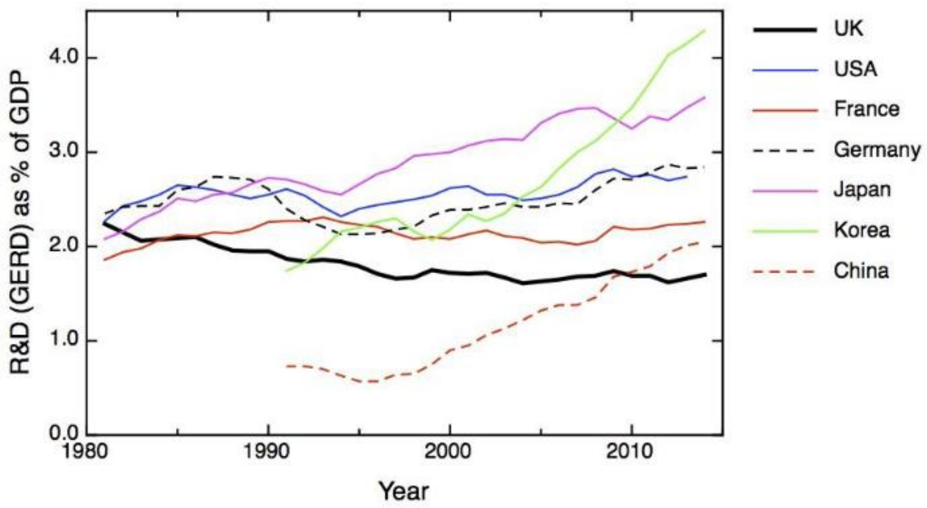


Source: OECD Science, Technology and Industry Scoreboard (2017)

R&D investment

R&D investment plays a key role in driving firms' innovations. However, since the 1980s the UK has diverted fewer resources to R&D (Figure 2.6). The comparison with top investing countries reveals lower R&D spending in proportion to GDP in the UK than in other major economies in the world. In fact, the UK spent 1.67 per cent of GDP on R&D in 2016, ranking 11th in the EU (ONS 2016, Gross domestic expenditure on research and development, UK).

Figure 2.6: Research Intensity: gross expenditure on research and development as a percentage of GDP



Source: Jones (2016).

We turn next to the two types of R&D spending – public and non-profit R&D spending and business spending. In gross domestic expenditure on R&D (GERD), government expenditure only accounted for 6.8% in 2015, compared to 12% in 28 EU countries. The weak public R&D spending by government in the UK was compensated to some extent by public

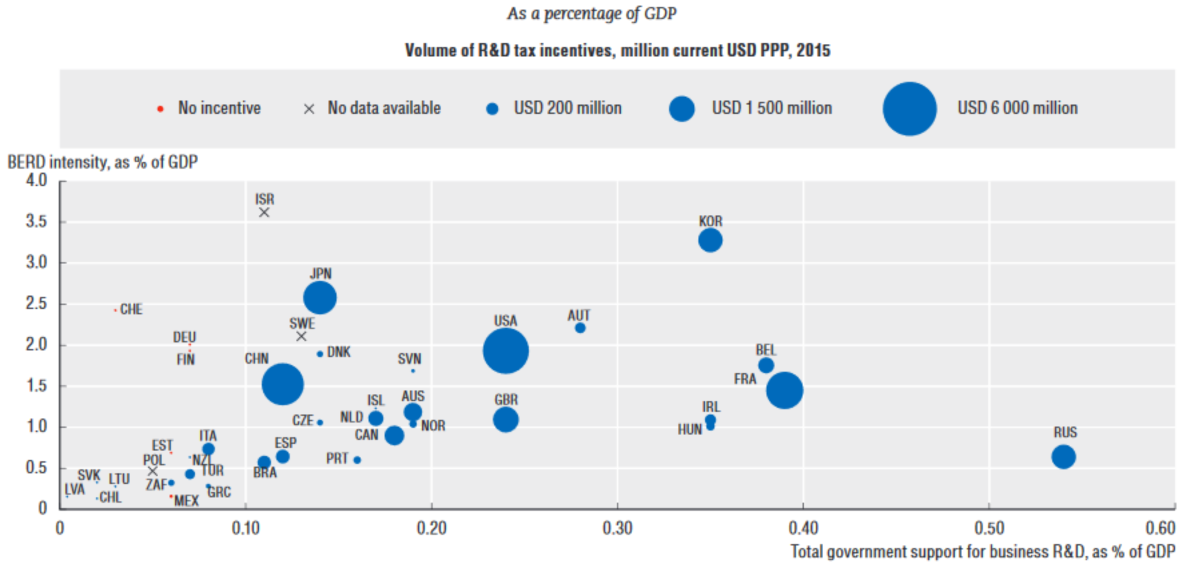
R&D spending by the higher education sector, which showed a higher percentage in GERD (25.6% in 2015) compared to the EU28 (23%).

The recent OECD Science, Technology and Industry (STI) Scoreboard Indicators (2017) report a strong positive association between research intensity and the intensity of R&D expenditure. The UK is on a par with other major developed economies in terms of the number of researchers in total employment, but the average expenditure on R&D is lower than in others, including Germany and France. This suggests that there are differences in research specialisation, as well as indicating the lower wage and capital investment associated with researchers in the UK, compared to researchers elsewhere.

In most of the OECD countries, R&D is mainly driven by business expenditure enterprises, accounting for more than 60% of the total R&D expenditure (OECD STI 2017). However, the UK business sector's R&D is lower than the OECD average. In addition, the UK's SME share of business R&D in total is lower than for most other countries, and only a quarter of the SME's R&D is supported by government, in comparison to 44% in Germany, 47% in the Netherlands and 31% in Italy (OECD STI 2017).

In promoting business R&D, especially by SMEs, government support plays an important role. In OECD countries, the correlation between R&D intensity and government support is around 0.3 on average (Figure 2.7). This indicator suggests the important role of public funding in stimulating and supporting business R&D. Among EU countries, Belgium, France, Hungary and Ireland are leading in this support, while the UK's ratio is around 0.23. The UK's government public R&D support in GDP is positioned in the middle of the EU group, but the business R&D intensity seems lower than in the US, though with the same level of government support.

Figure 2.7: Business R&D intensity and government support to business R&D, 2015

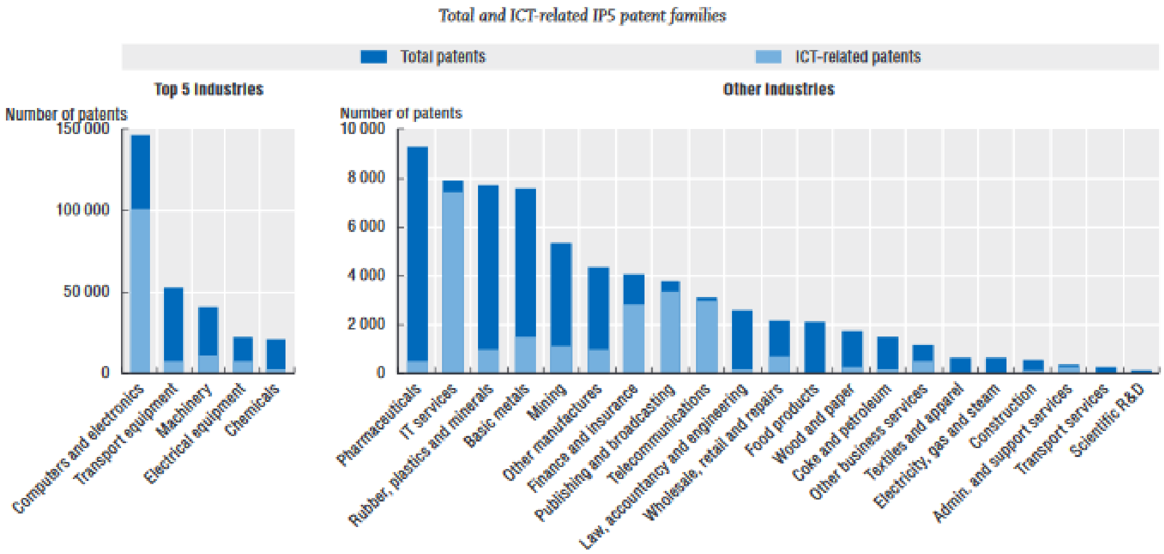


Source: OECD Science, Technology and Industry Scoreboard (2017)

ICT technology

Turning to intellectual property, globally the five industries, computer and electronics, transport equipment, machinery, electrical equipment and chemicals, are the leading sectors in the world in producing new patents (Figure 2.8). The computer and electronics industry is the sector with the highest share of information and communication technologies (ICTs)-related patents, accounting for more than 70% of global patents. IT services represent the dominant sector in relation to own ICT-related patents, but these are developed across all sectors.

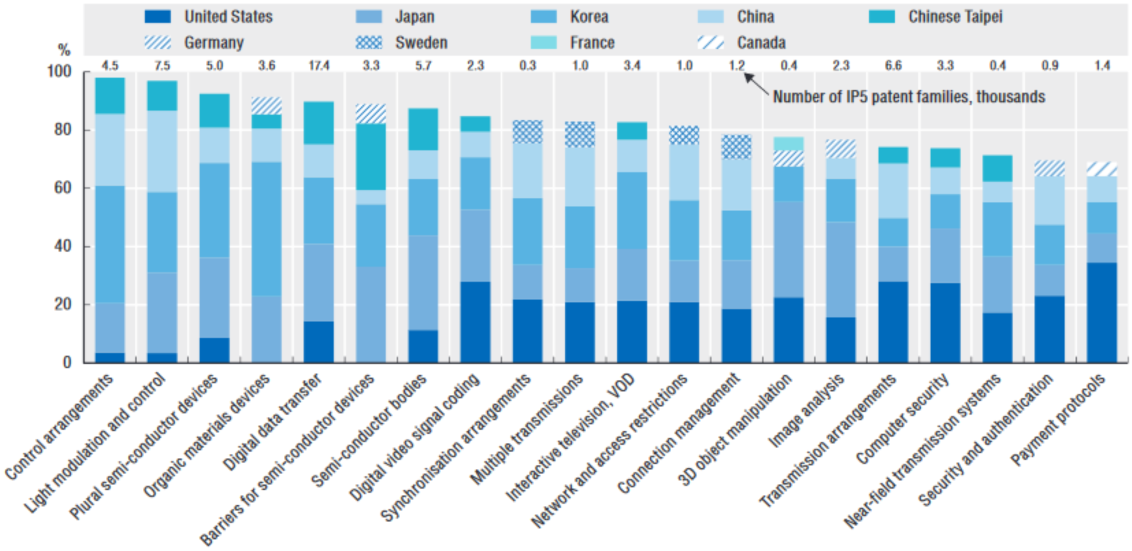
Figure 2.8: Patent portfolio of top R&D companies, by industry, 2012-14



Source: OECD Science, Technology and Industry Scoreboard (2017)

However, the UK does not feature among the top countries in the world patenting emerging ICT-technologies (Figure 2.9). The OECD STI Scoreboard (2017) suggests that five economies accounted for 69% to 98% of the top 20 cutting-edge ICT technologies over the period 2012-2015, specifically the US, Japan, Korea, China and Chinese Taipei. Only a few European economies, namely Sweden, Germany and France, featured among the top five leaders of some growing ICT fields, while the UK did not.[6]

Figure 2.9: Top players in emerging ICT technologies, 2012-15

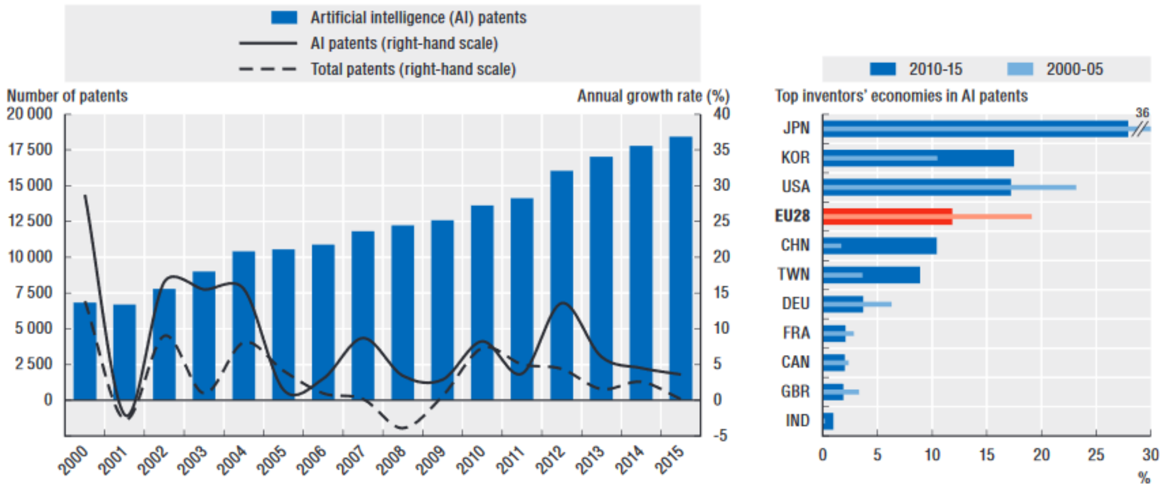


Source: OECD Science, Technology and Industry Scoreboard (2017)

We further look at artificial intelligence (AI) that has received considerable attention in recent years. AI aims at enhancing machine learning, developing a process of human-like cognitive functions such as learning, understanding and reasoning. Figure 2.10 reports the trend in AI-related developments measured by inventions patented in the five top Intellectual Property Offices (IP5). The growth rate of these technologies is substantial and on average was around 6% per year between 2010 and-2015 (OECD STI Scoreboard, 2017). During that period three countries (Japan, Korea and the US) accounted for the largest share, 62% of AI-related patents, and the EU28 accounted only for about 12% of the total of IP5 AI-related patents. The UK is behind Germany but on par with France and Canada, currently standing as a major inventor economy within EU28.

[6] The OECD STI Scoreboard (2017) notes that “As most inventions are only protected in certain economies, using data from different patent offices may lead to different results”.

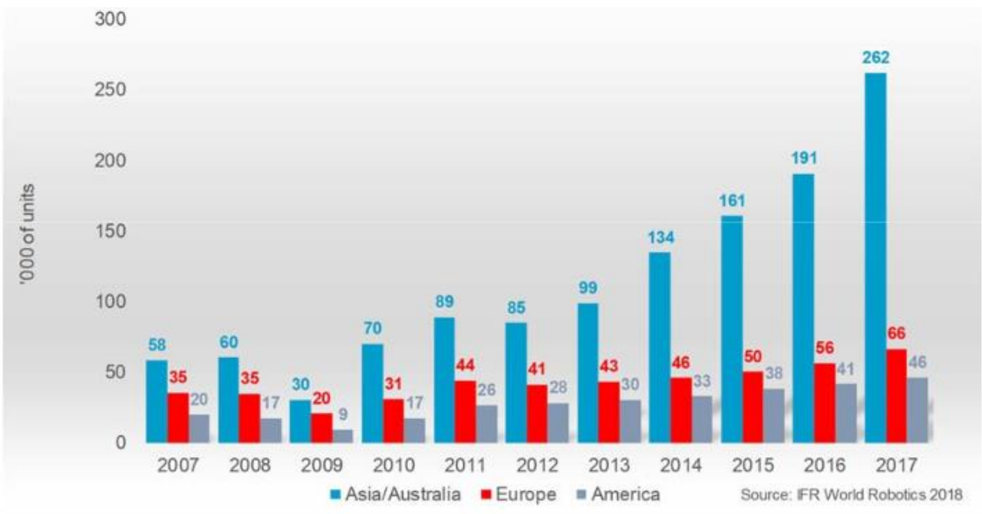
Figure 2.10: Patents in artificial intelligence technologies, 2000-15



Source: OECD Science, Technology and Industry Scoreboard (2017)

Turning to the adoption of robotic technologies, the world has seen a steady and fast growth in robot sales. The last five years have seen continuing growth and 30% growth in 2017 alone (IFR, 2018, Figure 2.11). While Asia, predominantly China, experienced the most remarkable growth, European growth was limited. Overall, five countries accounted for the largest share (73%), namely China, Japan, the Republic of Korea, the United States and Germany. The UK lies behind many other countries.

Figure 2.11: Estimates of worldwide shipments of robots across regions



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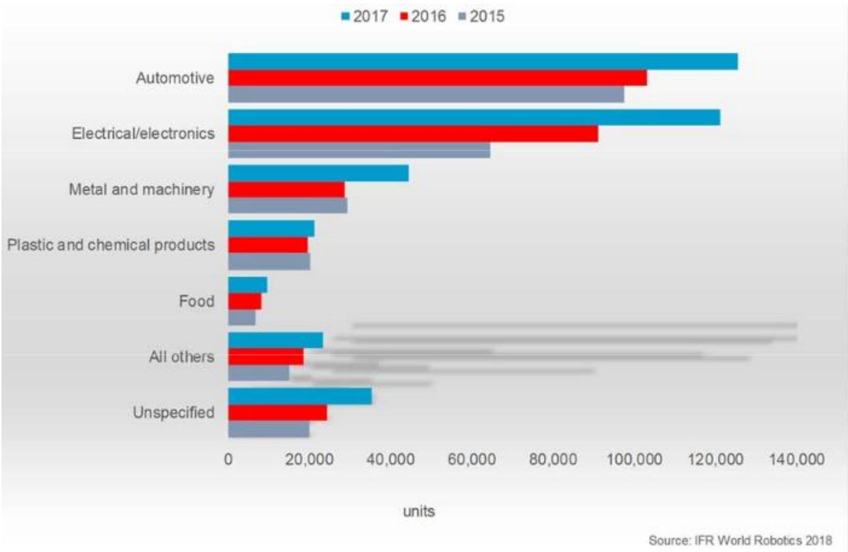
Source: IFR World Robotics 2018

Globally, the sharp increase in robotics adoption has been mainly in the metal industry (+55%) and the electrical/electronics industry (+33%), whereas in the automotive industry it increased by 22%. However, this sector still held the highest share in industrial robotics in terms of stock. In addition, there are other sectors which have seen a substantial increase in the adoption of robots over recent years, for example, the plastic and chemical products and food sectors (Figure 2.12).

Figure 2.12: Estimates of annual supply of robotics by sector



2.3 Human capital and skills

To sketch the current condition of the UK human capital and skills mix, we first look at the supply side: what the UK labour market offers in the skills mix – formal education, vocational and other types of skills. From the demand side, we probe the needs of businesses and other employers in the economy. Finally, we review the sparse statistics on skill mismatches, that is when skills supply and skills demand do not match. This section summarizes the key findings from recent work (see a review by Campbell 2016).

Skills supply: formal education

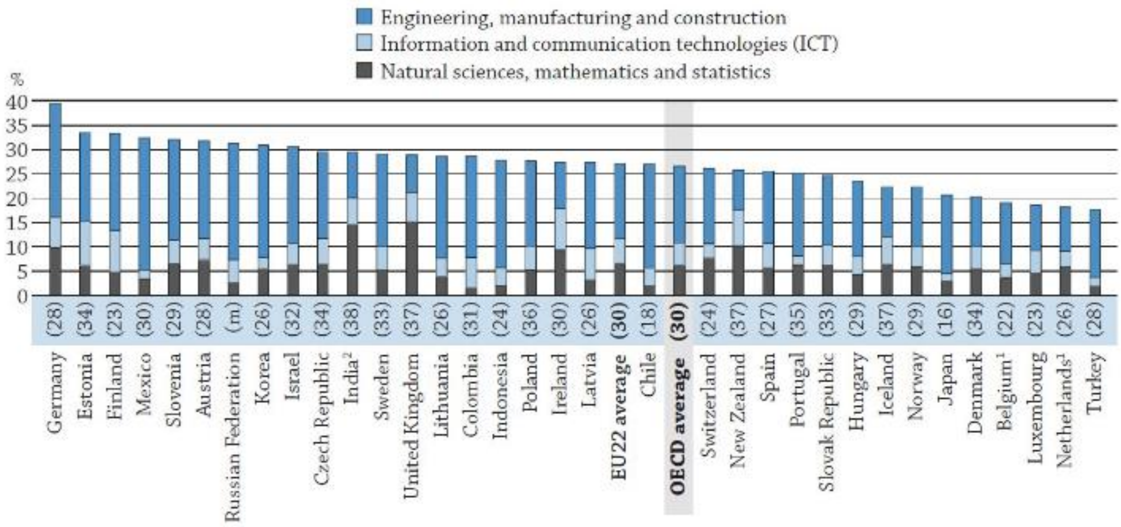
In a nutshell, the UK has become more highly skilled over time. The most commonly used indicators of skills supply are education and qualifications obtained by the working population. In recent years, the UK has improved at each skill level and is expected to continue to improve in the near future (Bosworth, 2014; Wilson et al., 2016). However, concerns arise when the UK is measured against its peers. The available statistics put the UK in a weaker position, with worsening prospects, in skills provisions at both the intermediate and low levels (BIS, 2015). For example, the OECD ranks countries according to their shares of the 25-64 years old population with low-level skills (below upper secondary education), intermediate level skills (upper secondary) and high-level skills (tertiary). In 2012 the UK was ranked 19th out of 34 OECD countries for low skills, 24th for intermediate skills, and 11th for high skills (OECD, 2014). The projection of these rankings for 2020 seems to reduce the UK's position to 22nd for low skills, reduce the position to 28th for intermediate skills, and raises it to 7th for high skills (OECD, 2016). Clearly, the skills inequality in the UK is expected to deteriorate further.

Consistent with the UK's high skills ranking, the UK tertiary education attainment has improved over the last decade. The number of students in tertiary education grew and more than 46% of adults in the UK aged 25-64 years old have some form of tertiary education, compared to an OECD average of 37%. The majority of these have at least a bachelor's degree, 23% versus 16% in OECD countries (OECD Education at Glance, 2017).

The UK has higher proportions of university student enrolment in science, technology, engineering and mathematics (STEM) subjects: 13% compared to the OECD average of 6%, in 2015. At the same time, the UK shows quite distinct patterns in the subject choices of university enrolments, with much higher enrolment levels in the more fundamental STEM subjects - in natural science, mathematics and statistics, and lower levels in applied STEM subjects like engineering, manufacturing and construction and ICT. Despite that, STEM subjects are seen as critically important to the UK's economic success (Morgan and Kirby, 2016), Skills shortages and mismatches still feature as the prominent problems faced by UK businesses, consistent with the perceived specific skill shortages in the UK's energy, construction, transport and manufacturing industries.[7]

Figure 2.13: Enrolment in STEM subjects (2015)

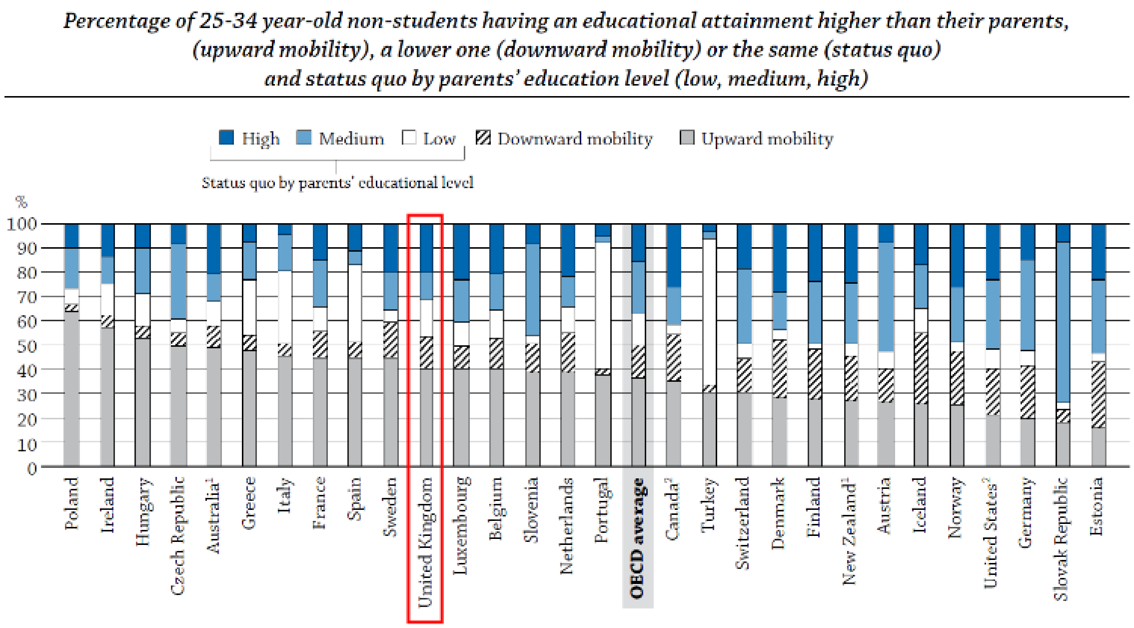
[7] See more details in the section below on "Workplace skill mismatch" and Figure 2.7.



Source: OECD Education at Glance 2017

In addition, the UK also enjoys high intergenerational mobility in higher education. About 41% of young individuals aged 25-34 attained higher levels of degrees than their parents (Figure 2.14) compared with 37% of the OECD average. Furthermore, the probability of obtaining a degree at a higher level than their own parents exceeded 60%.

Figure 2.14: Intergenerational mobility in education, 2009



Source: OECD at Glance 2012

Skills supply: vocational education and training

Vocational education is seen to play an increasingly important role in complementing formal education. Over the decade to 2014, the average expenditure on vocational training in OECD countries increases the average spending in post-secondary education by one-third (OECD STI Scoreboard, 2017). A recent report from Eurostat highlights that vocational programmes are still relatively rare. In 2016, only 3.3% of the total number of pupils in the EU-28 (including 2015 data for the United Kingdom) received vocational training.[8] The low rate of involvement is particularly the case for lower secondary education (ISCED level 2). Moreover, five EU Member States reported relatively high proportions of pupils following vocational lower secondary education programmes: Belgium, the United Kingdom, Croatia, Portugal, and the Netherlands. In the UK about 53.1% of all upper secondary (ISCED level 3) school pupils followed vocational programmes: slightly higher than the 49.3% average in the EU-28.

The UK has been catching up in recent years. The share of young adults enrolled in vocational education and training has risen to 43%, but remains lower than in many other European countries. Apprenticeships are also less popular, pursued in 2015 by around 24% of upper secondary students, compared to 59% in Switzerland or 41% in Germany (OECD, 2017).

Training plays a key role in augmenting the skills supply to meet the needs of the fast-changing economy. Skills may or may not be accredited and the contents of training are hard to quantify, hence training is difficult to measure. The most widely used statistics are obtained from the UK Employer Skills Surveys (Winterbotham et al, 2017). Based on the recent survey findings, two-thirds of employers in the UK provided some form of training for staff. BIS (2015) highlights that the UK and other major developed economies (Germany as an exception) saw stagnating or declining economy-wide training capital since the financial crisis in 2008, primarily due to the fall in the rate of training participation.

Looking more closely, in 2017 the UK employers seemed to provide an increasing amount of training than in previous years in terms of the number of employees trained, but less intensive training for each employee, which amounted to a decreased total training expenditure. An evident shift to E-training was also observed. However, there are no data on the contents and the quality of the training provided.

[8] Eurostat (2018), Vocational education and training statistics.

What are the outcomes of education and training, namely skill development? The international benchmarked test – the Programme for the International Assessment of Adult Competencies (PIAAC), also known as Surveys of Adult Skills – measures proficiency in literacy, numeracy and digital skills among the OECD countries (OECD, 2013; BIS, 2013). Based on 8,892 people in the data collected aged 16-65, the UK scores fairly high in literacy skills, in exactly the middle of the group.[9] But there was a slightly higher percentage (16%) of low literacy skills at the bottom level, representing 5.8 million people by scaling up to the population. On numeracy skills however, the UK performed poorly. Ranked 13th out of 18 countries, the UK had a staggering quarter of adults who scored at level 1 or below, more than the OECD average of 19%. Moreover, the UK was the only country where older people (55-64 years old) outperformed younger people (16-24 years old) in proficiency in both literacy and numeracy. Campbell (2016) points to this worrying evidence and highlights a downward trend in the relative proficiency of the UK compared to others. This is despite the increasing educational levels and hence alarming. Also, while the UK's digital literacy was ranked in the middle of the OECD countries, that of young people lagged behind young people of other countries, scoring lower than the OECD average.

Skills supply: cognitive skills

Cognitive skills are much in demand in the age of digital transformation, and progress in the skills mix is critical for problem resolving, critical thinking and quantitative abilities. The global benchmark test – the Program for International Students Assessment (PISA) assessment – provides a cross country comparison of the performance of 15-years old students on cognitive skills. The results rank Japan, Estonia, Canada and Finland at the top, while the UK position in this cross-country ranking is lower, yet still higher than the OECD averages.

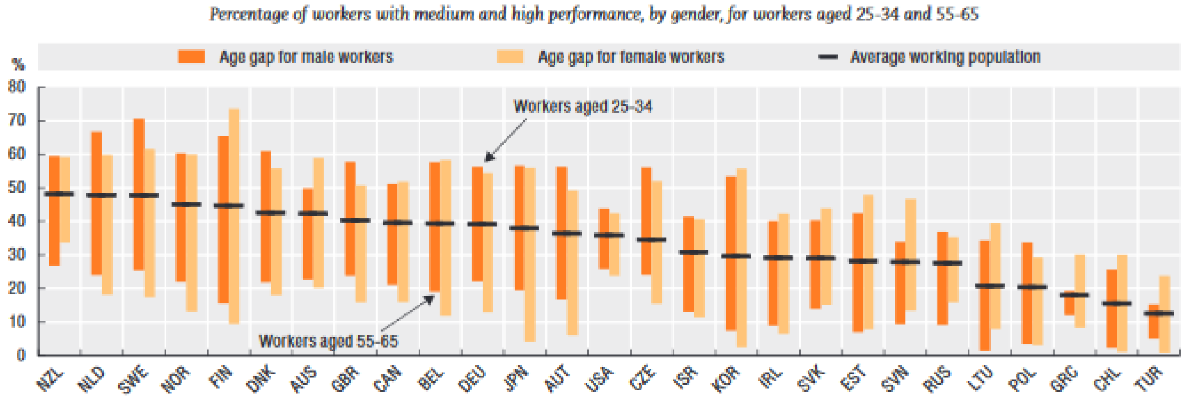
A look at the gap in performance between males and females in technology-rich tasks reveals quite substantial heterogeneity among countries (Figure 2.15). Furthermore, when looking at the percentage of the working population with medium and high skills in problem solving, what emerges is that young individuals exhibit better performances than the older workforce. On average 40% of the workforce in the UK is able to handle problem solving skills in technology-rich-environments. However, this is quite low compared to the average share in New Zealand, the Netherlands and Nordic countries. Among top performing countries

[9] The sample is based on England and Northern Ireland only.

(above 40%) only Finland and Australia see female workers rising above the average population score. However, in countries with 30% or less of the population with problem solving skills –i.e. in Turkey, Slovenia and Greece – females are able to significantly contribute to increasing the average score.

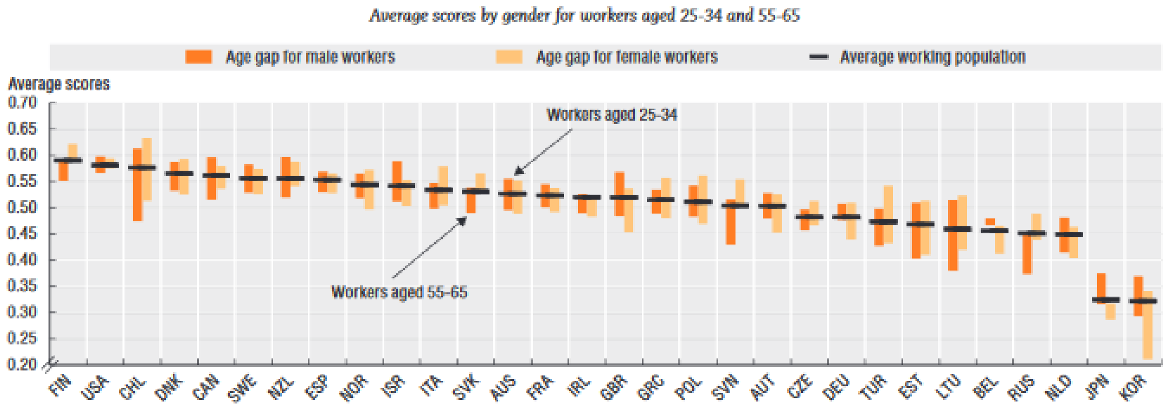
On the other hand, concerning readiness to learn as well as creative thinking, differences across countries are more significant than within countries (Figure 2.16). Finland and USA are the best performing countries with shares of around 60%. However in the former women are the key element in raising the average score. The UK shows a relatively different pattern, so although the average score is between 50-55%, male workers are the key element that increases the average score. Nevertheless, what emerges overall is that the UK is still behind many countries in terms of improvements in these skills.

Figure 2.15: Problem solving in technology-rich environments, 2012 or 2015



Source: OECD Science, Technology and Industry Scoreboard (2017)

Figure 2.16: Readiness to learn and creative thinking, 2012 or 2015



Source: OECD Science, Technology and Industry Scoreboard (2017)

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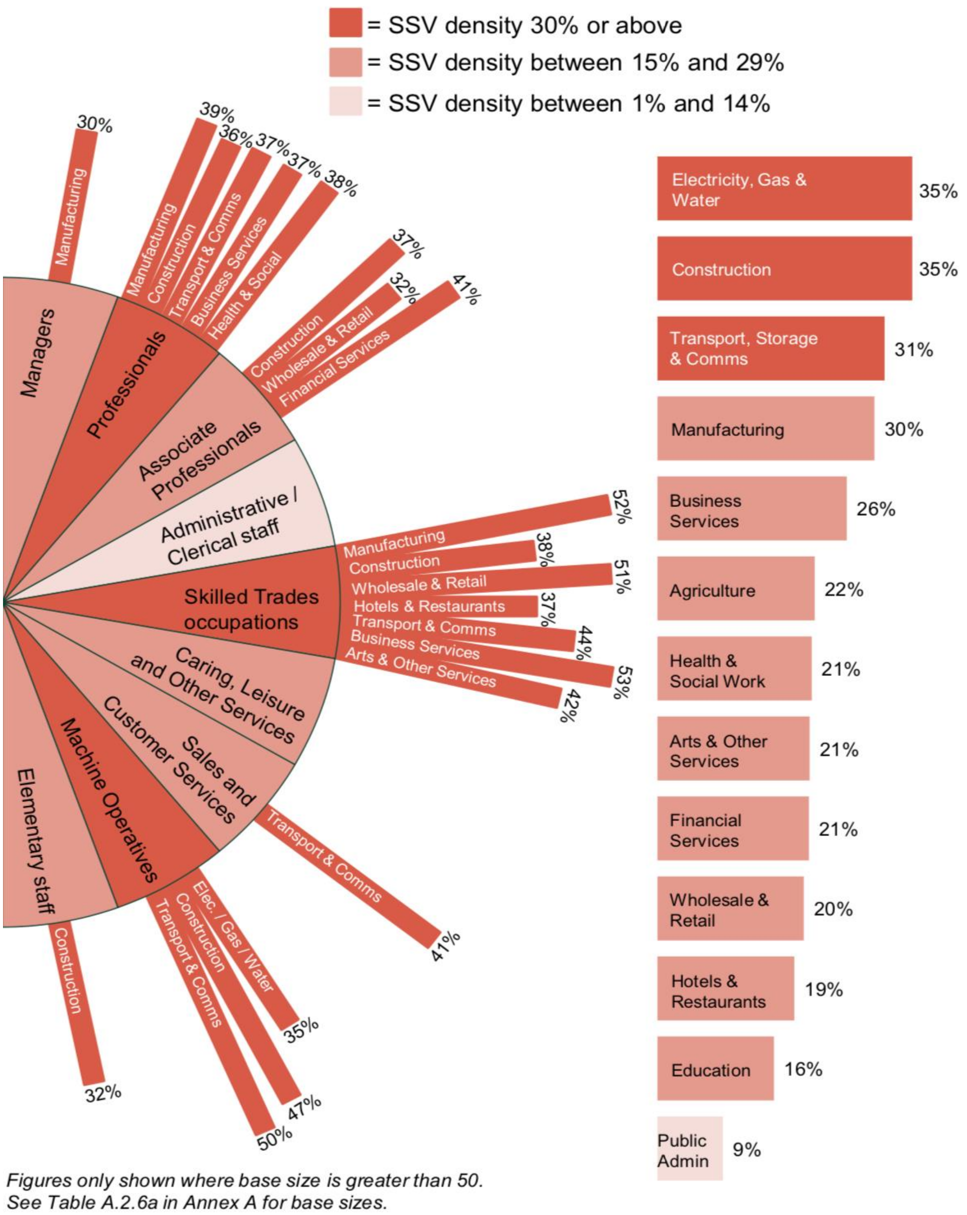
Another aspect that the current generation of workers faces is the increasing requirement to perform tasks that require substantial information and communication technology (ICT) skills. The OECD compares workers' remuneration levels, as reflecting skill requirements and the firm's performance. The UK is ranked in the middle, below the Nordic countries and the Netherlands, but higher than Germany, the USA and Canada (OECD STI Scoreboard, 2017). In addition, managerial and communication (M&C) skills, as a complement to ICT-intensive skills, especially in a digital era, are also important. The UK leads the ranking in terms of hourly returns in the jobs where these two tasks are performed together. That is, the overall return is about 3.2% additional to the hourly wage, compared to 2.5% additional to German jobs (OECD STI Scoreboard, 2017).

Workplace skill mismatches

When there is a discrepancy between skills supply and skills demand, skill mismatches occur. Skill shortages are commonly measured by the proportion of hard-to-fill vacancies reported by employers, reporting how many positions were not filled in proportion to the advertised positions, due to insufficient numbers or inadequate qualities of job applicants (known as density of skill shortage). The UK Commission for Employment and Skills (UKCES) National Employer Skills Survey (ESS) 2015 survey reveals that 1 in 4 positions were regularly not filled, amounting to 209,000 vacancies across 6% of all employers, a figure higher by far than in 2013 (Vivian et al., 2015). The industrial differences are substantial, ranging from a skills shortage density of above 1 in 3 in gas, electricity and water industries, and the construction sector, peaking in the skilled trades sector at 43%. (Figure 2.17).

Figure 2.17: Density of skill-shortage vacancies by sector and occupation within sector



Source: UKCES (2015) Employer Skills Survey. SSV: skill shortage vacancies.

Similar analyses were conducted to provide insights into skill shortages at sector and occupational level, including The Migration Advisory Committee (MAC, 2013), revealing widespread perception of skill shortages related to problem solving, numeracy, literacy and IT skills, in general engineering, management and specialized occupations.

In addition, skill gaps can occur within the workplace after recruitment, when employers identify employees who are not sufficiently proficient in their positions. The ESS

2015 reports 1 in 7 employers identifying such skill gaps, which amounts to 1.4 million employees or 5% of all the workforce in the UK (Vivian et al, 2015).

The opposite side of skill gaps and shortages is over-skilling, when employees are over-qualified or their skills are under-utilized. Needless to say, this is a waste of resources and a missed opportunity for productivity growth. The ESS estimates that 3 in 10 employers experience this situation, amounting to 2 million people or some 7% of all the workforce, most commonly among managers and administrative workers (Vivian et al., 2015). Similar patterns are found in different surveys, such as the UK's Skills and Employment Survey (Felstead et al., 2013).

The OECD (2018) Skills for Jobs Database reports that about 41% of British workers are either over-qualified or under-qualified for their job, higher compared with 33.5% average for the EU. In addition, there is a similar level of instances of working in a field of study different to the one in which workers studied at school. Furthermore, the same database reveals shortage pressures at similarly high levels in knowledge related to education and training, health services, and STEM subjects. Quite noticeably, the UK's over-skilling problems are worse than the OECD peers (CEDEFOP, 2015). The UK registered the highest for over-qualification in all 28 EU countries, implying a high level of qualification mismatch (CEDEFOP, 2015).

It is important to note that skill mismatches are found both in low-skilled jobs and high-skilled jobs. Perhaps it is not surprising that a high proportion of jobs remain low-skilled, while the proportion that are high-skilled remains low relative to the increasing supply of workers with higher level qualifications. Among the countries covered by the OECD Survey of Adult Skills, the UK is only behind Spain in terms of the share of jobs that require lower-level qualifications (22%) while the demand for higher level qualifications falls short of supply, with only a third of jobs requiring a tertiary education (OECD, 2017).

To address the issues of skill problems, one has to consider skill supply as well as skill demand. The level and changes in the sectoral distribution of jobs determine what skills are required and where the demand emerges. While the available statistics may help us to project long-term trends of skills demand, it is more challenging to predict changes of skills demand. In 2016 total employment in the UK was around 31.4 million, among which 58% were full-time employees, 28% were part-time employees and 14% were self-employed (Campbell, 2016). Working Futures[10] regularly makes projections about future jobs for sectors and occupations. For example, it is predicted that there will be a large increase in demand for skills in trade, accommodation and services, as well as in business and other services, projecting to 2024 (Wilson et al 2016). However, the crucial determinants of skills required by employers lie in technology and the industrial structure of a local economy. Technological development and its diffusion determine the dynamics of changing skill demands, which ultimately lead to some skill gaps, shortages and mismatches. Further, the industrial structure of a place is configured by its technological advancement and its position in the global value chains as a result of its competitive advantages, including those of the labour market. Therefore, it is the intertwined relationships between local economies, technology, links with global production networks, and changing skills that need to be analysed in a common framework in order to build a complete understanding about skills issues and inform a dynamic approach to policy making.

[10] Working Futures is an assessment of future employment prospects for UK conducted by Institute for Employment Research and Cambridge Econometrics, more details are at https://warwick.ac.uk/fac/soc/ier/research/wf/ .

3. The UK Productivity Puzzle: A Short-term Perspective

2.1.The problem

We first consider the most acute productivity problem of the UK from a short-term perspective, which is the question why the UK has suffered from a decline of productivity, similar to other developed countries, but has never recovered as swiftly and completely as others. There are various theories put forward to explain this phenomenon, and this White Paper does not aim to provide a comprehensive account of them. Several reviews (Du and Bonner, 2015; IPPR, 2015) provide accounts of the debate. Instead we highlight the most significant factors that have been argued as important in recent studies.

The UK's zero-productivity growth following the financial crisis seems have little connection with the financial crisis (Hughes and Saleheen, 2012; Oulton and Sebastiá-Barriel, 2013). In addition to the measurement issues discussed below, plausible explanations of the productivity puzzle are related to weakened demand globally and at home, and to labour market factors. Further, economists also identify signs of the economy experiencing a structural shift from high-productivity to low-productivity work. We discuss the evidence of this potential trend in terms of self-employment, capital shallowing and resource allocation factors. We also add to the list of issues some business dynamism factors that have not been focused on till recently.

2.2.Measurement issues

Before considering the reported discrepancies between UK productivity levels and those of others, it is necessary to bear in mind that statistical measurement issues in regard to labour inputs and outputs may affect the picture. First, the overestimation of past productivity might lead to lowering the measured level of current productivity. In addition, several sectors are identified as having experienced a specific growth trajectory, such as the oil, gas, and finance sectors, so that past GDP growth might have been inflated.

Second, working hours as a measure could be misleading. The most recent OECDadjusted labour productivity estimates also suggest the sensitivity of measurement elements and reveal as a consequence improved UK productivity records. According to the new estimates of 2018 the UK's gap in labour productivity levels with the United States is around 8 percentage points smaller than was previously estimated – down from 24% to

16%. The gap with Germany shrinks from 22% to 14% and with France from 20% to 11% (OECD, 2019).

However, measurement issues cannot be the exclusive focus when disentangling elements of the productivity puzzle, for the following reasons. First, the measurement issues do not fully explain the causes of the productivity decline over time, not do they explain the divergence of the UK on the path of recovery from the financial crisis post 2008. As an example of another potential factor, the role of intangible assets in generating output has also been discussed, but cannot fully explain the productivity puzzle (Goodridge, et al 2015).

Second, investigating the importance of measurement issues is not easy, as data are not sufficient to construct longitudinal series of capital stocks, and the methodologies adopted for calculating productivity vary among the existing studies. Given the absence of complete and high-quality data, this is an issue that cannot be easily verified and remedied.

Therefore, measurement issues clearly matter, but should not be the focus of the endeavour of understanding the productivity puzzle. These limitations nevertheless stress the importance of conducting research at disaggregated levels over a long period of time, using large samples and consistent statistical instruments to construct comparable statistics and enable robust analysis.

2.3.Global and domestic demand shortfall

Among the plausible explanations of the productivity puzzle is the weakened global demand, that is the macroeconomic perspective (Oulton, 2018). Given that aggregate global demand has fallen sharply during the financial crisis, the economy’s productive capacity has also fallen through cuts in investment and depressed technological progress (Pryce, 2015). The global demand shortfall has also been followed by weakened consumer confidence, intensified by government austerity, all adding up to a persistent effective demand failure. Yet this view is debatable, as there are suggestions that it cannot explain the prolonged period of reduced productivity growth.

The decline in demand would have a range of transmission mechanisms through trade, finance, and uncertainty (Chowla et al., 2014), as well as capital investment and firms’ innovation, which further dampens the potential for economic recovery. However, there is no decisive evidence so far.

2.4. Labour market factors

Labour hoarding is one of the key explanations put forward with supportive statistics of low levels of employment contraction during the crisis (Butcher and Bursnall, 2013; Barnett et al 2014; Riley et al 2014). This concept describes the situation when firms reserved labour as output fell in the recession, when facing uncertain demand, in order to avoid the costs of firing and then re-hiring (Martin and Rowthorn, 2012), to secure future contracts (Barnett, Broadbent et al 2014), or to allow skilled labour to build up intangible assets (Goodridge et al., 2013).

However, this theory falls short in explaining continuing weak productivity after 2011, when employers would have had enough time to react to weak demand, or in explaining the sustained employment growth of 1.6 million over 2012-2015 (ONS, 2015; Barnett et al 2014b).

Falling real wages in the UK have become more apparent as a characteristic of the sluggish response in the labour market to output decline. Real wage growth in Britain started to decrease in the early 2000s, before the recession (Gregg et al., 2014). The evidence also suggests that real wage decline occurs within the same workforce on a year-on-year basis, and not due to the changing composition of the workforce (Blundell et al., 2014). At the same time, the cost of capital has increased considerably, especially for smaller firms (Pessoa and Van Reenen, 2014). Labour as such was made relatively cheap for employers, hence there was a stronger incentive to substitute labour for capital (Bryson and Forth, 2015), and to delay upgrading capital-intensive assets which would enhance productivity. Although real wage levels and labour hoarding appear to share a strong movement, there is so far no robust evidence to prove a causal relationship.

2.5.Self-employment

One of the curious phenomena during the great recession was the prolific extent of job creation. With around half a million jobs lost in the public sector since 2010 as part of the austerity programme, the private sector has added 1.7 million jobs between 2012 and 2015 (Pryce, 2015). However, the evidence suggests that many of these are low-productivity jobs, often part-time, zero-hour contract jobs and self-employment, with lower pay, less training provided and poor skill utilisation (Martin and Rowthorn, 2012).[11] To be more precise, self-employment represents one-third of the increased employment in the UK in the recession (Martin and Rowthorn, 2012). It is estimated that to assume the self-employed produce no output at all would explain some 2 per cent of the current gap in productivity levels with respect to the pre-crisis trend (Barnett et al., 2014).

There are rationales for associating low productivity with self-employment businesses, due to the inability to take advantage of economies of scale, the lack of entrepreneurial ambition, the limited access to capital and the skill gaps among this particular type of business organization. Yet these issues are in no way unique to self-employment firms, but common for micro-businesses and start-ups.

2.6. Resource misallocation and business dynamisms

Related to the changes in business demography and reduced investment in the economy is the view that the UK economy has experienced impaired capital reallocation. Indeed, in any given economy, there are only certain ways to improve aggregate productivity. One way is to increase the productivity of an average firm, and the other is to allocate scarce resources from less productive firms to more productive ones. The mechanisms of such resource allocation are usually through the market, while in some economic contexts, government policy does play an important role.

Several studies point out that the financial crisis has resulted in a misallocation of capital to less productive firms, many of which are small but not productive (IFS, 2013; Bank of England, 2014; IPPR, 2015). Du and Bonner (2015) show that during the recession period the UK business population has undergone observable business demographic changes which underly UK aggregate productivity changes, featuring an increasing number of small businesses especially single-employee firms, yet fewer entrants and more exits; they discuss the implications of these changes in explaining the decline in productivity. From the more recent figures provided in Hart and Prashar (2018), the low firm entry rate during the recession had recovered considerably before dipping again in 2013. It then started a recovering trend till 2017 when it decreased further. Mirroring this is the firm exit

[11] Martin and Rowthorn (2012) suggest that both the output per head and the output per hour work have been decreasing.

rate that has increased in recent years. In addition, the contribution of the job-creating scale-up firms in the economy appears to have diminished, echoing the challenges of firms' upscaling recognized by the policy makers (BEIS, 2017).

Consistent with the observations on business demographic changes during the recession period and the most recent period, the lower wage levels and low interest rates supported low costs of business survival, while the restricted access to finance may well explain the lower entry rates and higher death rates of firms. The weakened level of demand and the uncertain economic and political environment also dampened incentives to invest in innovation and upscaling, which have long-term implications for productivity growth.

Clearly, building on the broad statistical observations and earlier analyses, more in-depth analysis is needed to understand the causal impact of the components of business dynamics on UK productivity growth.

4. Technology, Skills and Long-term Productivity

Technology and skills are the two pillars for long-term productivity growth. In brief, technological innovation is a fundamental source of growth at the firm, sector and country levels (Aghion and Howitt 1992 ; Aghion, Harris, and Vickers 1997). Meanwhile, the adoption and diffusion of technology place certain requirements on the skills of the workforce and the necessary transformation of the workforce to implement and exploit new technology. Inadequate or mismatched skills vis-a-vis technology will limit the rate of innovation, slow down productivity growth and therefore lessen the improvement of living standards. Therefore, the right level of skills, of the right amount, placed where they are needed could maximise the benefit of technology in driving growth.

This highlights two crucial issues related to skills. The first centres on what level of skills embedded in human capital are supplied and demanded in a given market, and how to reduce the gap between supply and demand. Addressing this question features in a large existing labour economics literature. However, given that in developed economies such as the UK, the increase in the stock of human capital is projected to be slow (Braconier et al., 2014), it is increasingly important to consider not just the skill gaps, but also the allocation effects of skills, skill mismatch problems. However, data limitations and empirical challenges have hindered researchers from generating more solid evidence on its effects.

Further, some specific skills are more important to a special element of creative destruction in the economy – the entrepreneurs, who are responsible for most new jobs created and for bringing innovation into action.

Below we briefly review the main concepts and theories on the relationships between technology, skills and productivity, as well as the empirical evidence that we have gleaned so far.

3.1. Human capital and economic growth

The origins of understanding the importance of education and skills in economic growth were in the neo-classical growth model (Solow, 1957; Barro, 1997) and the endogenous growth models (Lucas, 1988 and Romer, 1986). Through the voluminous literature developed thenceforth, human capital, as a factor of production, was emphasised as determining the productive efficiency of an economy and its long run growth rate. The countries with an initial higher ratio of the stock of human capital to physical capital grow faster, because more human capital facilitates the absorption of superior technologies. Because it is harder to adjust human capital than physical capital, countries with advantages of human capital tend to stay in an advantageous position. Not all dimensions of human capital are equal. The evidence based on data of over 100 countries shows that both the quantity and quality of education matter in relation to growth, while the latter may have much more importance (Barro, 2001).

Hulten and Ramey (2019) summarise this very large literature presenting five channels through which human capital affects GDP growth. First, worker productivity directly contributes to aggregate productivity and economic growth through raising the marginal product of labour. Education, cognitive skills and other attributes can all enhance worker productivity via raising wages, as the classic Mincer equation suggests. However, the recent estimates suggest that the contribution of education to growth seems reduced at the present (Hulten and Ramey, 2019 chs. 1, 2).

Second, skill-biased technical change has affected economic growth in recent decades (Acemoglu and Autor, 2011), driving output growth in sectors where high skills are abundant. Importantly, shifts in the microstructure of production activities have tended to involve workers with advanced skills that are strong complements to the more sophisticated types of capital and technology, and are thus necessary inputs whose absence can limit growth (Hulten and Ramey, 2019 ch. 3).

Third, education and skills matter for innovation. New idea generation that potentially leads to technical innovation relies on education and skills, and so do technology adoption and diffusion (Nelson and Phelps, 1969).

Fourth, not only does human capital determine productivity directly as a production input, but also indirectly through knowledge spillovers between workers (Winters, 2015). There are multiple channels through which this can happen, including, for example, by stimulating capital investment (Romer, 1986) and R&D (Romer, 1990), and by promoting technological diffusion (Nelson and Phelps, 1966; Benhabib and Spiegel, 2005), all leading to productivity growth. Despite the fact that knowledge spillovers are hard to measure, much evidence shows the impact of knowledge spillovers and how human capital as part of absorptive capacity can maximize positive knowledge spillovers (Cohen and Levinthal, 1989;1990).

Finally, social capital, as an important aspect of human capital, has positive implications for the performance of organizations as well as stimulating economic growth at the society level (Forte, A., Peiró-Palomino, J. and Tortosa-Ausina, E., 2015). The recent research on small business growth has identified that networks-based social capital facilitates entrepreneurs gaining access to knowledge resources, developing norms for trust, support, monitoring, and reciprocity, all promoting growth (Stam et al., 2014).

3.2. Technology, skills and jobs

In the production function framework that explains production output, capital and labour are commonly used to capture physical inputs, known as factors of production. In essence, skills are embodied in labour, and technology is embodied in capital. Labour and capital have intricate relationships - they can be substitutable or complementary in different conditions.

By and large, advanced technology can affect employment in two ways. First, advanced technologies can directly displace workers from the tasks they were previously performing. This is known as the *displacement effect*, and is backed with strong evidence. In the US, for example, Acemoglu and Restrepo (2017) found that in the post-1990s period one additional robot per thousand workers reduced the employment-to-population ratio by 0.37 percent and wages by 0.25-0.5 percent on average. Interestingly, this level of negative displacement effect in the US has not been found in Europe. Dauth et al. (2017) undertook the same local empirical exercise for Germany but did not find any negative significant impact of robots on employment. Chiacchio, et al. (2018) followed a similar approach for the EU, and the negative impact of robots on employment rate was more modest, and with no robust significant impact on wages.

On the other hand, technological advance can also increase the demand for labour in industries or jobs that arise or develop as a result of technological progress (the *productivity effect*). Bessen (2017), for example, found empirically that computer technology is associated with job growth, which was particularly observable in non-manufacturing industries. Pioneering the use of the industrial robots' database, Graetz and Michaels (2017) estimated that for the 17 countries observed, the increased use of robots per hour worked from 1993-2007 and raised the annual growth of labour productivity by about 0.37 percentage points.

There is a debate about when displacement effects and productivity effects may occur and predominate. In general, past industrial revolutions suggest that in the short run the displacement effect might predominate. But in the longer run, when markets and society become fully adapted to major automation shocks, the productivity effect can predominate and lead to a positive impact on employment (Chiacchio, et al 2018). However, there is a suggestion that the current technological progress driven by AI disruption seems to have far more impact than earlier major technological innovations.[12]

It is also important to note that these effects – displacement or productivity effects - have spillover effects on other sectors, although there is a dearth of research to provide evidence about their full extent. For example, while industrial robots have had a negative impact on employment in the German manufacturing sector, there is a positive and significant spillover effect as employment in the non-manufacturing sectors has increased and, overall, has counterbalanced the negative effect.

Different types of technologies affect employment (i.e. required skills) in different ways. This has become the centre of the debate in the recent literature that distinguishes different types of skills in the growth process. Evidence suggests that manufacturing technologies were skill complementary in the later twentieth century (Goldin and Katz,1998), but may have been skill substituting prior to that time during the nineteenth and early twentieth centuries (Braverman 1974).

What explains the contrasting effects of technical advances on demand for skills? Economists argue that the behavioural impact of technical change followed the development and use of technology as a response to profit incentives (Acemoglu, 2002). When developing skill-biased techniques is more profitable, new technology will tend to be skill-biased. According to this, the early nineteenth century was characterized by skill-replacing developments because the increased supply of unskilled workers in the English cities made the introduction of these technologies profitable. In contrast, the twentieth century has been characterized by skill-biased technical change because the rapid increase in the supply of skilled workers has induced the development of skill-complementary technologies.

Overall, there is consensus in the theoretical arguments that the creation of new technologies (i.e. innovation) and their subsequent adoption (i.e. diffusion) require different types of skills (Acemoglu et al., 2006; Vandenbussche et al., 2006). Innovation requires intensive highly-educated labour, while once new technologies have been invented, less-highly educated workers could play the main role in the process of imitating or applying such

12 The McKinsey Global Institute (2015) estimates that, compared to the Industrial Revolution of the late eighteenth and early nineteenth centuries, AI's disruption of society is happening ten times faster and at 300 times the scale.

technologies. In the last few decades, new technologies have been largely created in developed countries: hence high skills were favoured, and technical change has led to skilled workers replacing the tasks previously performed by the unskilled (Acemoglu, 2002). In contrast, imitation and technology diffusion occurred widely in underdeveloped countries where less highly-educated and skilled workers were favoured. This is known as skill-biased technological change.

Turning to a specific type of technology, automation, we now have increasing understanding of its implications for skills and labour. Autor, Levy and Murnane (2003) find that computerisation technology can replace human labour in routine tasks whether manual or cognitive, but (as yet) cannot replace human labour in non-routine tasks. Acemoglu and Autor (2011) found similar results for the US, while Darvas and Wolff (2016) reported similar developments for a selection of EU countries, including Germany, Spain, France, Italy, Sweden and the UK. Moreover, Goos, Manning and Salamons (2014) found evidence that supports the theory of routine-biased technological change, which claims that new technological innovation shifts demand away from workers who perform routine tasks.

Overall, some implications for the future of jobs seem to be emerging. Goos and Manning (2007) argue that the impact of technology leads to rising relative demand in relation to well-paid skilled jobs, which typically require non-routine cognitive skills, and rising relative demand in relation to low-paid least-skilled jobs, which typically require non-routine manual skills. At the same time, demand will fall for 'middling' jobs, which have typically required routine, manual and cognitive skills. This trend then implies that for countries like the UK, where competitiveness hinges on innovation, high levels of education and skills are needed to drive and sustain growth (BIS, 2015).

A lot of effort has been undertaken to investigate how new technologies affect the distribution of the wages and income, and exacerbate inequality (Acemoglu, 2002). This however is outside the scope of this White Paper.

3.3.Skills and productivity at the national level

Skills level and productivity

Economists agree on the importance of human capital in driving economic growth, but it is a longstanding subject for debate as to whether sustained growth is caused by the level of human capital in the nation or by the accumulation of human capital (Lucas, 1988; Uzawa, 1965). The quality of the human capital influences the adoption and take-up of technology and increases innovation (Romer, 1986; Nelson & Phelps, 1966). The recent trend to skill-biased technical change only energises the debates on the role of skills, in particular skill gaps and skill mismatches.

Typically, when modelling the role of skill-embedded human capital in productivity, economists distinguish skilled workers' and unskilled workers' contribution to productivity (eg. Haskel and Martin, 1993). Based on the premise that the marginal product of a skilled worker exceeds that of an unskilled worker, we would expect productivity to fall as the ratio of skilled workers in the economy falls. Thus, increasing the number of skilled workers would help to increase productivity. The size of the impact on productivity is not clear however, and will probably depend on how easy it is to substitute skilled workers for unskilled workers, and thus on the composition of jobs and industries within the nation. Furthermore, higher skill levels may have a positive influence on the technology used in production, with more skilled workers likely to push working practices forward and innovate more on the job, increasing how these factors of production can be combined.

However, the crucial issue here is to focus on skill gaps instead of skill levels. For example, is a skilled worker one with high skills, or one with the skills required for the job they undertake? For instance, an individual with a PhD in nuclear physics is likely to be considered highly skilled under the first definition, but if he is employed as carpenter he may fall into the unskilled group, without the tools to properly perform the job. Further, it may be assumed a mixture of both high skilled and low skilled workers is needed for an economy to reach its optimal productivity. It follows that adding more skills may not necessarily improve the economy, if it is already at or above the optimal demand for skills. Thus, it is more appropriate to consider skill gaps instead, the difference between the current level of skills and their optimal level.

Skill levels are linked with skill gaps through technology. A better trained workforce, capable of more abstract and critical thinking, has the potential to advance technology and increase output. Thus, the optimal level of skills in the nation is influenced by both the technology and capital in use. This factor motivates the debate on the low skill cycle, that is the skill levels in the economy influencing the skills demanded by firms and shaping the future investment in skills (Finegold and Soskice, 1988). Where skill levels are high, firms can utilise high performance production methods designed for skilled labour and create further demand for highly skilled workers. If on the other hand firms experience skill gaps due to a low level of skills in the economy, they will not seek to use complex production techniques, nor seek to hire as much skilled labour in the future, and the incentives for workers to up-skill will be reduced. Thus, today's skill gaps may have a detrimental effect both on tomorrow's skills and tomorrow's productivity, by limiting how technology is integrated into production processes. This is further compounded by the role that skilled workers are likely to increase technology diffusion within firms, driving innovation and further growth.

Empirical Challenges

While there are a number of key theoretical pathways through which skill gaps can be considered to influence productivity, the extent of empirical investigation is unfortunately limited by empirical challenges. The first of these challenges involves defining and measuring skills accurately. While skill levels are often proxied by educational attainment, this is an imperfect measure for skills, as formal education ends for most individuals in their early twenties (if not before), and yet they will be likely still to be acquiring skills throughout their careers as they gain experience, switch jobs and continue to train.

Furthermore, educational attainment does not provide a very granular measure of skills, with all those completing the same level of study assumed to hold the same "skill", an assumption which has not been seen to hold in a number of studies (Pellizzari and Fichen, 2017; Bacolod, Blum, and Strange, 2010). As the skills a worker needs for most jobs are multi-dimensional, often including language, numeric, problem solving and interpersonal skills, to assume that a given level of education captures all of these is problematic.

While the formal education measures used for skill levels raise measurement problems, so do the self-reported measures of skill gaps. As measures of skill deficiency require information to be held on both the skill requirements of a given job and the skills held by candidates they are often reported by employers or employees. This can cause problems, with reporting bias often being found, as firms wish to receive more funding from the government to deal with the skills issues they face (Richardson, 2009).

The second major challenge in this type of estimation is to ensure that the link found between skills and productivity is causal, i.e. that skills do have an impact on productivity rather than that productivity drives future skill acquisition. Endogeneity issues such as this exist in almost all areas of productivity estimation which thus requires more careful and complicated calculation, increasing the data requirements to justify robust inference.

Evidence

Despite these issues there have been some strong contributions in the literature at the national level. Sianesi and Van Reenen (2003) and BIS (2015) provide comprehensive reviews of the evidence. We will briefly outline the main findings on the skill level work,[13] before moving on to the more complex but ultimately rewarding task of investigating disequilibrium in the skill market through skill shortages and skill mismatch.

A voluminous literature on the returns to education concludes that human capital has positive and significant effects on productivity (BIS, 2015). The existing studies have examined educational participation based on schooling, public expenditure on education and educational attainments based on qualifications, highlighting the pros and cons of each approach. While this literature confirms that education enhances productivity, especially at the high-skilled level, it becomes more evident that training reinforces the return to education and skills (Mason et al 2014; O'Mahoney and Riley 2012).

Moving towards measuring skills through qualifications and uncertified skills, the most recent research benefits from the available internationally standardised measures of cognitive skills, such as PISA and PIAAC.[14] While the UK has a less than satisfactory performance in the international comparisons, the emerging evidence suggests that raising the average scores in the test performance, such as numerical skills, literacy and problem-solving skills, would enhance the long-run productivity growth (OECD, 2010).

The comprehensive Leitch Review (2006), and the interim report published in 2005, used a cost benefit model to quantify the impact of upskilling on the UK economy. It finds that

[13] There is a large literature on the links between human capital and productivity growth, as reviewed in BIS (2015). Our review here is not meant to be comprehensive, and chooses to focus on the studies using econometric approaches.
[14] PISA stands for Programme for International Student Assessment, and PICCA stands for Programme for the International Assessment of Adult Competencies.

the benefits of upskilling in the UK would far exceed the costs, with a return of more than £4 for every £1 invested. The Review estimates an overall net benefit of £80 billion over 30 years, equivalent to around £2.5 billion each year, even once the costs of this significant increase in skills is accounted for. The benefits would be both through productivity gains as well as diminished unemployment, further increasing output per year. This model appears to be a rather conservative estimate given the assumption that an individual's productivity is fully reflected in their wage. Wages commonly are set below marginal productivity and thus it is likely that productivity would increase by more than workers' wages.

Bosworth and Leach (2015) update the findings from the Leitch Review and show a similar broad picture, with high skills in the UK at a consistently high level but highlight that the nation lacks intermediate and low skills. The original Review does not try to estimate the impact this has on productivity, rather its focus is on projecting how the UK skill situation will look in 2020, given recent trends. The authors raise the point that the most pressing priority appears to be responding to the large proportion of low skilled individuals in the population. They further state that high levels of skills or qualifications are only two of the important issues that can be considered. Others lie in what skills are held, and how these link to the needs of businesses.

Taken all together, while considering skill levels is important, we need to understand the skills demanded in the economy; otherwise it is problematic to assume that any increase in skills will increase productivity by a fixed amount. Given the clear limitations of this assumption, focusing on skill gaps seems more appropriate.

Skill gaps and productivity

Measuring skill gaps does highlight further empirical issues, though it also provides many new insights. Early work that considers skill gaps found a strong link between skill shortages and productivity growth in the period of the 1980s (Haskel and Martin, 1993)[15]. The authors estimated that if Britain's skill shortages grew by the European Communities average of 1% per annum rather than their observed growth of 2.63% per annum, then productivity growth in

[15] Haskel and Martin (1993) lay out a model for how skill shortages may have an impact on an economy, and test this model using a panel of 81 industries over the years 1980 to 1986. They use information from the CBI Quarterly Industrial Trends survey and responses to its question `over the next quarter do you expect your output to be constrained by a shortage of skilled labour' to determine the impact of skills. Their results show a negative and significant impact of skill shortages on performance, most prominently when skills are lagged by a year (meaning skill shortages from 1980 have most impact on performance in 1981 for example).

the period would have been 5.1% per annum, 0.4% better than that which actually occurred. This not only suggests that the skill shortages are important but shows their variation across countries. Further, this study also found that skill shortages are more influential in reducing productivity in industries where there is a greater concentration of skilled labour. This suggests not only that there may be a differentially large impact by reducing some skill shortages, but also that there may be some form of spillover, where knowledge is shared between workers.

Other studies try to understand the mechanisms through which skills have an impact on productivity by disentangling the links between technology, skill levels, skill gaps and training (Finegold and Soskice 1988; Becker, 1962; Hart, 1991; Greenhalgh, 1993). Finegold and Soskice (1988) argue that the lagging skill levels seen in Britain were ‘both a product and a cause of the nation's poor relative economic performance’. The skill gaps experienced by the UK are seen as a cause, due to poor training leading to an economy that was struggling to adapt to changing working practices and different economic conditions, and also as a consequence, as the education and training within Britain had evolved to meet the needs of the world’s first industrialised nation. This is the idea that the current skills dictate the future skills (Redding,1996; Burdett, 2002), with the nation “trapped in a low-skills equilibrium, in which the majority of enterprises staffed by poorly trained managers and workers produce low-quality goods and services” (Finegold and Soskice, 1988, pp. 22). Although the existing evidence for the UK’s low skill equilibrium trap is weak at its best, it is clear that skill gaps are important in firms’ configurations of future production methods (Nickell and Nicolitsas, 2000). The evidence suggests that reported skill shortages led to decreased short-term R&D expenditure and decreased long-term fixed capital investment.

3.4. Skills and productivity from regional perspectives

Why do skills matter to productivity at regional level?

Further to the above outlined national level impact of skills issues, a growing literature considers the impact of regional factors upon productivity. There is a plethora of evidence of how labour productivity varies markedly across regions, with both human capital and agglomeration reasons appearing to be prime factors. Understanding the way clustering and other factors have an impact on productivity is thus important, so as to understand the interaction of these factors and skills. The regional perspectives on skill shortages are of particular interest given that labour markets are typically viewed as localised for the vast majority of workers, and thus skill gaps for any given job tend to be regional issues (Greenwood,1997, or Faini, 1999).

At the national level, a typical assumption made in analysing skills is that workers have a given level of skills which can be considered predetermined or only influenced by education/training. Quite distinctively, the regional perspective allows us to relax this assumption and opens the opportunity to consider the presence of knowledge exchanges between workers within an area (Fujita and Ogawa, 1982). There are now a several investigations of this, with tacit knowledge being found to be particularly transferable through human interactions (Gertler, 2003) and being dependent upon the firms' existing absorptive capacity (Cohen and Levinthal, 1990). The knowledge is assumed to be spatially bounded due to some form of distance decay, so that knowledge within one area does not have an impact upon workers everywhere. These spillover effects are typically hard to measure, with things like patent citations being used as a form of paper trail to form a tangible measure (Jaffe, Trajtenbery and Henderson, 1993). Here the theoretical literature posits that spatially bounded interactions and proximity to other workers creates learning effects and knowledge spillovers (Ciccone and Hall, 1996; Ciccone, 2002). Thus, high skill levels may play a role in creating even higher skill levels in an area. Or vice versa, skill gaps may reduce the exchange of knowledge within a region and create less opportunity for learning effects, slowing productivity further. This view is based on the concept that there are lower costs to information exchange in areas where there are more skills and thus knowledge is shared between workers and firms, enhancing working practices and productivity.

The evidence on these labour pooling effects and spillovers can be seen in seminal work by Glaeser and Resseger (2010) where the link between city size and productivity is shown not to hold for less skilled metropolitan areas.[16] Metropolitan areas that are highly educated see an increase in productivity which is not observed elsewhere, suggesting that the productivity boost was dependent upon the skills in the area. As the regional knowledge space becomes deprived of required skills in relevant activities, the strength of such learning opportunities and dynamics is much reduced. In this sense, external skills gaps may negatively affect companies regardless

[16] Labour market pooling refers to the phenomenon that workers clustering in a common space. It is considered a source of agglomeration (Overman and Puga, 2009) which benefits businesses by easier access to workers and skills required with lower costs.

of whether these present any internal skill gaps, as they diminish the strength of learning and agglomeration effects across the regional economy.

Another benefit of labour pooling is the ability of regional concentration to improve matching. With a larger pool of workers in an area it is easier for firms to find the appropriate workers with the skills suited for a given job. Thus, labour pooling within a region reduces mismatch and thus increases productivity (Haskel and Martin,1993; Helsley and Strange, 1990; Wheeler, 2001; Combes, Duranton and Gobillon, 2004; Andersson, Burgess and Lane, 2007). A recent study of high growth firms and their wider economic impact showed that in an industry-region where there were more fast-growth incidents in terms of employment, the average employment growth of the rest of the cluster seemed to dwindle, with the UK's peripheral regions in particular suggesting potential competition for skills and talents (Du and Vanino, 2018). Most of these studies only test the theory indirectly through assuming that agglomeration of local economy improves the chance for matching skills, but very little evidence is available to directly test the concept of skill mismatch.

Additional work has further investigated how these agglomeration effects influence job matching and thus productivity, through attempting to capture skill mismatches directly. Abel and Deitz (2015) constructed two direct measures of job matching for college graduates, based on how well their job corresponds to their college education, using information from the 2010 wave of the American Community Survey (ACS). They found that broader and deeper labour markets enable college graduates to find better jobs and earn higher wages. The authors take these higher wages as a sign that the improved match helps to increase productivity and thus enables higher wages to be paid in line with this.

Whether these spillover effects should be expected to be larger in sectors that are more specialised or more diverse is still debated. One idea posits that innovations from a given industry are transferred to others through these spillovers; and thus benefits are stronger when there is industrial diversity. On the other hand, labour markets with many skilled workers in one industry reduce training and hiring costs for firms, but may increase the cost of retaining workers and retaining sensitive firm information.

Evidence

The empirical work on how regional level skills influence productivity has recently been moving its focus from using education levels as a proxy for skills in labour markets to adopting measures of actual skills. Generally, the evidence supports the agglomeration effects of high skills using education as a proxy.

Galindo-Ruedo and Haskel (2005) used the linked microbusiness data (Annual Business Inquiry and the Employer Skills Survey) to show that a firm located in an area with 40% of the population holding a level 4 education was more productive by around 14% than if it was in an area with only 30% holding a level 4 education. This estimate maintains that controlling for the internal stock of skills, those with higher education levels (who hold a level 4 education or above) and who reside or work in the local authority area, increase the productivity of the firm. This finding on the localised spillover effects suggests that there is a market failure. Not enough education will be undertaken if those who receive the education are not the sole recipients of its benefit. Webber et al (2005) support this finding, with higher level skills (NVQ level 4 or above) found to increase productivity for firms within the region, analysing data from the Annual Respondents Database.

Mirroring this, more low education levels population density (those who have not yet obtained NVQ level 1) was found to decrease productivity (Boddy et al (2005); Oguz and Knight (2012). This is important as it shows that it is not just high skill levels that drive firms to higher performance, but the relationship is symmetric, with low skills also serving to hold back firms in some regions.

A word of caution is appropriate, as the authors note, in that the location decision of the firm may not be exogenous, meaning that more productive firms may choose to locate in markets where there are higher skill levels. This is a difficult issue to resolve, especially given the data limitations in this area, and thus the evidence so far should be treated with some caution.

These studies, however, only directly address the supply side of the market for skills. A complete picture of the skill situation can only emerge when the demand for skills is added to the equation. Despite high skill levels being desirable, the gap between skills demanded and skills supplied seems to be a more appropriate measure when considering productivity. High skill levels that do not meet the even higher skill demands in an area would probably cause a decline in productivity. Vice versa, low skill levels, which still exceed the skills required in a production process that is repetitive and simple, may not be expected to decrease productivity, and in fact the low skilled workers may still be overskilled for the job. In other words, we do not know how much skill levels can be increased to drive growth, without understanding the simultaneous demand for skills. This currently makes policy recommendations difficult.

The literature on regional skill gaps and productivity remains sparse. Dickerson (2006) investigated the observed positive link between the low productivity of UK regions and the skill shortages in the regions. To gain a better estimate of the underlying cause of these productivity differences he decomposed the labour productivity differentials into three effects. This disaggregated the industry mix, specialization in the industry and the relatively poor performance of the industry compared to the UK average. Using data from 2004 he showed that much more of the variation came from unproductive sectors in certain regions than was due to the allocation of sectors to regions or to specialization in the region. He further found that these sectoral productivity differences between regions partly resulted from the skills and occupations composition of the employees in the region, thus improving the skill profile of employees in these flagging regions could increase both regional and national productivity, largely driving down the regional differences. Similar results have also been found earlier by Esteban (2000), covering a range of countries, and by Kamarianakis and Le Gallo (2003).

3.5.Firm level skills and productivity

If the mechanisms through which regional level skills influence productivity requires careful thinking and nuanced evidence, the firm-level skill capacity having an impact on firm performance seems much more transparent. Given the asymmetric information for firms when hiring workers, it may not always be possible to find a suitable match in the labour market and some form of skill mismatch may arise, with workers being possibly less skilled than the job requires, or more skilled.

Overall, empirical work linking firm level skill problems and productivity is scant. The lack of suitable data is one of the key reasons. There are generally very few ways to match skill level information to productivity data at the firm level for UK businesses. This is due to a large amount of the firm or plant level productivity data not being associated with skill information, and the skill surveys typically not having any measures of productivity. Thus any work on the topic requires careful and often limited matching of datasets to provide a useful data source for empirical investigation.

In addition, there are also some key empirical challenges. For example, endogeneity issues arise when more productive firms potentially hire better matches, and thus the relationship between these factors needs careful causal estimation. This is extremely important given the large amount of unobserved variation between firms, meaning that panel data are almost certainly required for any accurate estimation. Typically, the tools needed to resolve these issues require a large amount of data for estimation, and thus data limitations again raise concerns. Due to this position, for a substantial time the only evidence available on this issue was indirect, and concerned the impact of education or skills upon wages, with the assumption that wages reflect productivity to a large extent.

Harris et al (2005) matched data from the Annual Respondents Database to the Employer Skills Surveys to provide a strong empirical contribution in this field. Their plant level analysis estimated the relationship between total factor productivity including the percentage of skill gaps within the firm. The results show that plants experiencing skill shortages were less productive than those which did not have any self-reported skill gaps. Restricted by the data available, this study could only investigate a one-period model, and without controlling for endogeneity - that higher performing plants might require higher level skills and thus more skills gaps would appear. In such cases, there might be an underestimate of the productivity effect, which would add strength to this finding.

Similarly, Galindo-Rueda and Haskel (2005) found that firm level skills did raise firm productivity, but only for higher level skills (level 3 and 4 skills). However, in most cases the data limitations prevented the researchers from being able to tackle causality, and thus while there appeared to be a relationship between skills and productivity, they could not say that this ran from skills to productivity, and not vice versa. Furthermore, the nature of small samples made it hard to firmly identify the actual strength of the relationship, and did not allow more discrete splits of the data to investigate which firms in particular gained the most from skills.

Regarding skill deficiencies rather than levels, Bennett and McGuinness (2009) utilised a number of skill related surveys from firms in Northern Ireland to investigate the impact of hard to fill vacancies upon the performance of high-tech firms. These surveys cover IT, mechanical engineering and electronic engineering and thus do not necessarily allow generalisation to the economy as a whole, but still provide interesting results. In their preliminary estimation they found that firms with skill shortages had higher productivity, a result that was contrary to expectations. The authors noted that skill shortages were not observed randomly and thus these results were likely to be biased. To remove any selection issues in the estimation the authors instead used a two-step model introduced originally by Heckman (1979), which allowed them to account for any differences in the characteristics of the firms that experienced skill shortages. The results showed that firms which experienced skill shortages had productivity levels almost 50% higher than the others, before skill shortages were controlled for, and productivity was reduced by 65% when considering these skill shortages. These results indicated that skill shortages did hamper performance in some sectors of NI, completely eradicating the previously held productivity advantage of the best performing high-tech firms in these particular industries. Furthermore, they highlighted the strength of the selection issues that can occur in firm level estimation. While not directly generalisable to the UK as a whole these findings do lay the groundwork for measuring the productivity effect of skill shortages.

A final point worthy of consideration from this perspective is that the majority of the skill shortages are found in relation to experienced professionals. This signals that perhaps expanding Higher Education will not provide the necessary skills to improve performance, and instead training may be a more appropriate government channel. This is further supported by the fact that a lot of firms in the sample were ceasing to hire new graduates given that even after university they did not possess the required skills. Again, whether this finding holds across nations and in other sectors is not yet apparent.

Another industry specific study worthy of note here is by Forth and Mason (2006). It focuses on the ICT sector in the UK, with evidence suggesting that skill shortages have an indirect negative impact upon firm performance, through restricting the adoption of new working practices, even if their direct effect is not seen to be significant. The ability to draw more general conclusions from this finding is limited, and ICT would be likely to be one of the areas where skills would be expected to play an important role.

While the above evidence shows the direct effects of skills and skill gaps on firm performance there may be other routes through which upskilling can have an impact on firms, such as through increased innovation, new product design and increased market share. While these are not of primary concern here it is worth reinforcing the point that skills may have a much wider role in firm development.

Summary of evidence

It is clear that the empirical evidence investigating the impact of skills on productivity is currently underdeveloped. The lack of true panels and the issue of endogeneity causes difficulties in finding rigorous causal estimates in the UK. This creates problems when trying to understand if one workplace is naturally more productive than another, or if skills are causing the observed productivity differences. Furthermore, the few panels that exist are not well suited to matching the more nuanced skill information in the UK.

National comparisons seem to show that skills do play a key role in productivity, but do little to identify which areas of the economy are best upskilled or how skill gaps fit into the current picture. Regional and industry studies seem to show the strongest evidence of links between skills and productivity, with both skill levels and skill shortages seen to have an impact. Again, more work is needed here to fully understand the routes through which this impact occurs and the areas in which skills have the largest effect. Firm level results are the hardest to estimate given the current data limitations, with results yet to show a strong causal and generalizable link between skills and productivity. On the whole it is clear that a move away from education levels towards skills analysis is important for future explanation of patterns and variations, with exploration of skill gaps providing a valuable alternative to the currently existing skill levels evidence about productivity in many areas.

3.6. Entrepreneurial skills and productivity

At least since Schumpeter (1934 [2008]), the role of those who create new ventures (entrepreneurs) has been highlighted as important in stimulating productivity and development. Schumpeter proposed two possible channels in conceptual terms– direct and indirect ones – along which the quality of entrepreneurship may affect productivity.

The first and direct channel relates to the transmission mechanism: the entrepreneur picks up an invention and implements it, turning it into innovation. Here, one needs to explain further what is the specific role that new firms may play compared with established, large companies. Baumol (2010) argues that while large companies may create routines for research and development, and incorporate these as their core activities, these typically lead to incremental innovation, which while significant, does not generate large, discontinuous jumps in productivity. In contrast, breakthrough innovations, as for example in information and telecommunication technology, which generate productivity-enhancing economic waves, typically come from entrepreneurs, with projects like Apple or Microsoft being emblematic.

Baumol's (2010) argument stresses the importance of property rights. Innovation, especially radical innovation (for example: the telegraph, planes, online exchange), is a high-risk high-reward activity. This asymmetry in costs and rewards makes incorporating such innovation into organisational routines a challenge (on that also see Williamson, 1985). The problem is amplified by the fact that those risks are difficult to verify objectively or even assess externally, which means that with respect to innovative entrepreneurship, there is not just risk, but rather uncertainty (Knight, 2009). This implies that contracting out radical innovation, and supporting it with the financial contract, does not necessarily work. We are left with a classic entrepreneurial firm, where decision making is combined with rights to residual value. The owner-manager handles uncertainty but acquires potential high rewards. Note that this goes beyond the original Schumpeter argument which assumed that risk could always be shifted from the entrepreneur to the capitalist (1911 [2008]). It cannot.

The second channel linking entrepreneurship with productivity increases is external. This consists of two different mechanisms. One is that of competitive disruption, which again can be traced back to Schumpeter (1934 [2008]). New firms are especially effective in stimulating other firms to try harder, and/or to eliminate less productive firms from using resources in a suboptimal way by forcing their exit. However, innovative entrepreneurs are able to appropriate only a small fraction of the value created by radical innovation. The rest of it creates spill-over effects from which other companies benefit. Recent empirical evidence of a positive influence on productivity of new firms' entry is provided for example by Brixy (2014).

Entrepreneurial skills: individuals

If there are entrepreneurial skills, their presence will shift the cost-benefit balance between becoming an employee and starting one's own business, in favour of the latter. But what are those skills and are they separate from other types of human capital? Extant research argues and documents that formal education is conducive to entrepreneurship (e.g. Estrin et al., 2016). It develops skills that are associated with creativity and innovation.

However, not all types of formal education are equally useful for entrepreneurship. An important line of argument stems from Lazear (2004). Entrepreneurship is a multi-facetted, multi-task activity and it is a balanced, wide set of skills that is needed. Where more specialised knowledge is required, the owner-manager of the entrepreneurial firm should know enough to ask the right questions, but answers can be found either by hiring people or contracting out.

This implies that multidisciplinary education is significant for entrepreneurship. One specific example of this approach, at the practical educational policy level, is to combine some business competence with technical engineering knowledge, to increase the chances of transition from technical innovations to business implementation in the form of new ventures.

However, the role of formal skills notwithstanding, the main problem with developing entrepreneurship-related skills is that many are tacit, and to a great extent result from practice and/or imitation. Serial entrepreneurship is a well-documented phenomenon; and those who discover their entrepreneurial skills and develop those further continue moving from one new venture project to another (Estrin et al., 2016).

Entrepreneurial skills: neighbourhood effects

The skills may also be acquired from the environment, and those who know other entrepreneurs are more likely to start new companies and to innovate. Therefore, the density of entrepreneurship in an area leads to more start-up activity, generating agglomeration effects. This phenomenon was described and empirically documented by Audretsch and Keilbach (2004a; 2004b; 2005) who coined the term 'entrepreneurship capital', which relates to a local pool of skills and culture that supports entrepreneurship and becomes spatially embedded.

Parallel to this, there is a stream of research that emphasises the role of a diverse pool of knowledge in entrepreneurship. We have already referred to Lazear's (2004) insights, pointing out that the entrepreneur combines different elements of knowledge, shaping these into a new venture project. The term describing this process is 'bricolage' (Baker and Nelson, 1995): with limited resources, the entrepreneur creates a patchwork of resources for the task at hand, including the skills needed for the project.

This in turn implies that local neighbourhoods, characterised by diverse pools of skills, are conducive to entrepreneurship, and also enhance the productivity of those projects as they face resource constraints. Such environments, dense in diverse skills, are typically to be found in big cities, for example London (Smallbone et al., 2010). There is also empirical evidence that diversity in the neighbourhood is associated with entrepreneurship (for the US: Lee et al., 2004; for the UK: Mickiewicz et al., 2017).

At the same time, diversity implies more than just easier access to various combinations of skills which are conducive to entrepreneurship, and especially conducive to its ambitious productivity-enhancing forms. If we return to the link between entrepreneurship, innovation and productivity growth, then skills that enhance creativity and innovation become equally important. Here, diversity may play an indirect but critical role. As discussed in Mickiewicz et al. (2017), it is the experience of social diversity that makes entrepreneurs first more tolerant of diverse ways of thinking, and then leads to openness to new ideas and enhances their creativity. Essentially, innovation is always a social phenomenon; radical business ideas are developed in discussion with others, and therefore require an environment where others are receptive to novelty and are open to thinking outside prevailing mental frameworks.

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5. Ways Forward

A productivity slowdown is not unique to Britain. From advanced market economies like the USA to emerging economies such as China, productivity slowdown is prevalent (OECD, 2015). It is therefore a global challenge to understand the reasons for stalled productivity, both in terms of the common factors across countries and the unique factors for a specific country context.

As reviewed in this report, the UK has two kinds of productivity problems of different natures. The global and national economic forces driven by the financial crisis in 2008 compounded the relatively long-term factors that restricted productivity growth in the previous decades, such as low investment. As has become clear from this review, there is not one single factor that has caused the UK's productivity problems.

In the short-run, the acute decline of global demand and the slow recovery have been partly responsible, but this is also alongside other concerns, such as a curbed business dynamism across regions and industries. However, it is the long-term slow productivity growth that is a real challenge to current understanding. There are many compounding factors contributing to it while at the same time intertwined with each other. Some common factors affect countries globally, such as technological change and globalisation, while they are also influential on national and local conditions. This report has examined the role of skills in driving productivity or otherwise impeding it.

Skills, embedded in human capital, are vital to a firm's productive performance. Skills need to meet the demands of evolving technology, for they not only determine the invention of new technologies, but also determine the adoption and implementation of technologies. Not having the right amount of the right kind of skills demanded in the right workplace at the right time limits productivity growth. The match is not straightforward, because the demand for skills changes with fast-evolving technologies – both of their invention and diffusion. The former is unpredictable while the latter is really a firm-level decision that hinges on other factors. In this regard, skills gaps and skill mismatches are hardly surprising phenomena for an economy experiencing technological advancement. Dealing with skills problems requires forward-looking policies and instruments to reshape skills to meet the new demands.

While the literature has established that a country's skills level determines productivity growth, it does not imply that any increase in skills will lead to productivity gains. Skill gaps however are detrimental to productivity. There is evidence, despite being limited, that skill gaps reduce R&D spending and capital investment, which in theory restrict productivity growth. This means that skill gaps are the most constraining, be they of high, medium or low skills levels.

Regional level studies on skills problems provide more nuanced views by allowing for knowledge spillovers between workers and firms. Studies reveal the benefits of larger labour pooling – better matching between skills demand and supply.

At a firm level, considerable challenges are posed in trying to disentangle the causal relationship between firm skills gaps and productivity, given the issues of measurement, selection and reverse causality. Nevertheless, existing evidence seems to suggest that both skills levels and skills gaps do hamper firm performance both directly, and indirectly through other firm-based activities such as innovation.

There are quite a few lessons to be digested from the knowledge stock we have.

First, while the UK enjoys a superior performance in developing a high-skilled labour force, the lower level skills seem to be slower to develop. Skills gaps can occur at every level, and it is skills gaps that hamper productivity.

Second, there are no systematic well-evidenced views about what causes skills gaps. Ever-evolving technology plays a key role, while information flow and connectivity have an impact. The benefit of agglomeration is a proof of the latter. Better understanding about how technology is likely to develop would influence the prospects for jobs. Although it is not possible to predict precisely when and where new technologies might emerge, nor is it possible to predict how broadly new technologies are likely to be adopted, forward-thinking and intelligence will be crucial for governments and workers to help actively prepare for the changes.

The next question is what can be done once skills gaps are identified. The Leitch Review (2006), which is an authoritative review on the impact of skills on the UK economy, sets its focus on structuring advanced skills towards the `desired' level in the UK, with a demand-led focus, routed with employer engagement and with costs/responsibilities shared between the government, individuals and employers. Vocational training is another area of policy advocated, but the evidence of its impact is still mixed. We also know little about what kind of training is effective and how management training helps with productivity, both being topics which we will investigate in the LBGCBP work plan.

While focusing on the complex relationship between technology, skills and productivity, we also acknowledge the importance of other aspects of the long-term productivity challenge, such as the inter-connection between technology, market structure and market power, and the implications on productivity distribution.

Another aspect that is relevant but less discussed in this context is the condition of international trade and global value chains. Places need to identify their specific advantages over competitors, not only nationally but also globally. What firms in a given place do to a large degree depends on their sector's global value chains, even if these firms do not trade internationally directly themselves. The microstructure of the industries of a nation determine the job opportunities and hence the required skills sets. But this microstructure is not permanent, for it depends on what everyone else does in the global marketplace. Technological changes in any place may alter the global value chains, and consequently tip the balance of the microstructure of a sector in another place. Hence, it is too narrow to only focus on the UK's productivity issues within a sector and in a specific place. A global view is essential for productive analyses. Again, this is one of the key approaches we will be using in the LBGCBP.

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