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The UK's business R&D workforce: skills, sector trends and future challenges

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1. INTRODUCTION

In July 2020, the UK Government published a new 'Research and Development Roadmap' for the UK setting out its aim to strengthen science, research and innovation through increased investment and support for research and development (R&D).[1] The R&D Roadmap described an ambition to improve innovation strengths across all parts of the UK, maintaining the UK's leading position as a global leader in science and innovation. Growing and developing the R&D workforce at all levels was a central concern of the Roadmap, which recognised that having an effective skills pipeline of highly qualified and skilled people to work in the sector is vital for its growth. A year later, in July 2021, the Government's Innovation Strategy set out plans to support UK businesses to innovate and make the UK a 'global innovation hub' by 2035. People are identified as one of the four pillars or objectives crucial to the success of the strategy, with an emphasis placed on the need to provide businesses with the skills they need by ensuring a strong R&D pipeline within the UK and attracting global talent.[2]

In this rapid evidence review, which was commissioned to inform the UK Innovation Strategy, we explore what the available research tells us about the main barriers the UK faces in increasing the research and development (R&D) workforce, with a distinct focus (where possible) on the private (business) sector. We review recent secondary research evidence on the qualifications and wider skills needs of firms undertaking R&D and look at the evidence on the supply of these skills. We also consider the available evidence on the extent of skills mismatch in the business R&D workforce and other problems with the skills pipeline.

[1] https://www.gov.uk/government/publications/uk-research-and-development-roadmap

[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009577/uk-innovation-strategy.pdf

2. DEFINING THE BUSINESS R&D WORKFORCE

The available evidence on definitions of the R&D workforce, in general, is at best patchy. This situation reflects the complexity of R&D activities, the variety of professionals performing them, the range of role types included, particularities of national labour markets and systems of education, as well as data collection practices.

R&D employment is spread across both the public and private sectors. It takes place in business enterprises, higher education institutions, government and private non-profit organisations. The barriers to increasing the R&D workforce within private business[3] is the focus of this literature review, although it should be noted that much of the available evidence focuses on the R&D labour pool more generally rather than on the segment working in businesses specifically. The UK's *general* R&D workforce (i.e., all of those holding the required specialist qualifications and skills regardless of where they are working) is spread across several different sectors and occupations and may also be 'hidden' among other non-R&D professions, as well as within the economically inactive population (STEM Returners, 2020).

The OECD's Frascati Manual (OECD, 2015) sets out an internationally recognised methodology for collecting and using R&D statistics. It defines those who contribute to R&D as 'R&D personnel', or "*people who perform R&D, the highly trained scientists and engineers (researchers), technicians with high levels of technical experience and training, and supporting staff who contribute directly to carrying out R&D projects and activities in R&D-performing statistical units*". Using this definition, R&D personnel are classified into one of three functional groups: researchers, technicians, and supporting staff, depending on the tasks performed and not on their job titles: thus, for example, an employee with researcher job contract/title but performing technical tasks for a specific R&D project should be classified as an R&D 'technician' and not as a 'researcher'. The categories are also not based on qualification level, experience or seniority: a 'researcher' function may be performed as well by a young person new in their career with a doctoral degree as by an older employee with a technical qualification. Although the Frascati methodology is an

[3] One particularity of business R&D (with all the implications it may have terms of the workforce) is that it is a part of more broadly defined 'innovation activities' and is primarily focused on applied research and experimental development, although basic research may also be carried out by enterprises (OECD, 2015).

international standard for measuring R&D employment, it also has its limitations: in the UK, it relies on the sample of about 5,400 businesses[4] and the sampling frame is based on a list of known R&D performers (the 'unknown' firms with no previous R&D record and smaller R&D performers are hard to identify). Therefore, it is likely that smaller firms are under covered by the survey. At the same time, as pointed out by Achs and Audretsch (2003) small firms play an increasing role in innovation in selected industries, challenging the effective measurement of R&D[5].

Other approaches to measuring R&D employment are based on 'R&D related sectors' and 'R&D related occupations'. R&D related sectors refer to those sectors where R&D is the principal activity of a firm[6] (Cardenas-Rubio and Hogarth, 2021). R&D related occupations refer to R&D jobs based on the Standard Occupational Classification - SOC (ONS, 2020e). Based on this classification, R&D employees can be mainly found in major groups of 'professional occupations' and 'associate professional occupations' and are represented by scientists in different branches of knowledge (chemistry, biology and biochemistry, physics, social sciences and humanities), engineers (civil, mechanical, electrical, electronics, design and development, production and processes), higher education teaching professionals, technicians and R&D managers. Generally, R&D employment based on the occupational classification excludes the supporting staff which may be involved in R&D projects. This is an issue, because, as noted in the Frascati Manual, when talking about business R&D we are most likely to talk about applied research (41% of business R&D expenditure in 2019 in the UK) and experimental development (49 %), and less so about pure basic research (10%). Thus, the great bulk of business R&D is directed not at fundamental research (where the role of scientists is essential) but is focused on improving existing products, services and production methods. This 'development' part of R&D is more likely to involve not only scientists but also a broader range of craft, technical and managerial skills, including supporting staff. However, when associated with survey

[4] https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/methodologies/ukbusinessenterpriseresearchanddevelopmentsurveyqmi

[5] There is an extensive discussion of the flaws that R&D data collection may represent using the US example in this book: https://www.nap.edu/catalog/11111/measuring-research-and-development-expenditures-in-the-us-economy

[6] In terms of SIC 2007 classification, it refers to division 72 'Scientific research and development' which is subdivided into two categories:
72.1 Research and experimental development on natural sciences and engineering
72.2 Research and experimental development on social sciences and humanities

data, such as the Labour Force Survey (LFS), the occupational approach provides richer information on the characteristics of R&D workers. Given that the SOC classifies jobs in groups according to the concepts of 'skill level' and 'skill specialisation', it can be argued that R&D occupations provide a good proxy for measuring R&D skills.

Although each approach to defining the general R&D workforce (i.e., functional, sectoral and occupational) has its flaws, using them in combination provides useful insights.

3. THE UK'S BUSINESS R&D WORKFORCE: AN OVERVIEW

The main picture that emerges from the available statistics on the general R&D workforce in the UK is that the last two decades, and particularly the post-recession (GFC) period, were marked by rapid employment growth. Using Labour Force Survey (LFS) data and taking an occupational approach, Cardenas-Rubio & Hogarth (2021)[7] estimate that, overall, the number of R&D workers across both the public and private sectors increased by 49.5 per cent, from 686,000 in 2001 to 1,026,000 people in 2019, with around 6 per cent of these workers being self-employed.

The same growth trend is observable when looking at R&D employment in businesses specifically, applying a functional approach. The number of individuals employed by UK businesses in R&D tasks passed a quarter of a million full time equivalent (FTE) jobs for the first time in 2018 and reached 263,000 FTEs in 2019 (ONS, 2020b). This represents 0.84 per cent of total employment, meaning that amongst the employed population, about one in 120 is directly involved in business R&D projects. When compared with total public and private R&D employment[8], the share of business R&D is about 55 per cent, with the second largest employer being the Higher Education sector (at around 40 per cent).

Figure 1 illustrates an interesting dynamic of business R&D employment in the UK over three and a half decades, marked by three different periods. From 1986 to 1997,

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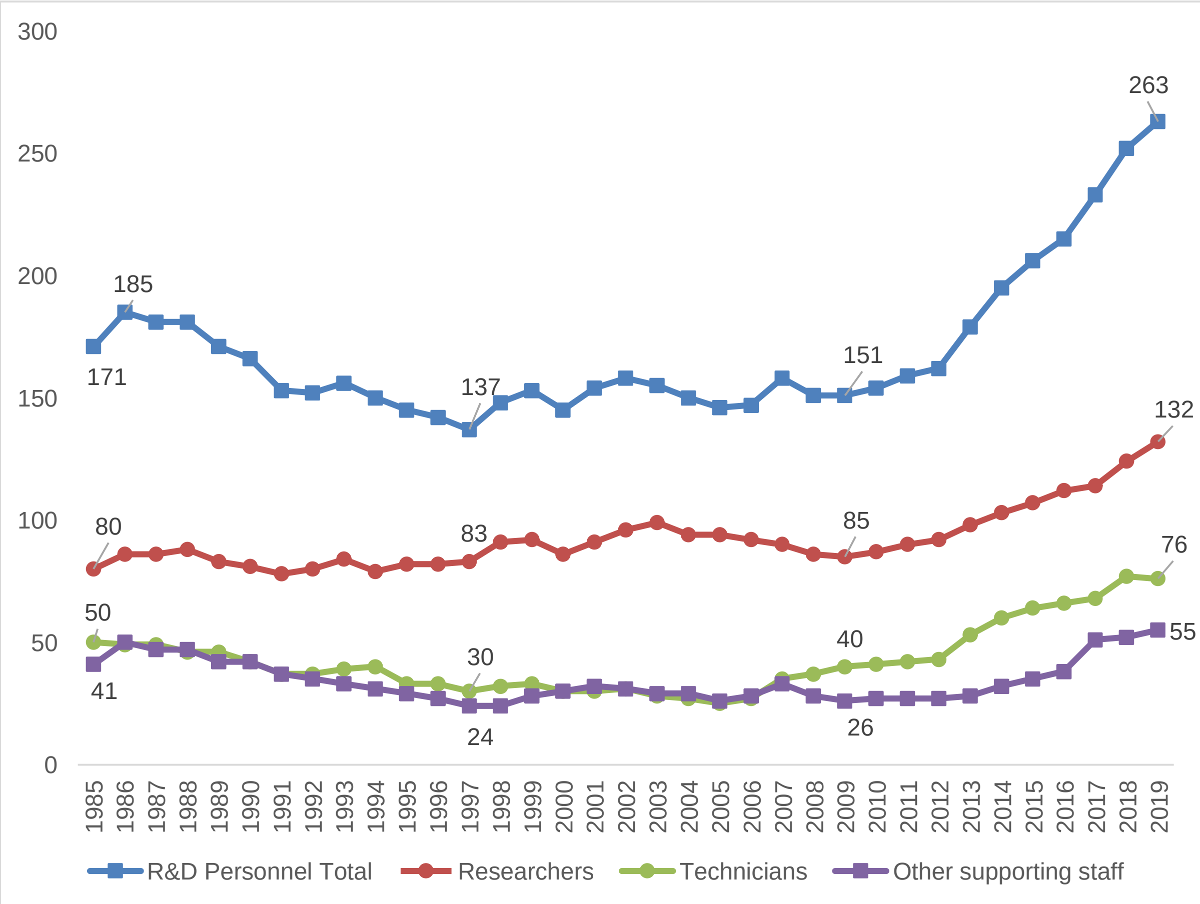
[7] The authors in their estimations use SOC 2010, and, amongst the technicians' group, include only laboratory technicians (excluding such occupations as engineering technicians, planning process and production technicians and science, engineering & production technicians). Another category excluded from the analysis is 'programmers and software development professionals'.

[8] Total R&D personnel across four institutional sectors (business enterprises, higher education, government and private non-profit organisations) represent about 1.54 per cent of total employment (Eurostat, 2020).

employment decreased by almost 50,000 from 185,000 to 137,000. This was driven by a decrease in the number of technicians and other supporting staff jobs, while the number of employed R&D researchers remained relatively stable. The period from 1998 to 2008 was a period of relative flatness followed by a period of continuous growth starting from 2009. More recently, in ten years between 2009 to 2019, business R&D personnel increased by more than 110,000 (74%). This increase covered all three categories of business R&D personnel.

Figure 1. Business R&D personnel by category in the UK (thousands of FTEs)

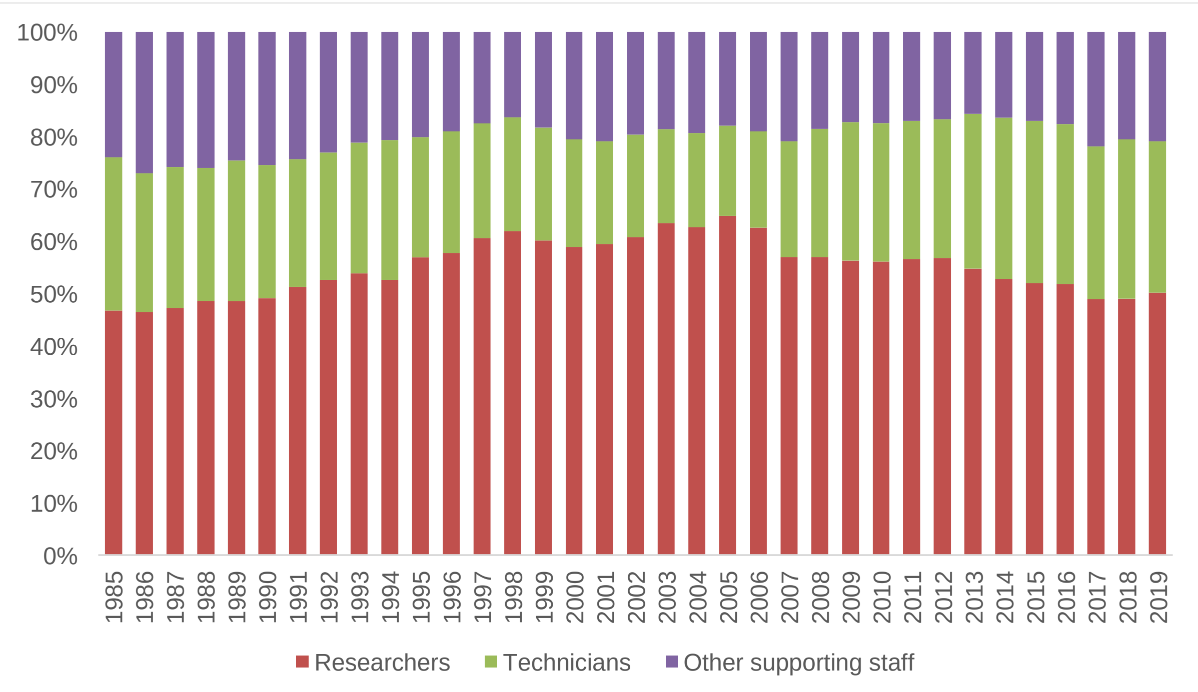


Source: ONS BERD (ONS, 2020c)

This growth in R&D employment took place in the context of a general rise in total employment in the UK labour market (ONS, 2019). However, structurally, the share of business R&D employment in total employment increased by almost 0.3 per cent: from 0.55 per cent in 2010 to 0.84 in 2019. There has also been a gradual shift in the functional structure of R&D employment over the past 15 years (ONS, 2019). Figure 2 shows that the share of researchers (scientists and engineers) in business R&D decreased from its highest level of 64 per cent in 2005 to 50 per cent in 2019 while the share of technicians increased from 17 per cent in 2005 to 29 per cent in 2019. This trend is also supported by evidence from a ManpowerGroup study on talent shortages which suggests that technician, engineering and IT professionals roles were in the top-ten of the most 'in-demand' roles in 2019, with researchers falling out of this group (Manpower Group, 2020).

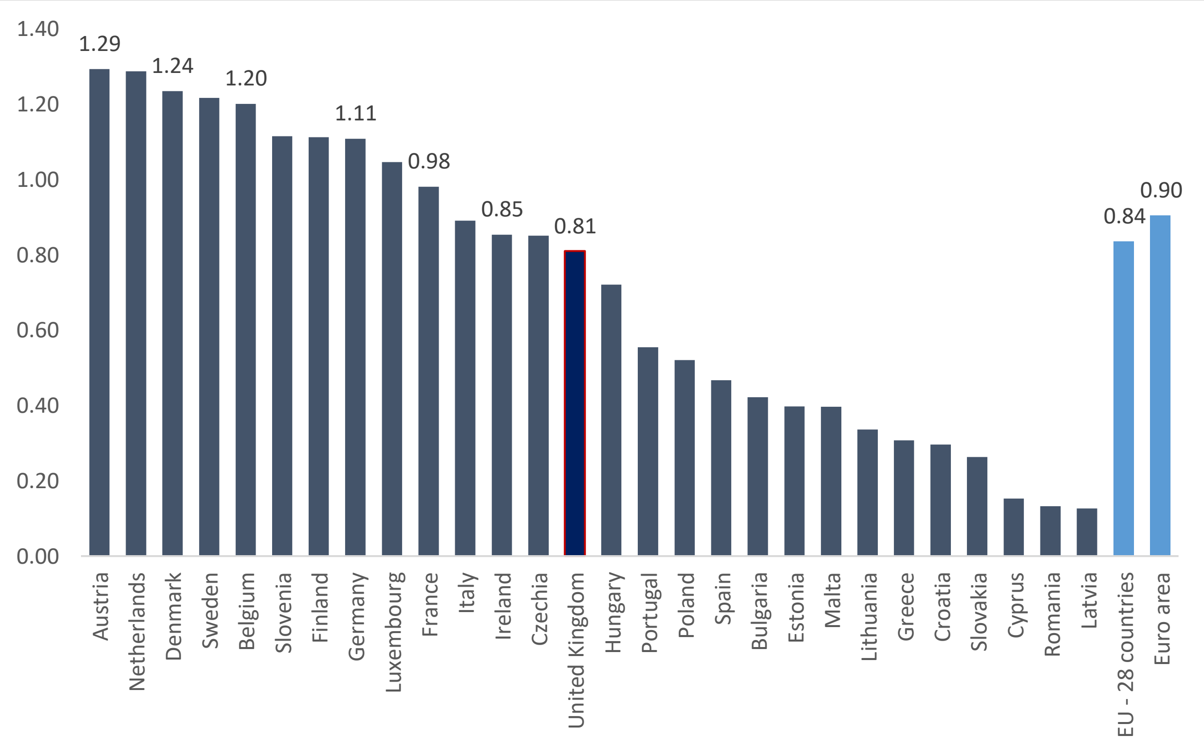
Taking a comparative view, the level of business R&D employment is broadly in line with the EU-28 average: 0.84 of the employed population (or 0.81 per cent of the economically active population). However, despite the increase in R&D personnel in the UK during recent years, these numbers are persistently lower when compared to several other of the UK's competitor countries in Europe, including for example France, Germany, Netherlands and Austria (Figure 3). According to the latest available data, the share of business R&D employment in the labour force in the UK was also lower than in the USA by around 0.2 per cent. When compared to the OECD business R&D champion – South Korea – the difference is around 0.6 per cent (OECD, 2020).

Figure 2. Relative structure of business R&D personnel in the UK (per cent of total)



Source: ONS BERD (ONS, 2020c)

Figure 3. Business R&D personnel in the EU by country (% of active population), 2019



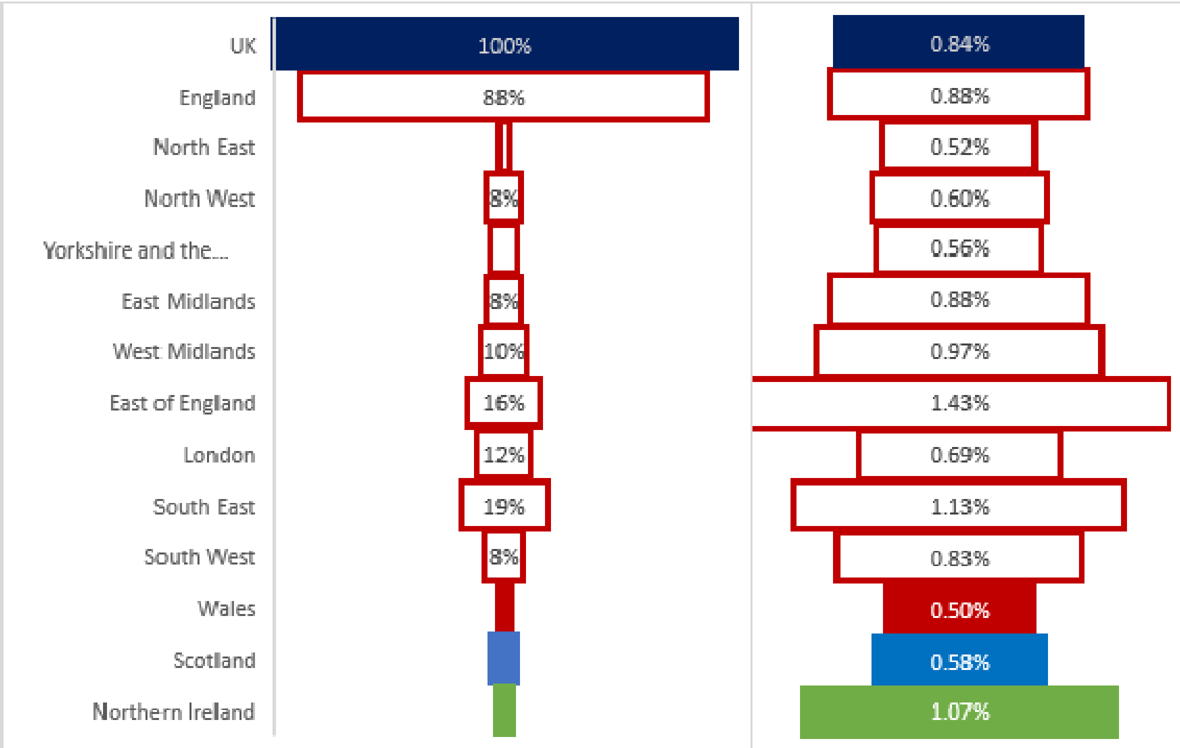
Note: numerator in full-time equivalent (FTE)

Sources: Eurostat (2020); data for the UK updated with the latest data (ONS, 2020a, 2020d)

3.1 Business R&D employment in the UK by location and sector

Turning back to look at business R&D employment in the UK context, according to R&D personnel statistics, in 2019 88 per cent of business R&D workers were concentrated in England (Figure 4). The South East and East of England dominate the geography of R&D expenditure and jobs in the UK. These two regions accounted for 35 per cent of business R&D personnel in 2019, although this has decreased from 43 per cent in 2011 (ONS, 2012, 2020d). London, the West Midlands and the North West have seen their percentage of business R&D employment increase over this time. With just 2 per cent of business R&D employment, the North East has the lowest number of R&D workers. Among devolved nations, Scotland comes at the top with 6 per cent of total UK business R&D personnel, while Northern Ireland and Wales account for 3 per cent each. However, when looking at the number of R&D workers per employee within a region (i.e., R&D employment density), Northern Ireland has the highest density while Wales demonstrates the lowest density of R&D workers amongst all UK regions. There are, therefore, significant regional differences which have implications for the current 'levelling up' agenda.

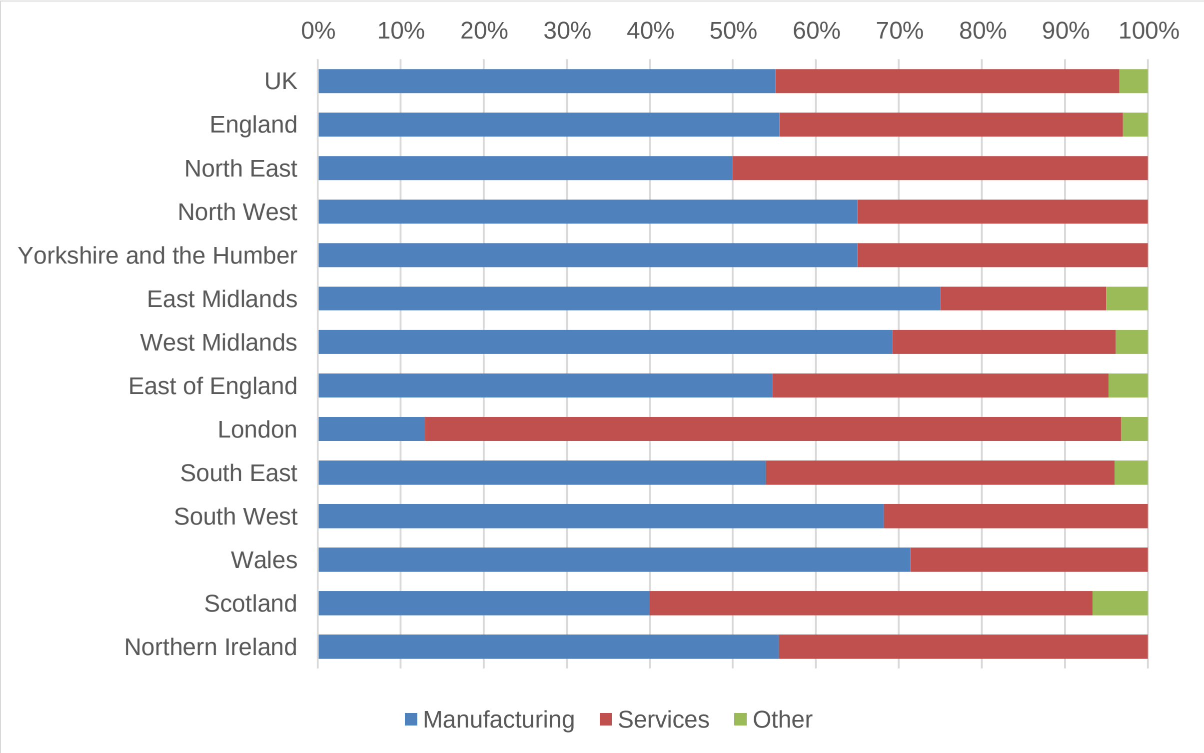
Figure 4. UK Business R&D personnel by region 2019: percentage of total UK business R&D employment, and percentage of employment in region



Source: authors' calculations based on ONS BERD (ONS, 2020c) and APS (ONS, 2020a)

Looking at the broad sectoral breakdown of R&D employment, R&D in manufacturing still occupies more workers than R&D in services in the UK. However, the global trend of the shift to services is also impacting the R&D workforce (OECD, 2017b). Thus, the percentage of business R&D personnel employed in the manufacturing sector in the UK decreased from 61 per cent in 2013 to 55 per cent in 2019 (ONS, 2015, 2020c). However, as Figure 5 shows, this changes significantly from one region to another. This trend also reflects the geographic distribution of R&D personnel discussed above.

Figure 5. Business R&D personnel in manufacturing and services by region, 2019



Source: authors' calculations based on ONS BERD (ONS, 2020c)

As well as being influenced by global trends towards an increasing service sector, the increase in the service R&D workforce in the UK is also likely to be related to the increasing 'servitisation' of manufacturing over recent years. Servitisation refers to 'the process of creating additional value through adding more services to products' which has become a growing characteristic amongst global firms (Cui and Liu, 2018), a trend driven in part by the emergence of new information and communications technologies. Recent research has argued that 'services have never been as tradable as today', as reflected in the growing international trade in services (Du and Shepotilo, 2021). The UK is the largest services exporter in Europe and the second largest (after the US) worldwide. An increase in the R&D workforce in services is perhaps one factor explaining the high position of the UK in terms of the trade of services.

R&D activities take place in a range of different sub-sectors across both manufacturing and services in the UK, including life sciences, aerospace, automotive, technology, energy and the creative industries. However, a small set of sectors have a large share of employment.

The three most R&D intensive sectors employed one-third of business R&D personnel in 2019. *Pharmaceuticals* with 11 per cent of business R&D personnel in 2019 remains the main employer of business R&D personnel in the UK. This sector also drives the geographic distribution of R&D business personnel, with around half of pharmaceutical businesses being located in the East and South East of England (ABPI, 2019). The sector *Miscellaneous business activities & technical testing and analysis* has seen impressive growth in employment over recent years and accounts for 10 per cent of UK business R&D personnel. *Software development* (accounting for 9 per cent of UK R&D personnel) is also a growing sector. Other spheres with an important rise both in absolute numbers and percentages were *Motor vehicles and parts*, *R&D service*s and *Construction* (Table 1). The way the workforce is split by functional category also varies by sector, reflecting specificities: thus, in some industries, the share of researchers is considerably higher than 50 per cent - e.g., software development (65%), aerospace (67%), precision instruments and optical products (70%), electrical equipment (75%). In others, the shares of technicians and other supporting staff are more important than on average: e.g., pharmaceuticals (28% and 34% respectively), miscellaneous business activities and technical testing and analysis (52% and 11%), machinery and equipment (33% and 25%), construction (17% and 67%).

R&D performed in businesses in the UK is concentrated in a relatively small number of sectors, and mainly in larger businesses (although, as previously mentioned, there are issues with measurement here). In 2019, the top 100 enterprise groups[9] contributed to almost half (47 per cent) of business R&D expenditure and employed one-third of business R&D personnel. Interestingly, while more than 70 per cent of business R&D expenditure is realised by large businesses of over 400 employees, their share in business R&D employment is only 56 per cent. Indeed, 25 per cent of business R&D employment is made up by small and medium-sized businesses of less than 99 employees and the other 19 per cent by businesses of 100 to 399 employees. In terms of business ownership, the share of R&D performed by UK-owned businesses increased to 52 per cent in 2019 (£13.6 billion), this followed eight years when the share of R&D by UK-owned businesses was 50 per cent or less (ONS, 2020d).

[9] An Enterprise Group consists of all the enterprises under the control of the same owner.

Table 1. Business R&D employment by product group, thousand FTEs *Source: ONS BERD (ONS, 2015, 2020d)*

	2019				2013			
	Total business R&D	Researchers	Technicians	Other supporting staff	Total business R&D	Researchers	Technicians	Other supporting staff
TOTAL	**263**	**132**	**76**	**55**	**178**	**98**	**52**	**28**
Pharmaceuticals	**29**	12	8	10	**23**	10	5	9
Miscellaneous business activities; Technical testing and analysis	**27**	11	14	3	**15**	7	7	1
Software development*	**23**	15	6	2				
Motor vehicles and parts	**22**	11	7	5	**14**	7	4	3
Computer programming and information service activities	**19**	9	7	3	**27**	14	10	2
Research and development services	**19**	10	2	7	**11**	8	2	1
Aerospace	**15**	10	4	1	**15**	10	4	1
Machinery and equipment	**12**	5	4	3	**11**	6	3	2
Precision instruments and optical products; photographic equipment	**10**	7	2	1	**7**	4	2	1
Telecommunications	**10**	5	3	2	**9**	6	2	-
Chemicals and chemical products	**9**	5	4	1	**7**	3	3	1
Electrical equipment	**8**	6	1	1	**5**	4	1	-
Construction	**6**	1	1	4	**1**	1	-	-
Consumer electronics and communication equipment	**6**	6	-	-	**7**	5	1	-
Wholesale and retail trade	**6**	2	2	2	**2**	1	1	1
Fabricated metal products except machinery and equipment	**5**	2	1	2	**2**	1	1	1
Food products and beverages; Tobacco products	**5**	..	..	2	**4**	2	2	1
Other manufactured goods	**4**	2	1	1	**3**	1	2	1
Public administration	**4**	1	2	1	**1**	1	-	-
Shipbuilding	**4**	..	..	-	**2**	1	-	-
Computers and peripheral equipment	**3**	3	-	-	**1**	1	-	-
Pulp, paper and paper products; Printing; Wood and straw products	**3**	-	-	2	**1**	-	-	-
Other non-metallic mineral products	**2**	1	1	-	**1**	1	-	-
Rubber and plastic products	**2**	1	1	1	**1**	1	1	-
Agriculture, hunting and forestry; Fishing	**1**	-	-	-	**1**	-	-	-
Casting of iron and steel	**1**	-	-	1	**-**	-	-	-
Electricity, gas and water supply; Waste management **	**1**	1	-	-	**1**	-	-	-
Extractive Industries	**1**	-	-	-	**1**	1	-	-
Non-ferrous metals	**1**	-	-	1	**1**	-	-	-
Other transport equipment	**1**	-	-	-	**1**	-	-	-
Refined petroleum products and coke oven products	**1**	-	-	-	**-**	-	-	-
Textiles, clothing and leather products	**1**	-	-	-	**1**	-	-	-
Transport and storage, incl. postal and courier activities	**1**	1	-	-	**-**	-	-	-

In sum, as pointed out by Toner (2011), R&D employment and demand for skills are not uniform across the economy, sectors, regions, and firm sizes, and reflect the marked variations in the propensity and intensity of innovation.

3.2 R&D workforce characteristics

Turning to look at the characteristics of the UK's R&D workforce, the available evidence is focused on the R&D workforce generally (working in both the public and private sectors) rather than looking at business R&D specifically. This evidence shows that there are no major differences in terms of the age distribution between R&D workers and non-R&D workers in the UK. The average age of an R&D worker has been estimated to be 40.8 years compared to 40.3 years for those in non-R&D sectors. However, it appears that the general R&D sector attracts a relatively larger group of young professionals in their late 20s and early 30s, although it is unclear if these young people remain in R&D occupations in the longer term (Cardenas-Rubio and Hogarth, 2021).

As might be expected, the qualification levels of R&D workers are high compared to those in non-R&D occupations, and this has been increasing recently. Thus, in 2019 79 per cent of workers in R&D occupations were qualified to NVQ Level 4 or higher. This is 35 per cent higher than in non-R&D occupations. The same can be said taking an R&D sector perspective: 85 per cent of those employed in the general R&D sector hold qualifications at NVQ Level 4 or higher (Cardenas-Rubio and Hogarth, 2021). This relatively high level of qualifications is related to the dependence of the sector on high-level science, technology, engineering and mathematics (STEM) skills (more discussion of employer skill needs follows in section 4 below).

Gender imbalances also exist in the UK's R&D workforce. The percentage of male workers in the general R&D sector in 2019 was 57 per cent which is higher than found in the rest of the country's workforce. According to OECD data, women researchers represent about 22 per cent of the total number of researchers employed in R&D projects by businesses in the UK.[10] This is just under the OECD average (Pollitzer et al., 2018; OECD, 2020). This gender imbalance is confirmed by evidence provided by professional bodies, with some

[10] Higher-education and Government sector demonstrate a better balance: women researchers account for around 45 and 38 per cent of total researchers in each sector respectively according to OECD data.

sub-sectors more affected than others. For example, making up just 12 per cent of the engineering workforce, women remain markedly underrepresented in engineering (EngineeringUK, 2018b). These patterns are linked to gender differentials in educational choices in higher education. It is well-known that women are underrepresented in STEM degree subjects; only 42 per cent of female undergraduates in England enrolled in a science subject area in 2017/18 compared with 52 per cent of male undergraduates (HESA, 2019). These gender imbalances arise from and are apparent in earlier educational choices made at schools and colleges, with females receiving only 43 per cent of awarded STEM A-levels in 2018 (IFS, 2018). In addition, an even more prominent gender gap is apparent in vocational education (McDool and Morris, 2020).

There is not much difference overall in the ethnic group profile of the general R&D sector's workforce compared with other sectors. However, there is evidence of under-representation in some areas, for example, engineering and technology graduates from a BAME background are less likely to be employed within the engineering sector or to be in engineering occupations than their white counterparts (Engineering UK, 2019). In addition, the general R&D workforce in the UK is much more likely to be either born abroad or have a nationality other than that of the UK (Cardenas-Rubio and Hogarth, 2021). The R&D labour market in the UK, therefore, is very much an international one. This is especially apparent in some sectors and occupations. For example, the biopharmaceutical and medical technology industry has a significant reliance on overseas workers in professional and associate professional and technical occupations (SIP, 2020). In professional occupations in this industry, overseas workers make up 31 per cent of the workforce, with the largest part originating from the EU (14 per cent), followed by Asia (11 per cent).

4. SKILL NEEDS IN THE BUSINESS R&D WORKFORCE

As noted above, the educational attainment of the general R&D workforce is relatively high when compared to the rest of the UK workforce, and the sector depends on high level skills. The entry-level qualification requirement for a high percentage of R&D occupations is Level 4 (degree) and above, and the qualification level of the workforce has been rising in recent years (Table 2).

Table 2. R&D Workforce Qualification Requirements (% of occupations)

	R&D Occupations		Non-R&D Occupations	
Qualification	2006	2019	2006	2019
NVQ Level 4 and above	71	79	31	44
NVQ Level 3	11	9	16	17
Trade Apprenticeships	6	3	6	3
NVQ Level 2	4	5	16	15
Below NVQ Level 2	2	2	13	9
Other qualifications	4	2	9	7
No qualifications	1	1	9	5
Total	100	100	100	100

Source: Cardenas-Rubio and Hogarth (2021)

A similar trend is observed when looking at sector level R&D employment, where around half of employment was accounted for by occupations requiring HE level skills in 2019 (ONS 2020). Working in an R&D role typically requires a degree level or equivalent qualification in a relevant subject, with many roles requiring a postgraduate qualification due to the in-depth academic and technical knowledge required.

It is not only formal STEM-related qualifications and scientific knowledge that are important in R&D roles, however. Several commentators have observed that human capital - or the combination of skills, competencies, knowledge, and experience possessed by individuals is vital to business innovation (Capozza and Divella, 2019). Human capital is important in the creation, development, and commercialisation of ideas, and therefore is crucial to R&D. It is also positively linked to a firm's 'absorptive capacity' (the ability to recognise, assimilate and use external knowledge) as well as to the identification and exploitation of new technologies (McGuirk and Jordan, 2012; Leiponen, 2005; Lundvall 2008).

R&D roles are diverse, and as such, they encompass a wide range of skills and competencies. Some of the skills required are generic, and others are highly job-specific, depending on the nature of the job function. Research over the last decade has shown that several generic skills such as IT literacy, academic skills, communication skills, management and leadership skills, creative and problem-solving skills are all commonly required in general R&D roles (OECD, 2011). A recent report by Emsi (2018) used Job Postings Analytics (JPA) to look in-depth at the types of hard and soft skills employers were seeking, analysing 1.33 million job advertisements in the UK between November 2017 to October 2018. The top soft skills required were leadership, learning, project management, and literacy. The top hard skills were management, engineering, testing, communications and information security. There was considerable variation in requirements when the focus was shifted to specific occupational areas, but noticeably, management skills emerged across all occupations as important, being the most sought-after skill in six out of the eight occupational clusters identified, and second most important in two others. Other research has shown that social skills, whilst being relevant to many job positions, are particularly important in R&D roles due to the nature of the demands and outcomes expected by employers. Research by Yun and Lee (2017) for example, found that abilities in knowledge sharing have a significant effect on job performance and that these abilities depend on strong social skills, highlighting the role of personal engagement in the innovation process. Creative skills are also important in R&D in terms of the development of concepts from ideas to useful products, processes, or services (Estrin et al., 2009; Hunter et al., 2012).

A study by Gupta et al. (2016) reports that private R&D firms generally attach importance to skills and knowledge centred on accelerating product development, Total Quality Management, understanding customer needs, monitoring multiple R&D projects, building cross-sectional teams, and developing technology commercialisation capabilities. Highly effective R&D firms tend to have a mix of skills and knowledge capabilities that foster the conversion of research ideas into viable new products, quick learning from past product development experiences, promotion of profitable strategic collaborations, and cross-functional integration and synergies. Having the right mix of human capital can act as a distinguishing factor between low performing and high performing firms. However, these skills and qualities cannot simply be instantly recruited from the labour market in new recruits from education. A combination of good human resource management practices, training and professional career development activities are also vital to ensure that they are continually developed.

Gonzalez et al. (2016) suggest that investment in workforce training can enhance R&D performance and a higher absorptive capacity in firms. This positive link is further buttressed in a study by Sung and Choi (2018) where findings suggest that investment in workforce training and development does not only enhance firm innovation through idea generation and concept development from newly acquired knowledge but can also lead to the development of a positively motivated workforce and increased competencies. Investment in both on-the-job and off-the-job training to ensure employee knowledge and skills are continuously updated can boost creativity and innovation (Boadu et al., 2018). Also, a firm's ability to assimilate and effectively integrate external knowledge for R&D is largely dependent on the firm's practices and employee skills (Kafouros et al., 2020). Hence, a highly trained workforce, due to their knowledge and competence level are better equipped to participate in collaborative innovation strategies as well as to derive benefits associated with such strategies. Furthermore, recent research has also shown that other aspects of human resource management are important, particularly employee involvement and support, and performance management. A study by Felstead et al for example shows that these practices are strongly associated with employees' 'willingness and ability to come up with innovative ideas' (Felstead et al, 2020).

5. THE R&D SKILLS PIPELINE IN THE UK

In this review so far, we have looked at the evidence on the characteristics of the UK's current business R&D workforce, and at the literature on the skills needed for effective R&D performance in firms. We now turn to consider what the evidence tells us about whether the UK's business R&D skills pipeline is working effectively in delivering these.

5.1 Is there an R&D skills shortage?

For several years, research from a range of sources has pointed to the existence of a shortage of high-level STEM skills in the UK labour force. Given the centrality of STEM skills for many R&D roles, this is clearly a potential concern for the sector.

The UK's STEM skills shortage has been highlighted in a range of different employer surveys. Data from the Department for Education's UK Employer Skills Survey (ESS) over time shows that vacancies for professionals working in science, research, engineering and technology occupations are 'harder to fill' than other occupations due to problems finding people with the right skills (Winterbotham et al., 2020). A survey carried out in 2018 of 400

HR directors and decision-makers in businesses that rely on staff with STEM skills, found that seven in 10 employers said they had found it difficult to hire staff with the required skills in the previous 12 months (STEM Learning, 2018). The same survey found that slightly over three-quarters (76%) of firms said that they were being forced to inflate salaries to attract appropriately skilled workers, while nearly half (48%) said that they were having to look abroad to adequately fill positions. The CBI has also reported that employers in STEM-based industries consistently report a lack of suitably qualified graduates, with 40 per cent of employers reporting a shortage of STEM graduates as being a key barrier in recruiting appropriate staff in 2017 (CBI, 2017). In addition, looking at innovation more generally, the recent UK Innovation Survey (UKIS) suggested that a lack of qualified personnel was reported by companies as one of the key barriers to investing in innovation 2018 (UKIS, 2020).

However, the evidence on the existence of a skills shortage in business R&D is not all one-sided, rather it is mixed and incomplete. This in part reflects the complex, multidimensional and dynamic nature of skill mismatches as a phenomenon (CEDEFOP, 2018), the different methods of measurement (labour surveys, qualitative analysis, quantitative data on wages, educational attainment and employment, analysis of published vacancies, etc.), and also the level of analysis used – whether this is considered at national, regional and sectoral level.

Some recent studies in fact suggest that, at the national level in the UK, at present, the supply of high-level skills *is* sufficient to keep up with demand in the R&D sector (Cardenas-Rubio & Hogarth, 2021; OECD, 2017a, 2017b, 2019). Crucially, this supply depends on a combination of workers from abroad as well as from within the UK education system, as we have seen above. In addition, the UK has a good track record in terms of producing individuals with high-level skills, and the proportion of people with education to tertiary level and share of doctorate holders is higher than on average in the OECD countries (OECD 2017b, 2019). The UK has also increased the number of STEM graduates it produces over the past few years (BEIS, 2017). Just under half of undergraduates in the UK now study STEM subjects. Research also shows that the number of people who study STEM degrees has been increasing faster than for non-science subjects. This is true at postgraduate and undergraduate levels, with particular growth in the number of computer science and biological science students. The growing popularity of STEM at the degree level partly reflects changes made in secondary level education at GCSE-level with an increase in students taking single science subjects (ABPI, 2021; Cardenas-Rubio and Hogarth, 2021; HESA, 2020).

Research published a few years ago by the UK Commission for Employment and Skills (UKCES) also questioned the existence of a general nationwide STEM skills shortage in the UK (Bosworth et al, 2013, UKCES, 2013). This work involved a thorough analysis of supply and demand for STEM skills and found no evidence of *overall* undersupply in the UK labour market of individuals with high level STEM skills. Instead, the research pointed to an issue of ‘concentrated pockets’ of skills shortages in specific skills areas. Skill shortages were most marked at the time among engineering professionals, followed by IT professionals and then by science, engineering and production technicians. The UKCES’ Strategic Skills Audit (UKCES, 2010) published a few years earlier and based on in-depth analysis of skills supply and demand also highlighted skills deficiencies at intermediate/technician level in several R&D sectors including chemicals, life sciences and pharmaceutical and automotive engineering.

Several other studies since have also pointed to the existence of pockets of imbalance between demand and supply for specific R&D jobs at sectoral and local levels. Research by the National Audit Office (NAO, 2018) indicates that it is more accurate to talk of the UK having a *mismatch* of STEM skills rather than a shortage, where there is 'misalignment between the skills needed and those available in the labour pool'. Their research indicates too that particular skills shortages exist at the technician level, while on the other hand, an oversupply exists in areas with less demand (i.e., the biological sciences).

Other evidence also suggests that specific skills are in short supply, especially those related to IT, engineering, and medicine (Gambin et al., 2016). A 2018 report by the Royal Academy of Engineering for example draws attention to the widening engineering skills gap in the UK. It anticipates an annual shortfall of up to 59,000 engineering graduates and technicians in 2024 (a forecast which may be slightly lower if more graduating engineers take up job roles in the profession) (Royal Academy of Engineering, 2018; Engineering UK, 2018). Skills issues are already evident in the software engineering sector, where according to a 2016 report, 72 per cent of large firms are already experiencing skills gaps within the workforce and access to a limited digital talent pool (BIS, 2016). Industry bodies also point to problems with skills supply in R&D roles in other sectors such as pharmaceuticals where research suggests there are shortages for different disciplines throughout the skills pipeline to postgraduate level (ABPI, 2019). It is also notable that an extensive number of R&D related occupations are also identified in the Migration Advisory Committee's list of shortage occupations. This list includes biological scientists and biochemists, chemical scientists in the nuclear industry, physical scientists in the oil and gas industry, engineers in all branches, ICT professionals in different branches (programmers and software developers, web designers, IT business analysts and system designers, etc) and graphic designers (Home Office, 2021).

Research also shows that skills shortages, as well as varying by sector and occupation, do not present uniformly across the whole of the UK. As a report by Emsi (2018) summarises, although much discussion is couched in general statements about the UK's "national" STEM skills shortage, the problem is more geographically nuanced. It is more accurate to see the issue as a number of different STEM skills shortages at local levels throughout the country. Some places in the UK currently have a very low demand for STEM jobs. London and the South East account for over a quarter of all R&D jobs, but in contrast the North East accounts for 4 per cent. Bosworth et al (2013) pointed out that London has acted historically as a magnet for STEM qualified graduates, creating difficulties for employers in neighbouring regions. More recent analysis shows that between 2015 and 2019 there was little change in the regional distribution of R&D employment in the UK (Cardenas-Rubio and Hogarth, 2021).

Table 3 below summarises the findings of some key recent reports on R&D skills mismatches, showing the complexity of the problem when more in-depth analysis is undertaken.

Table 3. R&D skills 'pinch points' in the UK

Source	Geography/ Focus area	Approach/Data	Insights/'Pinch points'
OECD (2017b) OECD (2019)	UK, England / skills mismatch (overall)	Sectoral and occupational approach, skills typology OECD Skills for Jobs database providing quantitative measures of skill shortage and surplus based on quantitative information on wages, employment and talent pressure; Last available data 2015 – accessible via interactive web page: https://www.oecdskillsforjobsdatabase.org/ Measures are for the UK as a whole and by region.	At national level, the UK performs relatively well in aligning the skills of its workforce to the needs of the labour market. The share of persons with tertiary education and share of doctorate holders in the UK are higher than on average in the OECD countries. On the other hand, *demand for higher-level skills fall short of supply*, with only a third of jobs requiring a tertiary education, while 43 per cent of adults have this level of qualification. However, there is evidence of skill imbalances in R&D related occupations: *Evidence of shortages in STEM*, particularly in the following knowledge domains: Education and training; Engineering and Technology, Health Services, Mathematics and Science. Needs in engineering and Technology are particularly acute in Yorkshire and the Humber, West Midlands, South East and Scotland; needs in Health services – in East of England and Wales. *Evidence of shortages in complex problem solving, technical and systems skills and reasoning, spatial and visual abilities.*
CEDEFOP (2018)	EU-28 / skills mismatch (overall)	Occupational approach, skills typology / European Skills and Jobs survey (ESJS)	Recently the EU labour market has undergone structural transformation marked by the following trends: declining manufacturing share of employment, *increasing demand for higher-level skills, professional, scientific and technical services*, crowding-out of middle-skill jobs. These trends are expected to continue in the future. Technological changes affect skill profiles making them outdated rapidly; the most affected occupations are ICT professionals and associate professionals. There is an increasing need for digital skills among other occupations. *High-demand future jobs are more likely to rely on advanced cognitive skills* such as problem solving, learning to learn, advanced literacy and numeracy and ICT skills. But *socioemotional skills*, such as communication, planning and customer service skills, become increasingly important. Evidence of high incidence of underutilisation of skills (overskilling) in the EU countries.

Winterbotham et al. (2020)	UK / skills mismatch (overall)	Occupational approach, skills typology / Employer Skills Survey (ESS) 2019, Scotland excluded	*Evidence of skill-shortage vacancy density above average for occupational group of 'Professionals'* which contribute to an important part of R&D workforce (33 per cent of vacancies were hard to fill), although the highest skill-shortage concerns non-RD occupations in skilled trades. The most common reasons of these shortages were lack of specialist skills or knowledge (74 per cent of respondents), solving complex problems (40 per cent) and knowledge of products and services offered (29 per cent). The most common consequence of skill-shortage vacancies was increase in workload of other staff.
Cardenas-Rubio and Hogarth (2021)	UK / R&D workforce	Sectoral and occupational approach / Labour Force Survey, Annual survey of Hours and Earnings	Wage growth analysis suggests that wage growth of R&D occupations was in line with all occupations. Therefore, based on this criterion, there is only weak evidence of presence of genuine skills mismatches for R&D jobs. The strongest growth in wages in the last five years concerned physical scientists, electrical engineers and R&D managers suggesting a demand-supply imbalance for these occupations. On the contrary, rapid wage growth in such occupations as biological scientist and biochemists and engineering professions during previous decade has slowed down recently.
Lewis (2019)	UK / Technicians	Literature review on contribution of technicians to R&D and innovation	*Evidence suggests a lack of skilled technicians in R&D workforce.* Technicians play an important role in 'bottom-up' innovation, by participating in experimental work involved in R&D and by enabling firms to successfully deploy new technology. The examples, of the areas with shortages in technicians' roles: Aerospace and automotive industries, advanced therapies, chemical industry, industrial biotechnology, cell therapy/regenerative medicine. Graduates are, one hand, over-qualified for this type of roles, but on the other hand, under-skilled, because they lack practical skills required to apply theoretical knowledge. There is also a higher labour turnover among graduates which discourages employers to invest in their training.
McKinsey&Company (2019) Bughin et al. (2018)	UK / future skills mismatch (overall)	Occupational and skills typology approach The Occupational Talent Shortage Index based on ONS SOC classification; Future growth projections by occupation based on a set of indicators such as previous annual average employment growth, average vacancy rate, average hourly pay. McKinsey Global Institute workforce skills executive survey (international)	*Structural changes in the labour market due to ongoing technological change and namely the diffusion of automation and AI* Future projected skills shortages concern those occupations that are already hard to fill, and particularly ICT professionals. The analysis predicts the *shift in skills needed in the workforce:* increased need of technological skills (especially, of advanced and basic IT skills and programming, but also engineering, design, scientific R&D), social and emotional skills (entrepreneurship and initiative taking, leadership and managing others), higher cognitive skills (creativity and complex information processing and interpretation).

ABPI (2019)	UK / Biopharma sector workforce	Occupational approach ABPI survey 2018 and 2015	Pinch points by occupation: • Biological science: Immunology and Genomics; • Clinical areas: clinical pharmacology / translational medicine • Computational and Statistics areas: Pharmacokinetic/ Pharmacodynamics Modelling, Computational Chemistry, Chemoinformatics and Chemometrics, Biomedical Imaging; • Chemical Sciences: Medicinal and Synthetic Organic Chemistry; • Regulatory Areas: Regulatory Affairs, Qualified Person (Pharmacovigilance) and Qualified Person (Quality Assurance) – roles considered to be particularly affected by the UK's departure from the EU. "Computational disciplines are becoming the biggest priority for the pharmaceutical industry." Shortages concern both quantity and quality of workforce. There is a variety of shortages across all qualification levels (non-graduate, graduate/MSc, PhD, postdoc) but the most demanded is experienced staff with relevant industry experience.
SIP (2020)	UK / Life science sector workforce	Occupational, sectoral and functional approach Analysis based on: Labour Force Survey, 2018; Office for Life Sciences (2018) Bioscience and Health Technology Sector Statistics; Annual Population Survey (2018)	Evidence of increase in R&D related occupations over 2013-2018 period and projected increase up to 2030. 'Professional Occupations' and 'Associate Professional and Technical Occupations' make up 71 per cent of sector's employment. To achieve projected growth, the sector will need to increase its R&D employment by 17,300 persons in biopharma R&D and by 8,000 in Med Tech by 2030. This increase consists in both life-sciences specialists' and persons qualified in other disciplines and is split between different qualification levels (e.g. in biopharma 32 per cent of future R&D workers will be required to have degree level qualification and 26 per cent postgraduate level). Overarching skill needs: • Digital, computational and statistical literacy • Leadership skills • Communication skills • Translation and commercialisation skills • Broader and deeper knowledge of robotics, data science, regulatory environment, etc. There is an increasing demand for transversal specialist/computational skills. In particular, the following skills shortages were identified: • Engineers (involved in chemical and/or process control) who understand both digital and pharmaceuticals and can drive process and efficiencies;
			• Engineers who can simulate processes and build digital twins; • Digital/data scientists who can create relevant programs and infrastructure to medicines manufacturing; • Chemists/pharmacists who understand AI and can adapt to and apply new technologies.

Finally, on the issue of R&D skill shortages, research has also pointed to the existence of another important issue, namely that the UK has a high share of STEM graduates working in non-STEM jobs. Analysis for the UKCES (Bosworth et al, 2013) showed that in 2011, only a third of new STEM graduates worked in either a STEM job or a STEM sector or both, which was down from 45 per cent in 2001. A more recent study (Smith and White, 2019) drew similar conclusions about the career destinations of STEM graduates. This research, which analysed a range of official data sources and administrative data, found that most science graduates choose not to/are unable to work in R&D occupations at any time in their careers, and that STEM graduates were more likely to work in teaching and management jobs than in R&D specific roles. The research also identified a range of other connected issues which complicate the picture further. There were large differences in destinations between different sub-groups of STEM graduates. For example, while most engineering graduates did work in engineering roles, a relatively small number of biological science graduates were employed in roles that required these specific skills. In addition, female graduates were less likely to work in STEM-specific jobs than male graduates, and graduates from post-1992 institutions were much less likely to work in highly skilled STEM jobs compared to those graduating from the older research-intensive universities. This evidence on career destinations shows that R&D employers could be recruiting from a potentially much wider labour pool than they do currently and indicates that there are issues relating to diversity that need to be addressed.

5.2 Workplace training and career development

Although the evidence indicates that it is inaccurate to talk about the existence of a national problem in terms of the supply of suitably qualified personnel in the R&D sector, as we have seen, pockets of skills shortages by sector and location are observable. When we get into more detail, the literature also uncovers issues around the content and applicability of some educational courses for certain job roles and suggests there may be a mismatch with specific employer skill needs (Bosworth et al., 2003; Boner et al., 2018; Keep, 2016; OECD, 2017). Some of these issues are related to the so-called “missing middle” concerns related to the lack of intermediate/technician level skills due to the deficiencies of higher technical education (HTE). It has been observed that the UK labour market is deeply polarised, with a large proportion of high-skilled labour and a large proportion of the workforce with no or minimal post-school qualifications and ‘striking absence at the heart of the English education system’ (Toner, 2011; OECD 2017b, Field, 2020). To address this gap the government is reforming HTE and introducing a new system for approving higher technical qualifications ensuring they are more informed by employer needs (Department for Education, 2020).

However, although there are undoubtedly issues for educational institutions to address here, it is also important to acknowledge that not *all* employer skill requirements will be met through the formal education system. The role of learning, training and development that takes place within the workplace also needs to be considered to ensure that the UK has an R&D workforce with the skills required to succeed (CIPD, 2018; Gambin et al., 2016). This also includes apprenticeships, work placements and internships for college, undergraduate and postgraduate students as a way of providing necessary skills and competencies required for R&D roles (Gazzard, 2011; Ranabahu, 2020).

The provision of workplace training is especially important given that there is evidence that suggests that high level STEM workers are often less likely to receive training than their counterparts in other roles. Data from the UK Employer Skills Survey, for example, indicates that training among science, engineering and technology professionals is lower than for other professional occupations. Employers will therefore need to raise their investment in workforce development (Bosworth et al., 2013; Belitski et al., 2019; Cardenas-Rubio and Hogarth, 2021).

However, in the context of the UK’s flexible labour market, increasing workplace training faces challenges. High labour turnover can reduce the incentive of firms to invest in costly training. Quantitative studies have found that firms using flexible forms of employment have a lower propensity to train and that high labour turnover reduces the propensity of firms to innovate (Draca and Green, 2004; Michie and Sheehan, 2003; Toner, 2011). It is also important to acknowledge that as well as providing training and development opportunities, creating the sort of working culture that allows innovation to take place -based on strong employee involvement and teamworking - is also crucial. Felstead et al (2020) have demonstrated that employee involvement exercised individually and/or collectively is positively and significantly associated with the capacity of employees to offer innovative ideas. However, despite these innovation benefits, data from large scale employee surveys such as the Skills and Employment Survey series[11] show that involvement has fallen in Britain over the last decade, with an accompanying fall in task discretion.

6. BARRIERS TO INCREASING THE R&D WORKFORCE

The UK government has clearly stated its intention to invest in science and research aiming to deliver future economic growth and societal benefits and increasing public investment in R&D to £22 billion by 2024 to 2025. In this review so far, we have considered the key evidence on the current state of the employer R&D workforce and skills pipeline. We will now turn to consider what the evidence indicates are likely to be the main barriers and challenges that the UK will face in expanding and developing its private R&D workforce in the future.

6.1 Addressing specific skills shortage issues

As we have seen, the available evidence shows that it is not particularly helpful to talk about a *general* shortage of R&D or STEM skills in the UK, but there are certain areas where there are well-established problems with the supply of STEM skills. These 'pinch points' fall across a range of sectors, occupations and they also vary geographically. They will need to be better understood and addressed if the growth of the R&D workforce is to be achieved. One key area where there is considerable agreement, and that falls across sectors, is the need for more technician level skills. Several commentators have pointed out that a 'blanket' approach that only focuses on increasing the take-up of STEM subjects amongst young people is likely to be ineffective in addressing the complex skills shortage issues that affect the R&D workforce (Cardenas-Rubio and Hogarth, 2021).

Properly identifying and addressing pockets of skills shortages is particularly important too when we look at the available evidence about the future of the R&D sector based on labour market projections. The Working Futures projections which have been compiled over several years by the Institute for Employment Studies (IES)[12] draw attention to the future

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[11] https://www.cardiff.ac.uk/research/explore/find-a-project/view/626669-skills-and-employment-survey-2017

[12] https://warwick.ac.uk/fac/soc/ier/research/wf/

growth of R&D job roles as well as the issue of 'replacement demand' - i.e., the need to replace people that will leave R&D job roles in the coming years, mainly due to retirement or for other reasons such as career breaks/changes. Together this means that the overall number of additional jobs that will need to be filled in the next few years will be substantial. Based on a continuation of existing trends (and it is important to bear in mind that this analysis was done assuming a steady state, pre-Brexit and pre-COVID-19 and not taking into account announcements of increases in public R&D funding), the Working Futures projections indicate that the number of people employed in R&D will increase by around 91,000 between 2017 and 2027. However, this rises to 382,000 people when replacement demand is accounted for too. As Cardenas-Rubio and Hogarth (2021) have argued, the scale of this labour demand is such that skills shortages are highly likely to continue, and in some cases, deepen without dedicated action.

6.2 Attracting and retaining international talent

If the UK is to be able to meet its ambitions of expanding the general R&D workforce, it will be important to be able to continue to recruit workers from abroad. As we have seen, the R&D sector in the UK is highly dependent upon workers from overseas. For this to continue, the ease of movement of highly skilled R&D workers is important. Several industry commentators have emphasised that this requires an immigration system that is informed by skill needs and is straightforward to navigate, with reciprocal arrangements in place to facilitate ease of movement for R&D workers, as well as guaranteeing the rights of international workers already working in the UK. Both Brexit and the COVID-19 crisis have had an impact in recent years, creating considerable uncertainty, and this uncertainty presents a significant barrier to expanding the UK's R&D workforce. For example, a recent survey of employers in the pharmaceutical sector found that concerns about recruiting highly qualified workers have increased in recent years, with uncertainty around post-Brexit regulatory frameworks also raised as an issue (ABPI, 2019). The same concerns are also expressed by engineering professional bodies (Engineering UK, 2019).

6.3 Utilising the existing R&D workforce

As well as the importance of making the most of the international labour pool, the evidence also points to an opportunity for R&D employers to make better use of the existing stock of people with STEM qualifications (STEM Returners, 2020). As we have seen, research shows that a significant proportion of STEM graduates do not go into STEM occupations despite being qualified to do so. This acts as both a barrier but also a potential opportunity for future growth. There is a need to better understand why such a large proportion of those with STEM qualifications do not move into R&D roles, and to make the sector a more attractive career proposition. A study by the Industrial Strategy Council (2019), like the Working Futures projections, predicts acute shortages of specialist skills in STEM and health services by 2030. It emphasises that it is important that not all attention is devoted to young people still in education or training in addressing this major future challenge. Instead, it argues that equal or perhaps even more pronounced focus should be given to the existing workforce. This includes both ensuring more STEM qualified individuals move into R&D roles and ensuring that the existing R&D workforce are given appropriate opportunities for learning and career development to ensure staff currently working in R&D roles are retained.

6.4 Increasing diversity in the R&D workforce

Another barrier to the future growth of the sector relates to the lack of diversity in the R&D workforce. This is particularly pronounced in terms of gender. As we have seen, women are under-represented in the R&D workforce, with unequal representation particularly pronounced in some occupations. These inequalities are firmly embedded into the education system. Women are underrepresented in STEM degree subjects, at A-Level and in vocational education. The evidence also shows too that even when they are qualified women are less likely to take up STEM careers (Smith and White, 2019). Addressing these issues and increasing diversity within the workforce will be important to enable the growth of the R&D workforce.

7. SUMMARY AND EVIDENCE GAPS

In this evidence review we have outlined some of the key sources of evidence on the nature of the UK's business R&D workforce, the skills challenge it faces now and in the future, and barriers to future growth. This is a complex research area with evidence coming from a range of sources over a few years, using different definitions and measures and sometimes contradictory findings.

Overall, there is a general lack of evidence on the *specific* issues facing private or business R&D, and much of the research in the area focuses on the entire general R&D workforce. Skills needs, training activity, managerial practices and barriers to expansion for businesses, therefore, could be an area for focused future research. This research would need to take a sharp sector focus given the existence of marked differences by industry that emerge clearly from the evidence. It would also be useful to know about the specific experiences and challenges being faced by SMEs too.

There is solid evidence showing that R&D employment across both the private and public sectors in the UK has been rapidly growing since the financial crisis so that its importance in the overall labour force structure is increasing. This trend, as well as the increase in R&D in the service sector, is likely to continue in the future with all that it implies in terms of demand for relevant skills. The evidence also indicates that there are skill shortage hotspots that are likely to become more pronounced given future labour market developments, and that these will act as a barrier to growing and developing the R&D workforce. There is particularly strong evidence on the increased demand for skills at the technician level in R&D roles.

Concerns about a shortage of STEM graduates in the UK have been regularly raised for many years and have led to changes in the education system that have led to an increase in students taking STEM subjects. However, the evidence shows that a focus on increasing the number of students studying STEM subjects at school, college and university will not be sufficient in responding to future skills shortages. Instead, there will also be a need to focus on how to make the best use of the existing R&D workforce, working both within and outside of the sector, improving diversity, and also managerial and training practices, as well as continuing to recruit skilled workers from overseas.

It is also important to note that most of the research that has been done to date on the R&D workforce does not consider the likely impact of COVID-19 and this is a research gap that urgently needs to be addressed. For example, trends in technological change have been accelerated by the COVID-19 crisis: as early evidence suggests, many employers are increasing the automation of their work processes (WEF, 2020). This increases demand for roles such as data analysts and scientists, AI and machine learning specialists, robotics engineers, software developers, 3D graphics and digital transformation specialists in all sectors of the economy. There is an overall tendency to 'hybrid' skills where a skill previously found in one group of occupations spreads to other roles (Burning Glass, 2019). For example, an analysis of the needs of the UK Life science sector, which is one of the most R&D intensive sectors, points out the acute need for not only specialist knowledge skills but also an increasing demand for statistical and computational skills (SIP, 2020). The R&D sector will undoubtedly play an important role in the UK's economic and social recovery from the impacts of COVID-19. If the opportunities are to be maximised, there is a need for a coordinated and cohesive approach that addresses these new skills issues and demands as well as the more established and ongoing problems in the sector.

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