UNIVERSITY OF CAMBRIDGE

Cambridge Industrial Innovation Policy

UK INNOVATION REPORT 2022

Benchmarking the UK's industrial and innovation performance in a global context

Institute for Manufacturing, University of Cambridge
March 2022

What makes this report different?

While numerous sources of data on the topic of innovation exist, the ***UK Innovation Report*** aims to make a contribution by bringing together, in a single place, **innovation and value-added indicators** in a concise and accessible format. The report seeks to demonstrate the value of combining different types of indicator and data sets to facilitate **policy discussions on innovation and industrial performance – and the interplay between them**.

Instead of structuring the report according to input and output indicators, as is typically done in reviews of innovation activity, the focus has been on bringing together indicators that provide rich quantitative representations that are relevant to the vitality of the **UK's innovation activity and its industrial performance in an international context**. While the report does not make specific policy recommendations, it does highlight areas where additional evidence and policy action may be required.

Motivation

- To review the UK's innovation and industrial performance and compare it with that of other selected countries;
- To facilitate discussions on the relation between innovation and sectoral competitiveness; and
- To contribute to the evidence base that is available to inform industrial and innovation policy.

Contributors and acknowledgements

Cambridge Industrial Innovation Policy

Cambridge Industrial Innovation Policy (CIIP) brings together the Centre for Science, Technology & Innovation Policy at the Institute for Manufacturing, the Policy Links Unit from IfM Engage and the Babbage Policy Forum. Our work is based around what we call industrial innovation policy, a policy domain that focuses on the interplay between technology, innovation and industrial competitiveness. CIIP is based at the Institute for Manufacturing, a division of the University of Cambridge's Department of Engineering.

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Disclaimer

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Executive summary

UK INNOVATION REPORT 2022

Executive summary (1/6)

Theme	(1) Structure and performance of the UK economy — Pages 15–27
Key policy questions addressed	▪ How has the structure of the UK economy changed in the last few years? ▪ Are these changes affecting economic performance? ▪ How does this compare with other countries?
Key findings	▪ **In the last two decades the share in the UK economy of high-productivity sectors such as manufacturing and mining has reduced, while the participation of sectors such as construction and services has grown.** Between 1998 and 2019, the manufacturing sector had one of the highest productivity growth rates in the UK economy, but it was also the sector whose share in the economy decreased the most (from 16.1% to 9.7%) during this period. ▪ **Finance was the main driver of productivity growth prior to 2008 but its contribution became negative in the post-crisis period.** Before the financial crisis, finance was the main driver of productivity growth in the UK, but Bank of England analysis suggests that this was likely driven by "unsustainable increased debt and higher risk tolerance". The contribution of finance to national productivity growth became negative post-crisis. ▪ **The loss of manufacturing has imposed a penalty on UK productivity growth of half a percentage point, on average, each year for the last two decades.** In contrast, manufacturing was responsible for around 30% of aggregate productivity growth in China and almost half in Taiwan during the 1998–2017 period. It also contributed to around 30% of aggregate productivity growth in Korea between 2005 and 2017 and 15% in Singapore between 2010 and 2017.

Executive summary (2/6)

Theme	(2) Investment in innovation — Pages 28–43
Key policy questions addressed	▪ Is the UK spending enough on R&D? ▪ How do the public and private sectors contribute to national expenditure on innovation? ▪ How does the UK compare with other countries?
Key findings	▪ **The UK spends less on R&D than the OECD average; a significant increase in public funding for R&D has been announced but delayed.** At 1.74%, the UK's gross domestic expenditure on R&D remains well below the 2019 OECD average of 2.5%. The UK government has committed to investing £22 billion in R&D by 2026/27 (pushing back the original target date of 2024). ▪ **Compared to other countries, the business sector in the UK contributes less to R&D funding; universities perform significantly more of the country's R&D and the government significantly less.** In the UK the business sector funds around 55% of R&D – a lower proportion than in countries such as Germany, Korea and Japan. The UK's higher education sector stands out from comparator countries, performing 23.1% of the country's R&D in 2019. The government sector in the UK performs only 6.6% of R&D, well below comparator countries. ▪ **Very few firms headquartered in the UK are global leaders in R&D investment and patent applications.** In 2020 only two companies headquartered in the UK were among the top 100 R&D investing firms and no firms headquartered in the UK were among the top 100 patent applicants at the United States Patent and Trademark Office (USPTO).

Executive summary (3/6)

Theme	(3a) Industrial performance – focus on the pharmaceutical manufacturing sector	Pages 44–61
Key policy questions addressed	▪ Are UK sectors becoming more or less competitive internationally? ▪ How are UK sectors performing in terms of productivity, value added and employment? ▪ What are the drivers behind the observed performance trends?	

Key UK pharmaceutical manufacturing trends in the last decade

- **The value added and productivity of the UK pharmaceutical manufacturing sector have declined significantly in the last decade.** Of the top 13 countries by pharmaceutical value added in 2018, the UK was the only one to have experienced a significant productivity decline, at a rate of -7.9% per year between 2008 and 2018.
- **The UK trade balance in pharmaceuticals has deteriorated significantly since 2014.** The UK has recorded deficits in pharmaceutical product trade in all years between 2014 and 2020, except in 2015, with the trade balance going from a $9.6 billion surplus in 2010 to a deficit of over $1 billion in 2020.
- **Pharma business R&D expenditure in the UK has remained stagnant in the last decade and remains significantly lower than comparator countries.** The sector spent only 6% more in 2018 than it did in 2008, compared to increases of around 30% in the US and Germany and over 100% in Korea.

Drivers identified in literature review and sector expert consultations

- Company restructuring and site closures, including those by major sector employers;
- Increased offshoring of pharmaceutical manufacturing, including a large share of APIs;
- The UK's inability to capture the "second wave" of international manufacturing investments;
- Greater incentives (e.g. tax) offered by other countries to attract manufacturing;
- New entrants focusing on early-stage drug discovery and non-manufacturing activities;
- An inability to commercialise and scale up the manufacture of technologies developed in the UK;
- Caps on drug spending having an impact on the perception of the UK by investors;
- Increased use of generics pushing prices downwards and driving imports upwards;
- The 2016 EU membership referendum adding uncertainty to investment decisions;
- The large share of domestic business R&D expenditure decisions taken abroad;
- Competitor countries having greater incentives to attract R&D investment;
- Difficulties accessing scale-up funding locally, leading to firm decisions to migrate; and
- UK companies reducing in-house R&D investment in favour of acquiring small firms.

Executive summary (4/6)

Theme	(3b) Industrial performance – focus on the automotive manufacturing sector	Pages 62–79
Key policy questions addressed	▪ Are UK sectors becoming more or less competitive internationally? ▪ How are UK sectors performing in terms of productivity, value added and employment? ▪ What are the drivers behind the observed performance trends?	

Key UK automotive manufacturing trends in the last decade

- **The value added and productivity of the UK automotive sector grew steadily between 2008 and 2018.** The UK belongs to a group of nations where productivity was high and rising over the 2008–18 period, together with Germany, Korea and the US.
- **Despite being the ninth largest exporter of vehicles in 2020, the UK maintains a significant deficit in automotive product trade.** Since 2010 the UK has recorded a persistent trade deficit in automotive products, standing at $21.8 billion in 2020. Industry reports suggest that 50% local content is a plausible target for the UK car industry.
- **UK business expenditure on automotive R&D grew rapidly between 2009 and 2016 but has declined in recent years.** UK business enterprise expenditure on R&D (BERD) for automotive grew by 11.7% (CAGR) between 2009 and 2018 (but with a slowdown in 2017 and 2018).

Drivers identified in literature review and sector expert consultations

- Increased specialisation of the UK's automotive sector in premium product segments;
- Future sector growth dependent on the UK's ability to produce electric and hydrogen vehicles and components;
- High levels of automation influencing the growth in employment in recent years;
- Skills' shortages, particularly in higher technical education reported by industry;
- Decisions by foreign original equipment manufacturers (OEM) favouring other locations;
- Increased competitive pressures from both established and upcoming nations;
- Increased uncertainty around trade and investment as a result of the 2016 EU membership referendum; and
- R&D investment decisions mostly driven by foreign OEMs.

Executive summary (5/6)

Theme	(4) Science and engineering workforce — Pages 80–89
Key policy questions addressed	▪ Is the UK producing enough scientists and engineers? ▪ Is the UK government investing enough in technical and vocational education? ▪ How does this compare with other countries?
Key findings	▪ **Tertiary education attainment in the UK is well above the OECD average – and a comparatively larger share of graduates is found in science, technology, engineering and mathematics (STEM) disciplines.** In 2019 graduates in STEM disciplines accounted for 43.4% of the total number of graduates in the UK, above comparator countries such as France (36.8%), Canada (37.8%) and the United States (37.6%) ▪ **Women are under-represented in STEM disciplines.** Only 27% of the STEM workforce in the UK is female, compared with 52% in the total workforce. For UK engineers a gender pay gap exists but it is smaller than the pay gap for all UK workers. ▪ **Higher technical education enrolment is comparatively low in the UK.** Enrolment rates in post-secondary education courses, below the standard three-year Bachelor's degree, are comparatively low in the UK when compared with countries such as the US, Korea and France. The government's White Paper, *Skills for Jobs*, recognises a "significant shortage of vital technician-level STEM skills".

Executive summary (6/6)

Theme	(5) Net-zero innovation	Pages 90–100
Key policy questions addressed	▪ How does the UK compare in low-carbon and renewable-energy technology research and development (R&D) investment? ▪ How is R&D expenditure translating into patenting performance? ▪ Is the UK capturing the economic potential of the transition towards net zero?	
Key findings	▪ **The UK is one of the global leaders in both public R&D budget and patenting of net-zero-related technologies.** The International Energy Agency (IEA) estimates that in 2020 the UK's public R&D budget in low-carbon and renewable-energy technologies was $1.2 billion (USD $2020), lower than France, Japan and the US but ahead of Germany and Canada. The UK ranks eighth in the registration of climate-change mitigation technology (CCMT) patents, behind Japan, the US, Germany, Korea, China, France and Taiwan. ▪ **Most of the low-carbon and renewable-energy sectors in the UK have been declining over the last five years.** The ONS defines the low-carbon and renewable-energy economy (LCREE) as 17 low-carbon sectors, including wind, renewables, PV, CCS, nuclear and energy-efficient products. A total of 10 out of 17 LCREE sectors showed a decline in turnover between 2014 and 2019. Overall, there were 27,000 fewer LCREE business and 33,800 fewer jobs in LCREE sectors in 2019 than in 2014. ▪ **There are some national disparities, with Scotland performing strongly.** At £1 million turnover, 4.1 jobs and 2.2 businesses per 1,000 inhabitants, Scotland performed above the UK annual average for all categories between 2014 and 2019. Wales also performs above the national averages for LCREE businesses and jobs, at 2.46 businesses and 3.35 jobs per 1,000 inhabitants.	

Introduction

UK INNOVATION REPORT 2022

Introduction

The aim of the *UK Innovation Report* is to facilitate policy discussions on innovation and industrial performance – and the interplay between them. The 2022 edition of the report is published amid a changing policy landscape. In March 2021 the UK government released a new strategy, Build Back Better: our plan for growth, which replaces the 2017 Industrial Strategy and sets out the government's plan to address the "invented in Britain"/"made elsewhere" disconnect. A new Innovation Strategy published in July 2021 sets out a "long-term plan for delivering innovation-led growth", announcing a commitment to increase annual public investment on R&D to £22 billion. The government has also established a new Office for Science and Technology Strategy and a National Science and Technology Council. In February 2022 the first chief executive of the new Advanced Research and Invention Agency (ARIA), modelled after the US Advanced Research Projects Agency (ARPA), was appointed.

The *UK Innovation Report 2022* maintains last year's four core sections (**structure and performance of the UK economy**, **investment in innovation**, **industrial performance** and **science and engineering workforce**) and incorporates a new one (**net-zero innovation**). It not only provides updates using newly available data but also seeks to address policy questions from different angles. The report uses new indicators and longer time series, integrates additional national and international databases, and analyses more granular data at industry and firm level.

Section 1 provides new decompositions of productivity growth rates and international productivity comparisons at sector level, building on a related project being conducted by the Policy Links Unit in collaboration with the National Institute of Economic and Social Research. **Section 2** presents firm-level data on R&D investment and patent applications. **Section 3** deep-dives into the pharmaceutical and automotive manufacturing sectors, incorporating insights gathered during consultations with industry experts from the public and private sectors from around twenty different organisations. **Section 4** places additional emphasis on science, technology, engineering and mathematics (STEM) disciplines and technical education. Finally, **Section 5** incorporates data on innovation and the economic performance of low-carbon and renewable-energy sectors.

New section in this edition: net-zero innovation

For many, the greatest challenge of the 21st century is climate change. Net zero refers to achieving a balance between the carbon emitted into the atmosphere and the carbon removed from it. Markets for new technologies that can help businesses and countries to achieve net zero are expanding, and therefore they are a key area in which innovative activity has the potential to contribute to national economic growth and competitive advantage. Our 2022 report has chosen net-zero innovation as a topic in focus, to highlight how the UK is performing in what has the potential to be a high-growth economic sector.

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UK INNOVATION REPORT 2022

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Special theme in this edition

Theme 1: Structure and performance of the UK economy

UK INNOVATION REPORT 2022

Theme 1: Policy questions and key messages

- How has the structure of the UK economy changed in the last few years?
- Are these changes affecting economic performance?
- How does this compare with other countries?

In the last two decades high-productivity sectors such as manufacturing and mining have reduced their participation in the UK economy in favour of sectors such as construction and services

- The manufacturing productivity growth rate was among the highest in the UK economy between 1998 and 2019, but it was also the sector whose share in the economy decreased the most (from 16.1% to 9.7%) during this period.
- Services whose share of the economy increased during this period include (change in value-added shares in brackets, percentage points): human health and social activities (2.1); professional, scientific and technical activities (2.0); and administrative service activities (1.4).

Finance was the main driver of productivity growth prior to 2008 but its contribution became negative in the post-crisis period

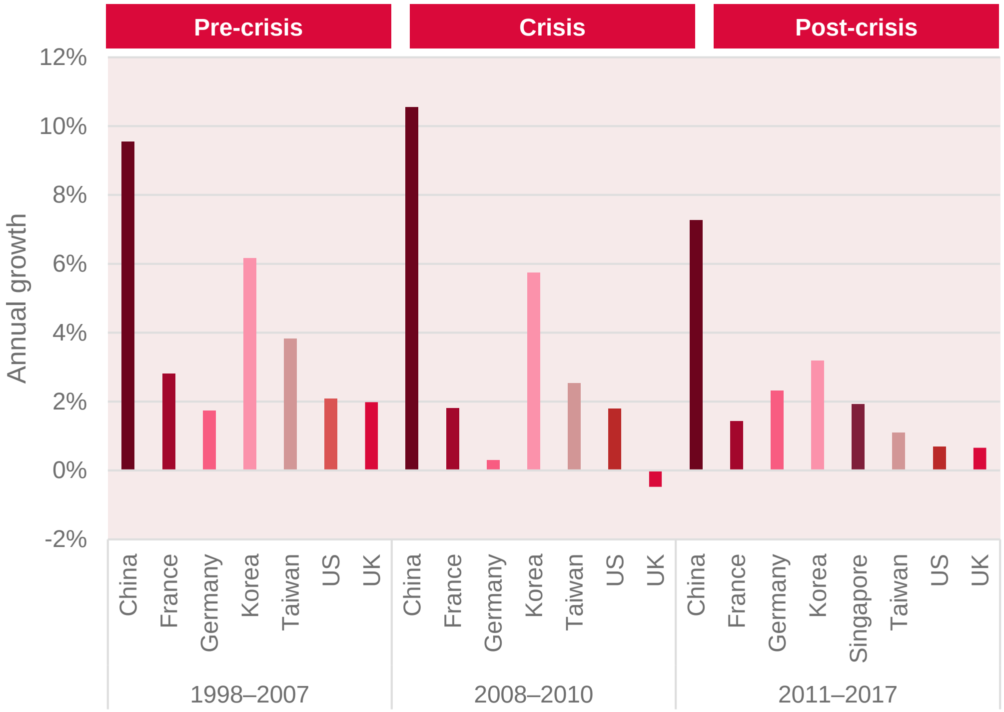
- In the period 1998–2007, finance was the main driver of productivity growth in the UK, adding 0.37 percentage points, on average, each year to aggregate productivity growth. After the crisis, finance's contribution to national productivity became negative.
- Administrative services, construction, information and communication, and professional, scientific and technical activities were among the top contributors to aggregate productivity growth in the post-crisis period (2011–19).
- Following the COVID-19 pandemic the main contributor to productivity growth was human health and social activities.

The loss of manufacturing has imposed a penalty on UK productivity growth of half a percentage point each year, on average, for the last two decades

- The reduction in manufacturing share in economies is a common feature across most of the economies examined between 1998 and 2017. But as a result of its high-productivity growth rates, manufacturing is one of the sectors that makes the largest contribution to aggregate productivity growth in the best-performing countries.
- During 1998–2017, manufacturing was responsible for around 30% of the aggregate productivity growth in China and almost half of productivity growth recorded in Taiwan during 1998–2017. Manufacturing also contributed to around 30% of aggregate productivity growth in Korea between 2005 and 2017 and 15% of productivity growth in Singapore between 2005 and 2017.
- In contrast, manufacturing had a negative contribution to aggregate productivity growth in the UK during this period, mainly due to a reduction in its participation in the economy (as reflected in a negative allocation effect of -0.5 percentage points).

Chart 1.1. Labour productivity: international comparison

Output per worker, selected countries, 1998–2017



- In the **pre-crisis period** (1998–2007) UK labour productivity growth rates were similar to those observed in other developed countries such as **Germany** and the **US**. **China, Korea** and **Taiwan** recorded the strongest performance during this period**.**
- In the **aftermath of the financial crisis** (2008–10), most countries analysed experienced a significant slowdown in productivity growth. However, the **UK** was hit the hardest, recording a negative growth rate of -0.5%.
- In the **post-crisis period** (2011–17) the strongest productivity performance was recorded by **China**, **Korea** and **Germany** (7.3%, 3.2% and 2.3%, respectively). Productivity growth in the **UK**, the **US** and **Taiwan** was considerably weaker (0.7%, 0.7% and 1.1%, respectively).

Source: Authors' computation based on data from the APO Productivity Database 2020 Ver.1 (5 August 2020); OECD STAN Industrial Analysis (2020 ed.); Korea Productivity Center; Singapore Department of Statistics; Singapore Ministry of Trade and Industry; Manpower Research & Statistics Department; Taiwan Statistical Bureau UK Office for National Statistics; US Bureau of Economic Analysis and US Bureau of Labor Statistics.

Chart 1.2. UK economic structure and sectoral productivity

Labour productivity and value added, 1998 and 2019

More productive / Less productive

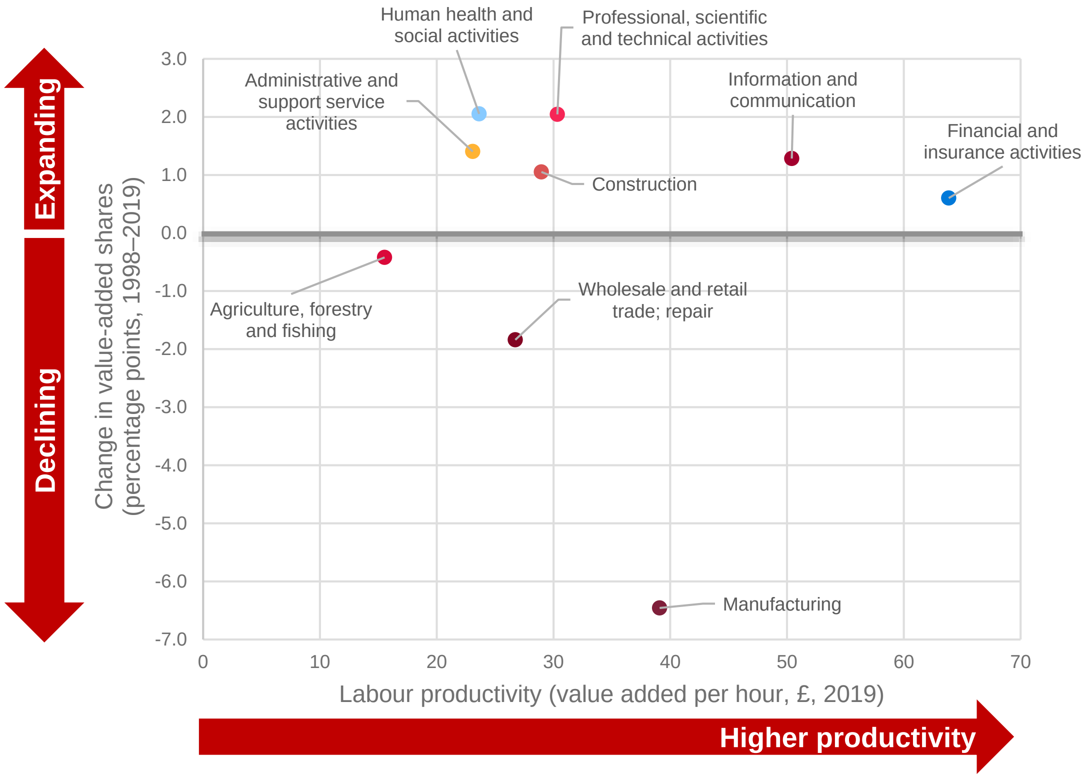
Economic sector	1998		2019		Change 1998–2019	
	Value added per hour (pounds)[1]	Value-added shares	Value added per hour (pounds)[1]	Value-added shares	Value added per hour (annual average growth rate)	Value-added shares (percentage points)
Real-estate activities[2]	411.6	14.7%	292.9	13.3%	-1.6%	-1.4
Mining and quarrying	300.3	1.5%	163.2	1.0%	-2.6%	-0.5
Electricity, gas, steam and air-conditioning supply	109.5	1.5%	98.9	1.4%	-0.1%	-0.1
Activities of households	50.6	0.2%	98.8	0.3%	4.6%	0.1
Water supply; sewerage, waste management and remediation	73.0	1.4%	69.0	1.2%	0.3%	-0.2
Financial and insurance activities	46.2	5.7%	63.9	6.3%	2.5%	0.6
Information and communication	24.4	5.6%	50.4	6.9%	3.7%	1.3
Manufacturing	24.4	16.1%	39.1	9.7%	2.2%	-6.5
Public administration and defence; compulsory social security	35.0	5.1%	39.1	5.0%	0.5%	-0.1
Professional, scientific and technical activities	20.4	5.7%	30.3	7.7%	2.1%	2.0
Education	38.4	4.9%	29.9	5.9%	-1.3%	1.0
Construction	25.1	5.5%	29.0	6.5%	0.6%	1.1
Wholesale and retail trade; repair of motor vehicles and motorcycles	18.8	12.2%	26.7	10.3%	1.6%	-1.8
Transportation and storage	24.7	4.4%	26.2	4.1%	0.4%	-0.3
Other service activities	26.2	1.5%	25.6	1.7%	0.1%	0.3
Arts, entertainment and recreation	30.2	1.2%	23.7	1.6%	-0.7%	0.5
Human health and social activities	19.7	5.5%	23.6	7.6%	0.9%	2.1
Administrative and support-service activities	14.3	3.9%	23.1	5.3%	2.2%	1.4
Accommodation and food-service activities	16.4	2.5%	17.5	3.0%	0.4%	0.5
Agriculture, forestry and fishing	10.4	1.1%	15.5	0.7%	2.7%	-0.4
Whole economy	**28.2**	**100%**	**35.4**	**100%**	**1.1%**	**0**

Notes: [1] Chain volume measure (CVM) prices. [2] The productivity of the real-estate sector is distorted by the inclusion of imputed rents from owner-occupied dwellings in the value added of this sector.
Source: Own computation based on data from the UK Office for National Statistics (1998,2019).

- Sector-level analysis reveals the key structural factors behind the relatively slow rates of productivity growth in the UK. The contribution of economic sectors to aggregate productivity growth depends on how productive they are (usually measured by value added per hour), their rate of productivity growth and their relative size in the economy (usually measured in terms of value added and employment shares).
- In 2019 the most productive market sectors in the UK economy included (overall value added per hour worked in brackets): **mining and quarrying** (£163.2), **electricity and gas** (£98.9), **water supply** (£98.8), **financial and insurance activities** (£63.9), **information and communication** (£50.4) **and manufacturing** (£39.1).
- The case of **manufacturing** stands out. While manufacturing productivity growth was among the highest between 1998 and 2019 (with an annual growth rate of 2.2%), it was the sector with the largest decline in value-added shares during this period (-6.5 percentage points).
- Meanwhile**, mining and quarrying** almost halved its labour productivity, while reducing its value-added share by 0.5 percentage points during this period.

Chart 1.3. UK economic structure and sectoral productivity

Labour productivity and value added, selected sectors, 1998–2019



Source: Own computation based on data from the UK Office for National Statistics (1998, 2019).

- Chart 1.3 shows the productivity in 2019 and the changes in value-added shares between 1998 and 2019 for selected sectors.
- The participation of **manufacturing** in the economy declined significantly during this period (by 6.5 percentage points). Meanwhile, **construction** and both high- and low-productivity **service activities** increased their participation in the economy.
- Services that experienced the largest increase in value-added shares during this period include (changes in percentage points in brackets)**: human health and social activities** (2.1); **professional**, **scientific and technical activities** (2.0); and **administrative and support-service activities** (1.4).

Chart 1.4. Sectoral sources of UK productivity growth

Sectors with the largest and lowest contributions to UK aggregate productivity growth, selected time period

	Pre-crisis (1998–2007)		Post-crisis (2011–19)		COVID-19 (2019–20)	
	UK aggregate productivity growth (average): **2.1%**		UK aggregate productivity growth (average): **0.3%**		UK aggregate productivity growth: **1.2%**	
	Economic sector	**Contribution**	**Economic sector**	**Contribution**	**Economic sector**	**Contribution**
Top 5	Financial and insurance activities	0.37	Real-estate activities	0.19	Human health and social activities	1.97
	Construction	0.29	Administrative and support services	0.14	Real-estate activities	0.63
	Human health and social activities	0.29	Construction	0.11	Education	0.56
	Professional, scientific and technical activities	0.29	Information and communication	0.10	Public admin, defence, social security	0.53
	Information and communication	0.23	Professional, scientific and technical activities	0.08	Financial and insurance activities	0.32
Bottom 5	Water supply, sewerage, etc.	0.02	Wholesale, retail trade and repair	-0.06	Transportation and storage	-0.41
	Mining and quarrying	0.02	Public administration, defence, social security	-0.06	Manufacturing	-0.44
	Activities of households	0.00	Manufacturing	-0.07	Construction	-0.56
	Agriculture, forestry and fishing	-0.03	Mining and quarrying	-0.08	Administrative and support services	-0.64
	Manufacturing	-0.31	Financial and insurance activities	-0.17	Accommodation and food-service activities	-1.18

Note: Contribution to aggregate productivity is computed as the sum of intra-industry productivity growth (within) effect and allocation (between) effect. Figures correspond to average annual contributions.
Source: Own computation based on data from the UK Office for National Statistics (1998-2019).

- Sectors contribute differently to aggregate productivity growth because of disparities in their productivity performance and their participation in employment and output.
- In the pre-crisis period (1998–2007) **financial and insurance activities** were the main driver of productivity growth in the UK, with an average annual contribution to productivity growth of 0.37 percentage points. In contrast, **manufacturing** had a negative contribution (-0.31).
- In the post-crisis period (2011–19), the contributions of the financial and insurance sector to aggregate productivity growth declined to negative levels (-0.17 percentage points), with **real-estate activities, administrative and support services and information and communication** having among the largest contributions (0.19, 0.14 and 0.10, respectively).
- A likely explanation for the decline of the **financial sector** is that, in the pre-crisis period, high growth was mainly driven by unsustainable increased debt and higher risk tolerance.[1]
- It is important to note that the contribution of the **real-estate sector** is distorted by the inclusion of imputed rents from owner-occupied dwellings in the value added of this sector.[2]
- The increasing demand for **health and social services during** the **COVID-19** pandemic meant that this sector was responsible for the largest contribution to aggregate productivity growth in 2020 (1.97 percentage points). Meanwhile, **accommodation and food-service activities** had a negative contribution (-1.18 percentage points).

[1] Teneyro, S. (2018). The fall in productivity growth: causes and implications.
[2] Riley et al. (2018). Below aggregate: a sectoral account of the UK productivity puzzle.

Chart 1.5. Sectoral sources of UK productivity growth, pre-crisis

Sectors with the largest and lowest contributions to UK aggregate productivity growth, 1998–2007

Pre-crisis (1998–2007)

	Economic sector	Change 1998–2007			Contribution to productivity growth 1998–2007 (annual average)		
		Value added per hour[1] (annual average growth rate)	Value-added shares (percentage points)	Employment shares (percentage points)	Intra-industry productivity effect	Allocation effect	Total
Top 5	Financial and insurance activities	6.8%	2.6	-0.2	0.38	-0.01	0.37
	Construction	0.1%	1.2	0.6	0.03	0.26	0.29
	Human health and social activities	1.8%	1.5	1.2	0.09	0.20	0.29
	Professional, scientific and technical activities	3.5%	1.2	1.1	0.20	0.08	0.29
	Information and communication	6.7%	0.7	0.2	0.40	-0.17	0.23
Bottom 5	Water supply, sewerage, waste management, remediation activities	2.0%	-0.1	0.0	0.03	-0.01	0.02
	Mining and quarrying	-2.2%	0.3	-0.1	-0.02	0.04	0.02
	Activities of households	-4.7%	0.0	0.2	0.00	0.00	0.00
	Agriculture, forestry and fishing	4.0%	-0.4	-0.4	0.05	-0.07	-0.03
	Manufacturing	4.2%	-5.4	-5.5	0.57	-0.89	-0.31

Note: [1]Chain volume measure (CVM) prices.
Source: Own computation based on data from the UK Office for National Statistics (1998-2007).

- In the decade before the financial crisis (1998–2007) the sectors with the largest contributions to aggregate productivity growth were: **financial and insurance activities** (0.37); **construction** (0.29); **human health and social activities** (0.29); **professional, scientific and technical activities** (0.29); and **information and communication** (0.23)
- The contributions of **financial and insurance activities, information and communication** and **professional, scientific and technical activities** during 1998–2007 were mainly driven by the growth of productivity in each of these sectors (intra-industry productivity effect).
- Meanwhile, the contributions of the **construction** and **human health and social activities** sectors during this period are largely explained by their expansion (allocation effect).
- At 4.2%, the productivity growth rates of the **manufacturing** sector were among the highest during 1998–2007 (resulting in an intra-industry productivity effect of 0.57). However, its employment share declined by 5.5 percentage points (resulting in a negative allocation effect of -0.89). As a result, the contribution of manufacturing to productivity growth in this period was the lowest in the economy (-0.31).

Chart 1.6. Sectoral sources of UK productivity growth, post-crisis

Sectors with the largest and lowest contributions to UK aggregate productivity growth, 2011–2019

Post-crisis (2011–19)

	Economic sector	Change 2011–19			Contribution to productivity growth 2011–19 (annual average)		
		Value added per hour[1] (annual average growth rate)	Value-added shares (percentage points)	Employment shares (percentage points)	Intra-industry productivity effect	Allocation effect	Total
Top 5	Real-estate activities	-0.4%	1.0	0.2	-0.06	0.25	0.19
Top 5	Administrative and support service activities	2.7%	1.1	0.6	0.12	0.02	0.14
Top 5	Construction	0.7%	0.7	0.1	0.04	0.07	0.11
Top 5	Information and communication	1.3%	0.5	0.3	0.08	0.01	0.10
Top 5	Professional, scientific and technical activities	1.0%	0.6	1.2	0.07	0.00	0.08
Bottom 5	Wholesale and retail trade; repair of motor vehicles and motorcycles	2.1%	-0.4	-1.0	0.23	-0.28	-0.06
Bottom 5	Public administration and defence; social security	0.5%	-0.5	-0.9	0.03	-0.09	-0.06
Bottom 5	Manufacturing	0.1%	-0.9	-0.6	0.01	-0.09	-0.07
Bottom 5	Mining and quarrying	-2.2%	-0.8	0.0	-0.07	-0.02	-0.08
Bottom 5	Financial and insurance activities	-1.0%	-1.7	-0.4	-0.08	-0.10	-0.17

Note: [1]Chain volume measure (CVM) prices.
Source: Own computation based on data from the UK Office for National Statistics (2011,2019).

- In the decade after the financial crisis (2011–19) the sectors with the largest contributions to UK aggregate productivity growth included: **real-estate activities** (0.19); **administrative and support-service activities** (0.14); **construction** (0.11); **information and communication** (0.10); and **professional, scientific and technical activities** (0.08).
- Except for **real-estate activities**, the contributions of these sectors are largely explained by relatively higher productivity growth rates (intra-industry productivity effect).
- The sectors with the weakest contributions to aggregate productivity in the reference period include: **financial and insurance activities** (-0.17); **mining and quarrying** (-0.08); **manufacturing** (-0.07); **public administration** (-0.06); and **wholesale and retail trade** (-0.06).
- Except for **mining and quarrying**, the negative contributions of these sectors were due to their contraction in size (allocation effect). Among these activities, the **wholesale and retail trade** sector experienced the largest contraction in employment.

Chart 1.7. Sectoral sources of UK productivity growth, COVID-19

Sectors with the largest and lowest contributions to UK aggregate productivity growth, 2019–2020

COVID-19 (2019–20)

	Economic sector	Change 2019–20			Contribution to productivity growth, 2019–20		
		Value added per hour[1] (annual growth rate)	Value-added shares (percentage points)	Employment shares (percentage points)	Intra-industry productivity effect	Allocation effect	Total
Top 5	Human health and social activities	-7.3%	1.9	0.2	-0.56	2.53	1.97
	Real-estate activities	-2.1%	0.5	0.2	-0.28	0.90	0.63
	Education	-5.9%	0.5	0.1	-0.34	0.91	0.56
	Public administration and defence; social security	-0.8%	0.5	0.2	-0.04	0.57	0.53
	Financial and insurance activities	-4.8%	0.2	0.1	-0.30	0.62	0.32
Bottom 5	Transportation and storage	-3.6%	-0.5	0.0	-0.15	-0.26	-0.41
	Manufacturing	4.5%	-0.5	-0.1	0.43	-0.87	-0.44
	Construction	3.9%	-0.6	-0.1	0.25	-0.81	-0.56
	Administrative and support-service activities	-1.8%	-0.7	-0.3	-0.10	-0.54	-0.64
	Accommodation and food-service activities	-11.9%	-1.2	-0.2	-0.36	-0.82	-1.18

Note: [1]Chain volume measure (CVM) prices.
Source: Own computation based on data from the UK Office for National Statistics (2019, 2020).

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- **During the COVID-19 pandemic (2019–20)** the sectors with the largest contributions to aggregate productivity growth included: **human health and social activities** (1.97); **real-estate activities** (0.63); **education** (0.56); **public administration** (0.53); and **financial and insurance activities** (0.62).
- Other sectors (not presented in the table) with relatively large positive contributions in the reference period include **professional, scientific and technical activiti**es (0.28) and **information and communication** (0.10).
- The sectors with the weakest contributions to aggregate productivity in the reference period include: **accommodation and food services** (-1.18); **administrative and support services** (-0.64; **construction** (-0.56); **manufacturing** (-0.44); and **transportation and storage** (-0.41).
- The negative contributions of **accommodation and food services** and **transportation and storage** during this period are explained by both deterioration in productivity growth (negative intra-industry productivity effect) and a reduction in size (negative allocation effect). Meanwhile, the negative contributions of **administrative and support-service activities**, **construction** and **manufacturing** are a result of their reduction in size.

Chart 1.8. Sectoral productivity: international comparison

Labour productivity growth in selected countries, 1998–2017

Economic sector	Output per worker (average annual growth rate, 1998–2017)							
	China	France	Germany	Korea	Singapore	Taiwan	US	UK
Agriculture, forestry and fishing	6.8%	3.3%	3.3%	4.5%	N/A	N/A	2.9%	2.4%
Mining and quarrying	11.6%	4.8%	4.2%	3.6%	N/A	1.1%	2.6%	-2.8%
Manufacturing	8.3%	2.5%	3.0%	7.0%	7.0%	6.0%	3.7%	2.5%
Electricity, gas, steam and air-conditioning supply	N/A	2.4%	3.9%	N/A	N/A	2.8%	N/A	0.1%
Water supply; sewerage, waste management and remediation	N/A	2.0%	2.7%	N/A	N/A	2.5%	N/A	0.2%
Construction	6.9%	2.7%	2.1%	4.5%	1.7%	-0.2%	-0.9%	0.5%
Information and communication	N/A	1.4%	1.6%	4.1%	1.1%	5.0%	6.5%	4.0%
Financial and insurance activities	6.7%	3.0%	2.9%	6.0%	4.5%	2.0%	2.3%	3.4%
Professional, scientific and technical activities	N/A	2.2%	-0.7%	3.2%	-1.0%	1.0%	1.4%	2.3%
Education	N/A	2.3%	1.1%	4.1%	N/A	1.2%	-0.4%	-1.2%
Wholesale and retail trade; repair of motor vehicles and motorcycles	7.1%	1.7%	2.4%	6.0%	4.0%	2.2%	2.1%	1.4%
Transportation and storage	7.3%	2.4%	1.9%	4.6%	1.0%	2.7%	0.6%	0.4%
Accommodation and food-service activities	N/A	2.1%	1.2%	4.7%	1.6%	-1.8%	0.0%	0.4%
Real-estate activities	N/A	3.4%	1.2%	2.4%	0.8%	2.3%	1.9%	-1.3%
Administrative and support-service activities	N/A	1.0%	0.4%	2.4%	7.6%	0.4%	N/A	2.3%
Public administration and defence; compulsory social security	N/A	2.6%	2.7%	5.0%	N/A	N/A	0.0%	0.5%
Human health and social activities	N/A	2.7%	1.6%	1.1%	N/A	-1.2%	0.6%	1.3%
Arts, entertainment and recreation	N/A	2.0%	1.0%	N/A	N/A	0.6%	0.6%	-0.5%
Activities of households	N/A	0.1%	1.5%	N/A	N/A	N/A	N/A	5.9%
Other service activities	6.9%	1.8%	0.8%	3.3%	0.9%	2.4%	-1.2%	-0.1%
Whole economy	8.9%	2.2%	1.7%	5.1%	3.1%	2.7%	1.6%	1.2%

Note: N/A not available. *2010–17 annual average is computed for Singapore.
Source: APO Productivity Database 2020 Ver.1 (5 August 2020); OECD STAN Industrial Analysis (2020 ed.); Singapore Department of Statistics; Singapore Ministry of Trade and Industry; Manpower Research and Statistics Department; Taiwan Statistical Bureau; UK Office for National Statistics; US Bureau of Economic Analysis and US Bureau of Labor Statistics.

- Between 1998 and 2017 **China** and **Korea** experienced the strongest productivity growth among the eight economies studied (8.9% and 5.1% on average per year, respectively).
- The UK showed the lowest productivity growth rate in this period. However, some UK sectors performed relatively better. Service sectors in which the UK may have comparative advantages include (average annual growth rate in brackets): **information and communication** (4.0%); **financial and insurance activities** (2.3%); **professional, scientific and technical activities** (2.3%); and **administrative and support services** (2.3%).
- In contrast, UK market sectors that performed relatively worse than those in other countries in the reference period include (average annual growth rate in brackets): **mining and quarrying** (-2.8%); **transportation and storage** (0.4%); **wholesale and retail trade** (1.4%); **and manufacturing** (2.5%).

Chart 1.9. Structural change: international comparison

Output shares in selected countries, 1998 and 2017

Country	Year	Agriculture, forestry and fishing	Mining and quarrying	Manufacturing	Utilities	Construction	Knowledge-intensive services	Other services
China	1998	19.5%	4.2%	34.9%	2.0%	6.1%	8.8%	24.5%
	2017	7.9%	2.6%	29.3%	2.0%	6.7%	14.5%	36.9%
	Change	-11.6	-1.7	-5.6	0.0	0.6	5.7	12.5
France	1998	2.7%	0.2%	16.2%	2.9%	5.0%	14.9%	58.1%
	2017	1.7%	0.1%	11.2%	2.4%	5.6%	17.0%	61.9%
	Change	-1.0	-0.1	-5.0	-0.5	0.6	2.1	3.8
Germany	1998	1.1%	0.3%	22.1%	3.0%	6.4%	15.2%	51.9%
	2017	0.9%	0.1%	22.8%	2.8%	4.7%	15.0%	53.6%
	Change	-0.2	-0.2	0.7	-0.2	-1.7	-0.1	1.7
Korea	1998	5.2%	0.3%	25.9%	2.1%	9.2%	15.4%	41.9%
	2017	2.0%	0.1%	29.5%	2.4%	6.0%	16.3%	43.6%
	Change	-3.2	-0.2	3.6	0.3	-3.2	0.9	1.8
Singapore	2005	N/A	N/A	29.3%	N/A	3.1%	19.4%	46.6%
	2017	N/A	N/A	20.6%	N/A	4.2%	23.7%	50.2%
	Change	N/A	N/A	-8.6	N/A	1.1	4.3	3.6
Taiwan	1998	2.4%	0.3%	26.1%	2.8%	4.1%	13.7%	50.5%
	2017	1.9%	0.1%	33.5%	2.0%	2.4%	12.2%	48.1%
	Change	-0.6	-0.2	7.4	-0.8	-1.7	-1.6	-2.4
US	1998	1.1%	0.9%	15.8%	1.8%	4.2%	17.8%	58.4%
	2017	0.9%	1.4%	11.2%	1.6%	4.1%	20.3%	60.5%
	Change	-0.2	0.5	-4.6	-0.2	-0.1	2.5	2.1
UK	1998	1.1%	1.5%	16.1%	2.9%	5.5%	17.0%	56.0%
	2017	0.6%	0.9%	10.2%	2.7%	6.5%	21.1%	57.9%
	Change	-0.4	-0.6	-5.9	-0.1	1.0	4.1	1.9

Source: APO Productivity Database 2020 Ver.1 (5 August 2020); OECD STAN Industrial Analysis (2020 ed.); Korea Productivity Center; Singapore Department of Statistics; Singapore Ministry of Trade and Industry; Manpower Research & Statistics Department; Taiwan Statistical Bureau; UK Office for National Statistics; US Bureau of Economic Analysis and US Bureau of Labor Statistics..

- The **shrinking of manufacturing** is a major structural change observed in most of the economies examined between 1998 and 2017.
- The biggest declines in **manufacturing** shares were recorded in (changes in percentage points in brackets): **Singapore** (-8.6), the **UK** (-5.9%) and **China** (-5.6). There have, however, been some exceptions. **Manufacturing** output shares expanded in **Germany** (0.7), **Korea** (3.6) and **Taiwan** (7.4). And while **Singapore** reported the largest decline in manufacturing output shares among the countries examined (-8.6), this trend has reverted in the years since 2017.
- Meanwhile, **service activities** have expanded in most of the countries analysed. This is true for both **knowledge-intensive services** and **other services** (see note).
- The largest expansions in output shares of **knowledge-intensive activities** were seen in (changes in percentage points in brackets): **China** (5.7), **Singapore** (4.3) and **the UK** (4.1). **Other service activities** have also expanded; changes range from 1.7 percentage points in **Germany** to 12.5 in **China**.

Note: Knowledge-intensive services group together information and communication, financial and insurance activities, professional, scientific and technical activities, and education, with the exception of China, which only groups together financial and insurance activities. Other services include wholesale and retail, transportation and storage, accommodation and food-service activities, real-estate activities, administrative and support-service activities, public administration and defence, human health and social work activities, arts, entertainment and recreation, and other service activities, with the exception of China, which groups together wholesale and retail, transportation and storage, and community, social and personal services.

Chart 1.10. Sectoral contribution to aggregate productivity growth: international comparison (1/2)

Decomposition based on output per worker measures, selected countries, 1998–2017

Intra-industry productivity growth effect (Annual average 1998–2017)								
Economic sector	China	France	Germany	Korea*	Singapore**	Taiwan	US	UK
Agriculture, forestry and fishing	0.74	0.07	0.03	0.10	-0.11	N/A	0.03	0.02
Mining and quarrying	0.51	0.01	0.01	0.00		0.00	0.06	-0.06
Utilities	0.31	0.06	0.09	0.12		0.06	0.03	0.00
Manufacturing	2.66	0.35	0.63	1.61	1.50	1.82	0.51	0.33
Construction	0.42	0.14	0.09	0.22	0.10	0.00	-0.04	0.03
Knowledge-intensive services	0.69	0.47	0.23	0.50	0.52	0.44	0.55	0.52
Other services	2.23	1.29	0.82	1.52	1.34	0.76	0.60	0.21
Whole economy	7.56	2.38	1.90	4.06	3.34	3.03	1.74	1.05

Allocation effect (Annual average 1998–2017)								
Economic sector	China	France	Germany	Korea*	Singapore**	Taiwan	US	UK
Agriculture, forestry and fishing	-0.25	-0.07	-0.03	-0.09	0.13	N/A	-0.04	-0.04
Mining and quarrying	-0.17	-0.01	-0.01	0.00		-0.01	-0.02	0.03
Utilities	0.00	-0.02	-0.05	-0.03		-0.04	-0.02	0.03
Manufacturing	-0.12	-0.31	-0.21	-0.24	-1.02	-0.67	-0.55	-0.50
Construction	0.16	0.02	-0.08	-0.03	-0.15	-0.04	0.12	0.11
Knowledge-intensive services	0.55	0.10	0.11	0.19	0.29	-0.23	-0.06	0.03
Other services	1.21	0.08	0.09	0.39	0.54	0.38	0.39	0.43
Whole economy	1.34	-0.21	-0.18	0.19	-0.22	-0.61	-0.19	0.10

Total contribution to productivity growth (Annual average 1998–2017)								
Economic sector	China	France	Germany	Korea*	Singapore**	Taiwan	US	UK
Agriculture, forestry and fishing	0.49	0.00	0.01	0.00	0.00	N/A	0.00	-0.01
Mining and quarrying	0.33	0.00	0.00	0.00		-0.01	0.04	-0.03
Utilities	0.31	0.04	0.04	0.09		0.02	0.01	0.03
Manufacturing	2.54	0.03	0.42	1.37	0.48	1.15	-0.04	-0.17
Construction	0.59	0.16	0.01	0.19	-0.06	-0.04	0.07	0.14
Knowledge-intensive services	1.24	0.57	0.34	0.69	0.81	0.21	0.49	0.55
Other services	3.44	1.37	0.91	1.91	1.88	1.14	0.99	0.65
Whole economy	8.90	2.17	1.72	4.26	3.12	2.43	1.55	1.15

Note: Decomposition based on output per worker. Figures may not add up to total because of rounding. *For Korea, the 2005–17 annual average is computed; ** for Singapore, the 2010–17 annual average is computed.

Source: Authors' computation based on data from APO Productivity Database 2020 Ver.1 (5 August 2020); OECD STAN Industrial Analysis (2020 ed.); Korea Productivity Center; Singapore Department of Statistics; Singapore Ministry of Trade and Industry; Manpower Research & Statistics Department; Taiwan Statistical Bureau; UK Office for National Statistics; US Bureau of Economic Analysis and US Bureau of Labor Statistics.

- As a result of its high productivity growth rates and relatively large output shares, manufacturing is one of the sectors with the largest contributions to aggregate productivity growth in the best-performing countries.
- Manufacturing was responsible for around 30% of the aggregate productivity growth in **China** and almost half of the productivity growth recorded in **Taiwan** during 1998–2017. Manufacturing also contributed to around 30% of the aggregate productivity growth in **Korea** between 2005 and 2017 and 15% of the productivity growth in **Singapore** between 2010 and 2017.
- In contrast, manufacturing had a negative contribution to aggregate productivity growth in the **UK** during this period, mainly due to a reduction in its participation in the economy (as reflected in a negative allocation effect of -0.5, on average).
- This means that the loss of manufacturing imposed a penalty on **UK** productivity growth of half a percentage point per year between 1998 and 2017.
- Another distinctive feature of the UK economy is a lower intra-industry productivity growth effect (due to lower productivity growth) than the other countries analysed across most sectors.

Chart 1.10. Sectoral contribution to aggregate productivity growth: international comparison (2/2)

Decomposition based on output per worker measures, selected countries, 1998–2017

Intra-industry productivity growth effect (Annual average 1998–2017)								
Economic sector	China	France	Germany	Korea*	Singapore**	Taiwan	US	UK
Agriculture, forestry and fishing	0.74	0.07	0.03	0.10	-0.11	N/A	0.03	0.02
Mining and quarrying	0.51	0.01	0.01	0.00		0.00	0.06	-0.06
Utilities	0.31	0.06	0.09	0.12		0.06	0.03	0.00
Manufacturing	2.66	0.35	0.63	1.61	1.50	1.82	0.51	0.33
Construction	0.42	0.14	0.09	0.22	0.10	0.00	-0.04	0.03
Knowledge-intensive services	0.69	0.47	0.23	0.50	0.52	0.44	0.55	0.52
Other services	2.23	1.29	0.82	1.52	1.34	0.76	0.60	0.21
Whole economy	7.56	2.38	1.90	4.06	3.34	3.03	1.74	1.05

Allocation effect (Annual average 1998–2017)								
Economic sector	China	France	Germany	Korea*	Singapore**	Taiwan	US	UK
Agriculture, forestry and fishing	-0.25	-0.07	-0.03	-0.09	0.13	N/A	-0.04	-0.04
Mining and quarrying	-0.17	-0.01	-0.01	0.00		-0.01	-0.02	0.03
Utilities	0.00	-0.02	-0.05	-0.03		-0.04	-0.02	0.03
Manufacturing	-0.12	-0.31	-0.21	-0.24	-1.02	-0.67	-0.55	-0.50
Construction	0.16	0.02	-0.08	-0.03	-0.15	-0.04	0.12	0.11
Knowledge-intensive services	0.55	0.10	0.11	0.19	0.29	-0.23	-0.06	0.03
Other services	1.21	0.08	0.09	0.39	0.54	0.38	0.39	0.43
Whole economy	1.34	-0.21	-0.18	0.19	-0.22	-0.61	-0.19	0.10

Total contribution to productivity growth (Annual average 1998–2017)								
Economic sector	China	France	Germany	Korea*	Singapore**	Taiwan	US	UK
Agriculture, forestry and fishing	0.49	0.00	0.01	0.00	0.00	N/A	0.00	-0.01
Mining and quarrying	0.33	0.00	0.00	0.00		-0.01	0.04	-0.03
Utilities	0.31	0.04	0.04	0.09		0.02	0.01	0.03
Manufacturing	2.54	0.03	0.42	1.37	0.48	1.15	-0.04	-0.17
Construction	0.59	0.16	0.01	0.19	-0.06	-0.04	0.07	0.14
Knowledge-intensive services	1.24	0.57	0.34	0.69	0.81	0.21	0.49	0.55
Other services	3.44	1.37	0.91	1.91	1.88	1.14	0.99	0.65
Whole economy	8.90	2.17	1.72	4.26	3.12	2.43	1.55	1.15

Note: Decomposition based on output per worker. Figures may not add up to total because of rounding. *For Korea, the 2005–17 annual average is computed; ** for Singapore, the 2010–17 annual average is computed.

Source: Authors' computation based on data from APO Productivity Database 2020 Ver.1 (5 August 2020); OECD STAN Industrial Analysis (2020 ed.); Korea Productivity Center; Singapore Department of Statistics; Singapore Ministry of Trade and Industry; Manpower Research & Statistics Department; Taiwan Statistical Bureau; UK Office for National Statistics; US Bureau of Economic Analysis and US Bureau of Labor Statistics.

- Across the countries studied, **the contraction of the manufacturing sector has been mirrored by a greater contribution of services to aggregate productivity growth**.
- Between 1998 and 2017, the contribution of **knowledge-intensive services** was positive in all of the countries analysed (ranging from 0.2 in **Taiwan** to 0.55 in the **UK** and 1.2 in **China**). The positive contribution of **knowledge-intensive services** is mainly explained by high productivity growth rates (as reflected in positive intra-industry productivity growth effects).
- In comparison, **other services** contributed less to aggregate productivity growth in the **UK** than they did in the other seven countries during this period. The contribution of **other services** to **UK** productivity growth was 0.65, compared to 3.44 in **China**, 1.91 in **Korea** and 1.88 in **Singapore**.

Note: Knowledge-intensive services group together information and communication, financial and insurance activities, professional, scientific and technical activities, and education, with the exception of China, which only groups together financial and insurance activities. Other services include wholesale and retail, transportation and storage, accommodation and food-service activities, real-estate activities, administrative and support-service activities, public administration and defence, human health and social work activities, arts, entertainment and recreation, and other service activities, with the exception of China, which groups together wholesale and retail, transportation and storage, and community, social and personal services.

Theme 2: Investment in innovation

UK INNOVATION REPORT 2022

Theme 2: Policy questions and key messages

- **Is the UK spending enough on R&D?**
- **How do the public and private sectors contribute to national expenditure on innovation?**
- **How does the UK compare with other countries?**

The UK spends less on R&D than the OECD average; a significant increase in public funding for R&D has been announced but delayed

- At 1.74%, the UK's gross domestic expenditure on R&D (GERD) remains well below the 2019 OECD average of 2.5%.
- The UK's expenditure on R&D has risen steadily over the past decades but, as a proportion of GDP, its growth has been slower than the OECD average.
- The UK government has committed to investing £22 billion in R&D by 2026/27 (pushing back the original target date of 2024).

Compared to other countries, the business sector in the UK contributes less to R&D funding; universities perform significantly more of the country's R&D and the government significantly less

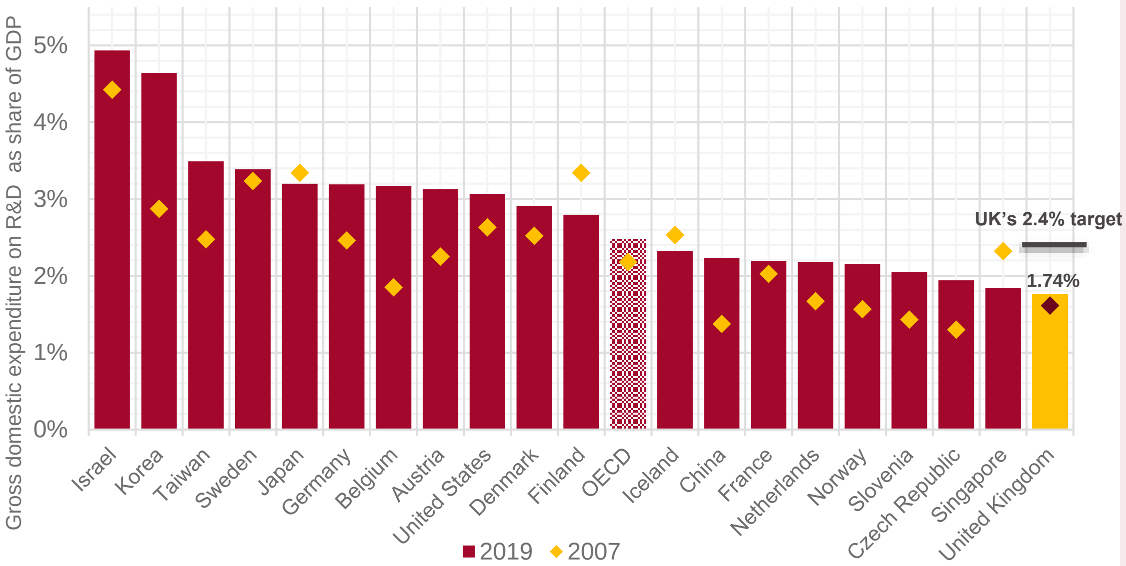
- In the UK the business sector funds around **55%** of R&D – less than in Germany (64.5%), Korea (76.9%) and Japan (78.9%).
- The UK's higher education sector stands out from comparator countries, performing 23.1% of the country's R&D in 2019, compared to 20.1% in France and 17.4% in Germany.
- The government sector in the UK performs only 6.6% of R&D, well below comparator countries.

Very few firms headquartered in the UK are global leaders in R&D investment and patent applications

- Only two companies headquartered in the UK are among the top 100 R&D investing firms in 2020.
- Among the top 2,500 R&D investing firms in the world, only 105 were UK-based in 2020 (779 were based in the USA, 597 in China, 293 in Japan and 124 in Germany).
- There were no firms headquartered in the UK among the top 100 patent applicants at the United States Patent and Trademark Office (USPTO) in 2020.

Chart 2.1. R&D expenditure: international comparison

Gross domestic expenditure on R&D (GERD) as a share of GDP, selected countries, 2019 or latest available

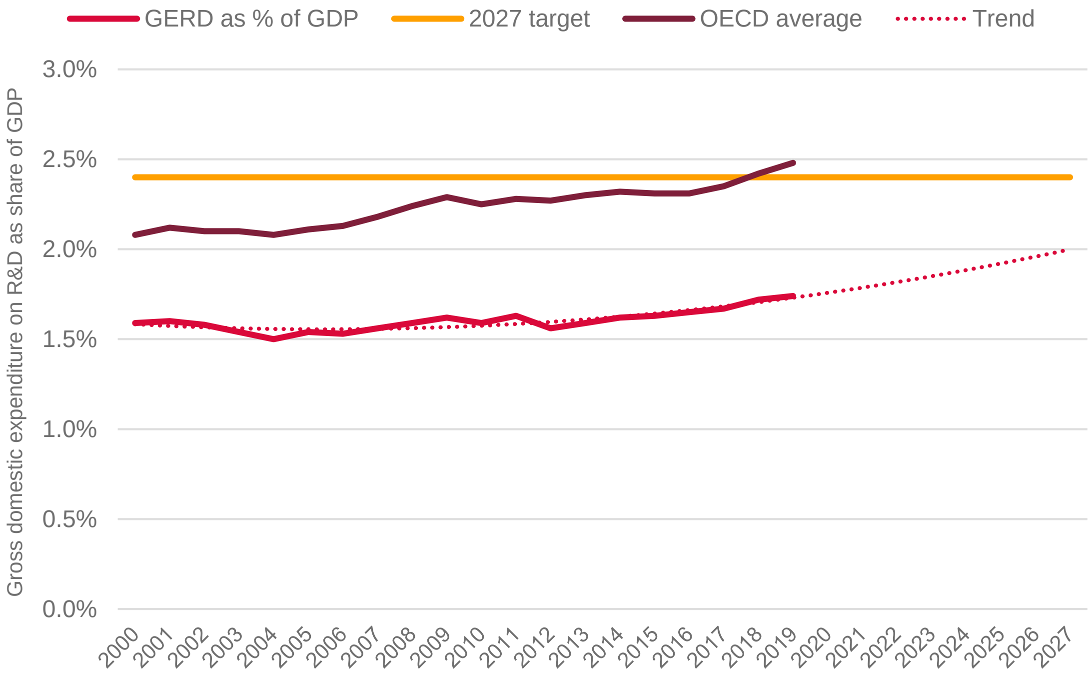


Source: OECD (2021). Main Science and Technology Indicators.

- At 1.74%, the UK's gross domestic expenditure on R&D (GERD) remains well below the 2019 OECD average of 2.5%.
- The UK spends less on R&D as a percentage of GDP than OECD countries, including **Israel, Korea**, **Japan**, **Germany** and the **United States**.
- The UK also spends less than non-OECD countries such as **China** and **Singapore**.
- The UK government has set a target to boost investment in R&D to 2.4% of GDP by 2027. This includes a commitment to increasing public funding for R&D to £22 billion per year by 2026/27.

Chart 2.2. Actual UK R&D expenditure against 2.4% target

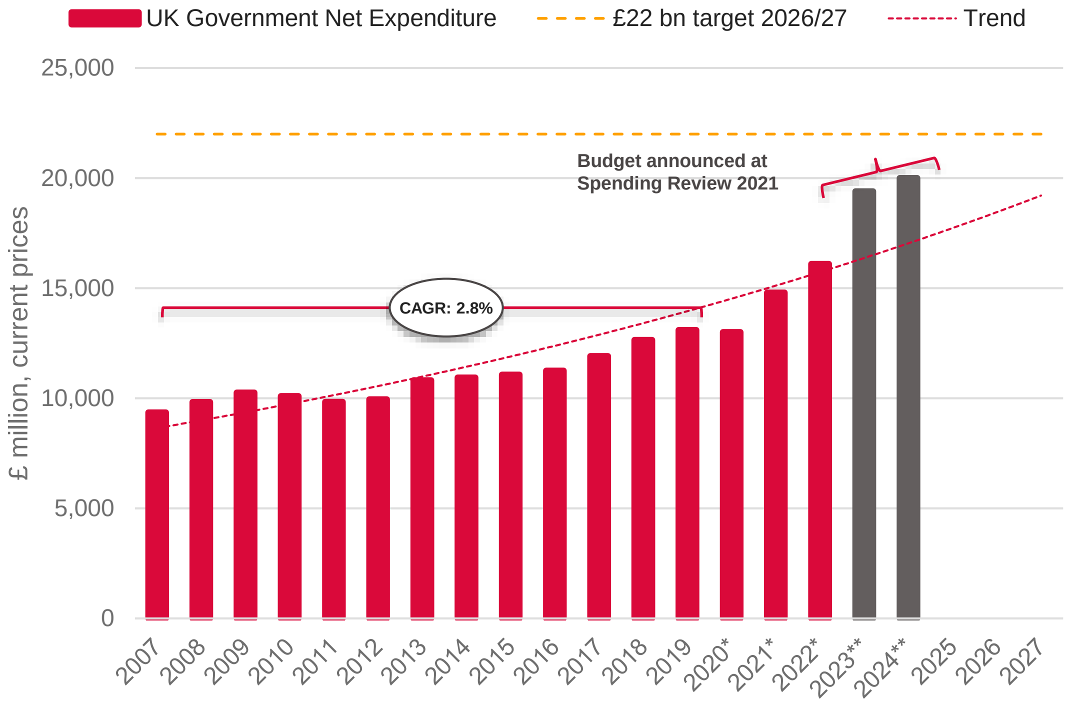
Gross domestic expenditure on R&D (GERD) as a share of GDP, 2000–2019



Source: Office for National Statistics (2021). Gross domestic expenditure on research and development time series (GERD).

- The UK's gross domestic expenditure on R&D (GERD) as a share of GDP increased from 1.59% in 2000 to 1.74% in 2019.
- This represents an average annual growth rate of 0.5%, while the **OECD average** grew at an annual rate of 0.9%.
- To narrow the gap between the UK's GERD and the OECD average, the UK's 2017 Industrial Strategy committed to spending 2.4% of GDP on R&D by 2027.

Chart 2.3. UK government net expenditure on R&D against the 2026/2027 £22 billion target



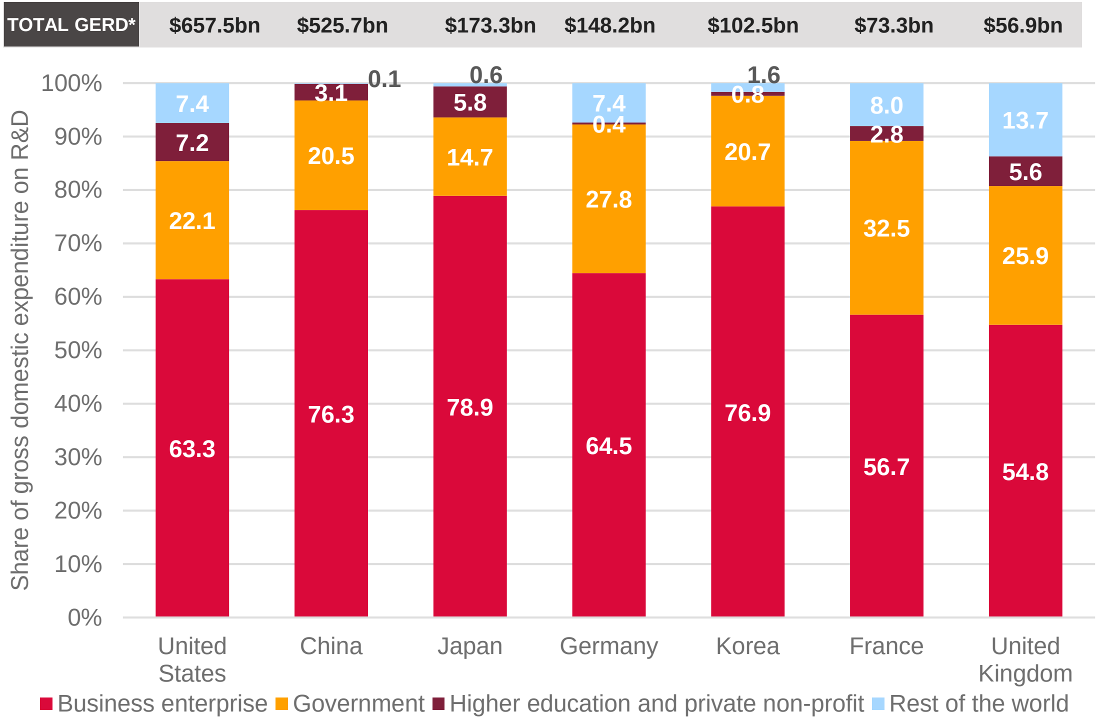
Note: * Estimated. ** Budget announced at Spending Review 2021.
Net R&D expenditure is defined as: "In-house R&D plus purchased or funding provided for R&D less funding received for R&D" (ONS).

Source: Office for National Statistics, ONS (2021). Research and development expenditure by the UK government; HM Treasury (2021). Spending Review 2021.

- From 2007 to 2019 the UK government's net expenditure increased from £9.8 billion to £13.1 billion in current prices. This represents an annual growth rate of 2.8%.
- The government net expenditure in 2020, however, was expected to be lower than in 2019.
- Reaching the £22 billion target would require an annual increase by more than 10% in the next four years.
- In the March 2020 Budget the government announced that public R&D expenditure would rise to £22 billion by 2024/25.
- However, in the 2021 Autumn Budget and Spending Review, the date to reach the £22 billion target was pushed back to 2026/27.
- Reaching the 2.4% target (R&D investment as a percentage of GDP) will require a significant increase in private investment, in addition to public investment.

Chart 2.4. R&D expenditure by source of funding

Share of gross domestic expenditure on R&D (GERD), 2019 or latest available

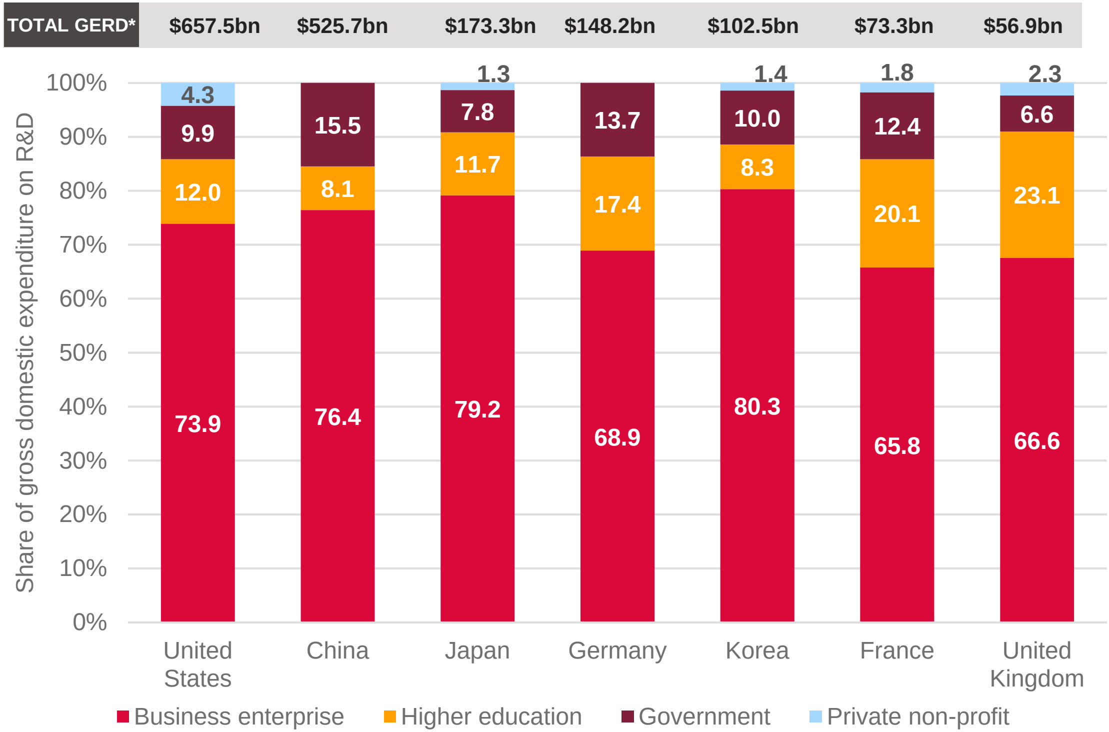


Note: *US$ billion PPP – current prices. 2018 data for the UK.
Source: OECD (2021). Main Science and Technology Indicators database.

- In the UK the business sector contributes to around 55% of R&D funding. This is less than in comparator countries, such as **Germany** (64.5%), **Korea** (76.9%) and **Japan** (78.9%).
- The UK government (including national and regional governments, as well as their agencies) funds roughly 26% of total R&D expenditure, which is higher than **Japan**, **Korea** and **China**.
- The UK has a relatively high share of R&D funded by businesses and institutions located abroad (13.7% in 2018).

Chart 2.5. R&D expenditure by sector of performance

Share of gross domestic expenditure on R&D (GERD), 2019 or latest available



Note: *US$ billion PPP – current prices.
Source: OECD (2021). Main Science and Technology Indicators database.

- In terms of R&D expenditure by sector of performance, the UK's higher education sector stands out from comparator countries**,** with a 23.1% share in 2019, above countries like **China**, **Korea**, **Japan**, **the United States**, **Germany** and **France**.
- Conversely, the government sector in the UK performs only 6.6% of R&D, well below comparator countries.
- In line with comparator countries, the business enterprise sector performs the highest share of R&D, at 66.6% in the UK in 2019.

Chart 2.6. UK government net expenditure on R&D by department

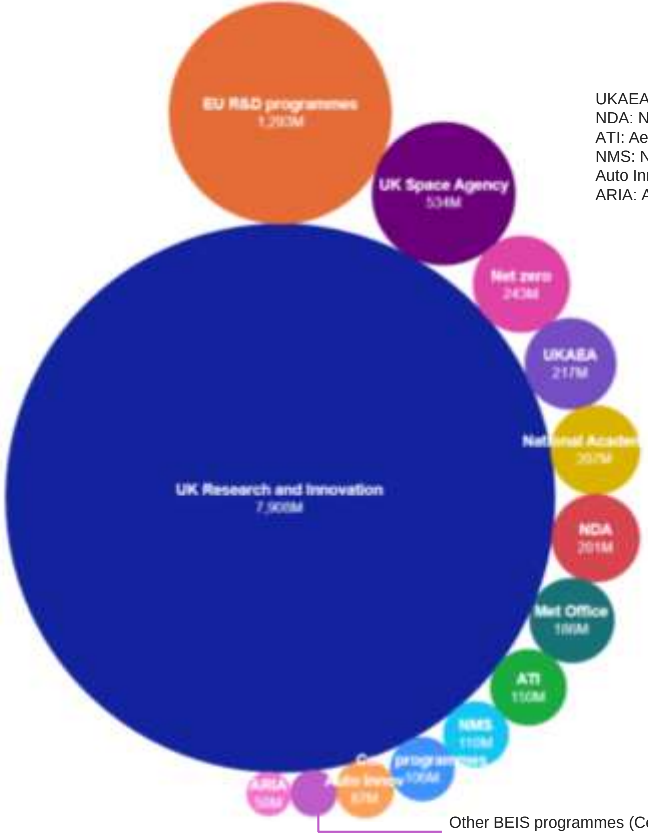
2016–2019 (£ million current prices)

Department		2016 £ m	2016 %	2017 £ m	2017 %	2018 £ m	2018 %	2019 £ m	2019 %
Research councils	UKRI includes all seven research councils and Innovate UK					4,756	37.6%	5,024	38.4%
	Engineering and Physical Sciences (EPSRC)	818	7.3%	830	7.0%				
	Medical (MRC)	649	5.8%	716	6.0%				
	Science and Technology Facilities (STFC)	621	5.5%	645	5.4%				
	Natural Environment (NERC)	402	3.6%	476	4.0%				
	Biotechnology and Biological Sciences (BBSRC)	422	3.7%	473	4.0%				
	Economic and Social (ESRC)	176	1.6%	190	1.6%				
	Arts and Humanities (AHRC)	101	0.9%	102	0.9%				
	Pensions	65	0.6%	70	0.6%	74	0.6%	70	0.5%
	Total	**3,254**	**28.9%**	**3,502**	**29.4%**	**4,830**	**38.2%**	**5,094**	**38.9%**
Higher education funding councils (HEFCs)	Research England (part of UKRI)		0.0%		0.0%	2,050	16.2%	2389	18.2%
	England (HEFCE)	1,783	15.8%	1,803	15.1%	-		-	
	Scotland (SFC)	285	2.5%	299	2.5%	309	2.4%	311	2.4%
	Wales (HEFCW)	86	0.8%	82	0.7%	88	0.7%	95	0.7%
	Northern Ireland (DELNI)	53	0.5%	53	0.4%	53	0.4%	68	0.5%
	Total	**2,207**	**19.6%**	**2,236**	**18.8%**	**2,499**	**19.8%**	**2,863**	**21.9%**
Civil departments	National Health Service (NHS)	1,043	9.3%	1,126	9.5%	1,191	9.4%	1,215	9.3%
	Business, Energy and Industrial Strategy (BEIS)	1,330	11.8%	1,579	13.3%	721	5.7%	1,022	7.8%
	International Development (DFID)	328	2.9%	394	3.3%	398	3.1%	394	3.0%
	Other civil departments	548	4.9%	482	4.0%	517	4.1%	559	4.3%
	Total	**3,249**	**28.9%**	**3,581**	**30.1%**	**2,827**	**22.4%**	**3,190**	**24.4%**
Ministry of Defence (MoD)		1,623	14.4%	1,634	13.7%	1,647	13.0%	1,017	7.8%
Indicative UK contributions to EU R&D expenditure		921	8.2%	961	8.1%	841	6.7%	935	7.1%
Grand total		11,255	100.0%	11,914	100.0%	12,644	100.0%	13,098	100.0%

Note: HEFCE closed in 2018 and its functions were divided between the Office for Students and Research England.
Source: Office for National Statistics, ONS (2021). Research and development expenditure by the UK government.

- In 2019 most (38.9%) of the UK government net expenditure on R&D was allocated to UK research and innovation (UKRI). This represents an increase by 10 percentage points in comparison to the proportion spent by research councils in 2016.
- The proportion of government expenditure on R&D by higher education funding councils also increased, from 19.6% in 2016 to 21.9% in 2019.
- Meanwhile, the absolute and relative expenditure on R&D of civil departments decreased from £3,249 million (28.9%) in 2016 to £3,190 million (24.4%) in 2019.

Chart 2.7. BEIS R&D funding allocation, 2021–2022



UKAEA: UK Atomic Energy Authority
NDA: Nuclear Decommissioning Authority
ATI: Aerospace Technologies Institute
NMS: National Measurement System
Auto Innov: Automotive Innovation Programmes
ARIA: Advanced Research & Invention Agency

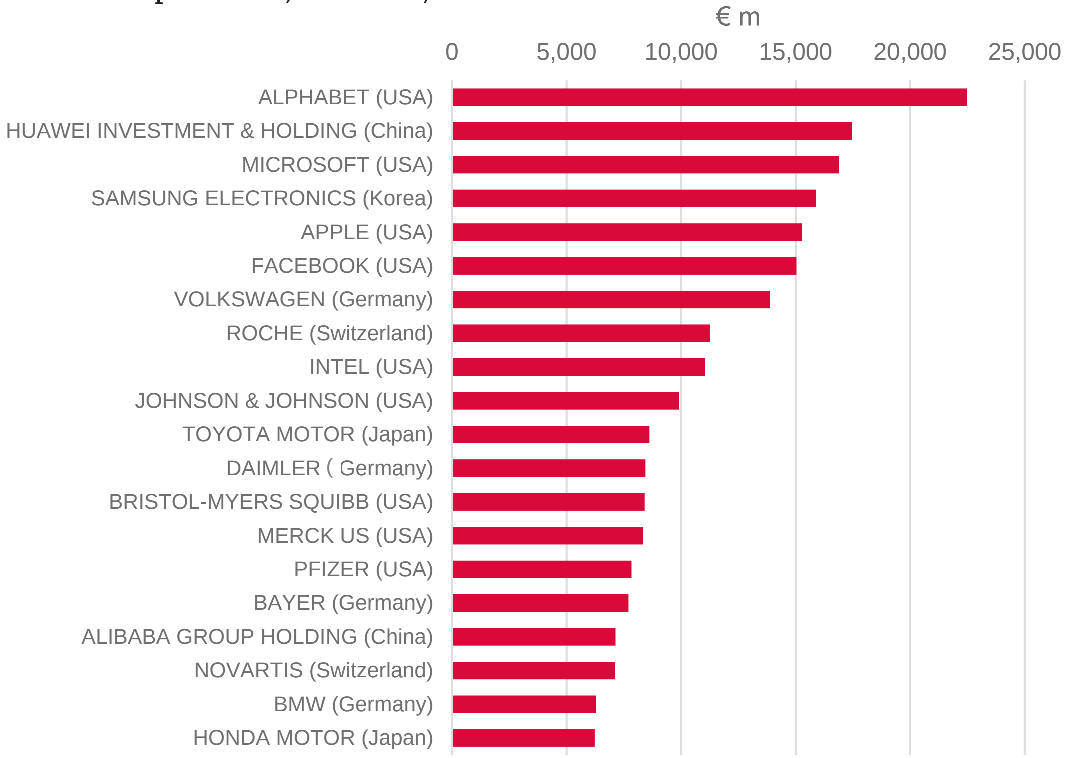
Other BEIS programmes (Centre for Connected Autonomous Vehicles, Knowledge Assets, GO-Science and MPI UK)

Source: BEIS (2021). BEIS research and development (R&D) budget allocations 2021 to 2022.

- Most of the public expenditure on R&D in the UK is delivered through the Department of Business, Energy and Industrial Strategy (BEIS), which allocates funding to different agencies and programmes, including UKRI, the UK Space Agency and the National Academies.
- UKRI funding includes the investments of the seven research councils, Research England and Innovate UK.
- In the March 2020 Budget the UK government committed to the creation of the Advanced Research and Invention Agency (ARIA), an independent research body to fund high-risk, high-reward scientific research.
- The commitment to create ARIA involves an allocation of £800 million over the next four years. From this amount, £50 million is included in the 2021–22 Budget.

Chart 2.8. Top 20 R&D investing companies in the world

R&D expenditure, € million, 2020



Source: European Commission (2021). The 2021 EU Industrial R&D Investment Scoreboard.

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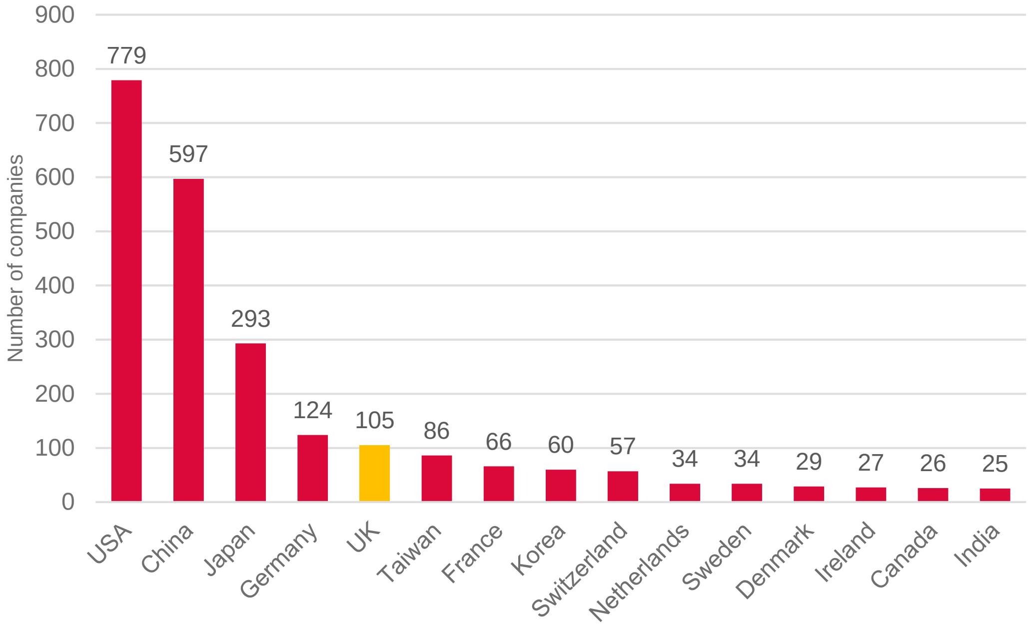
- The chart shows the top 20 R&D investing companies in 2020.[1]
- The **USA** (nine companies) and **Germany** (four companies) are followed by companies based in **Japan, Switzerland, China and Korea**.
- Industries of specialisation include: **pharmaceuticals and biotechnology; automobiles and parts; software and computer services; technology hardware and equipment;** and **electronic and electrical equipment.**[2]

[1] R&D investing companies are the 2,500 firms that invested the largest sums in R&D worldwide in 2020, as defined in the *EU Industrial R&D Investment Scoreboard.* Those companies have headquarters in 39 countries and represent 90% of the expenditure in R&D by the business sector in 2020.

[2] Sectors are defined according to the Industry Classification Benchmark (ICB) FTSE International.

Chart 2.9. Top R&D investing companies worldwide

Number of companies, top 15 countries, 2020

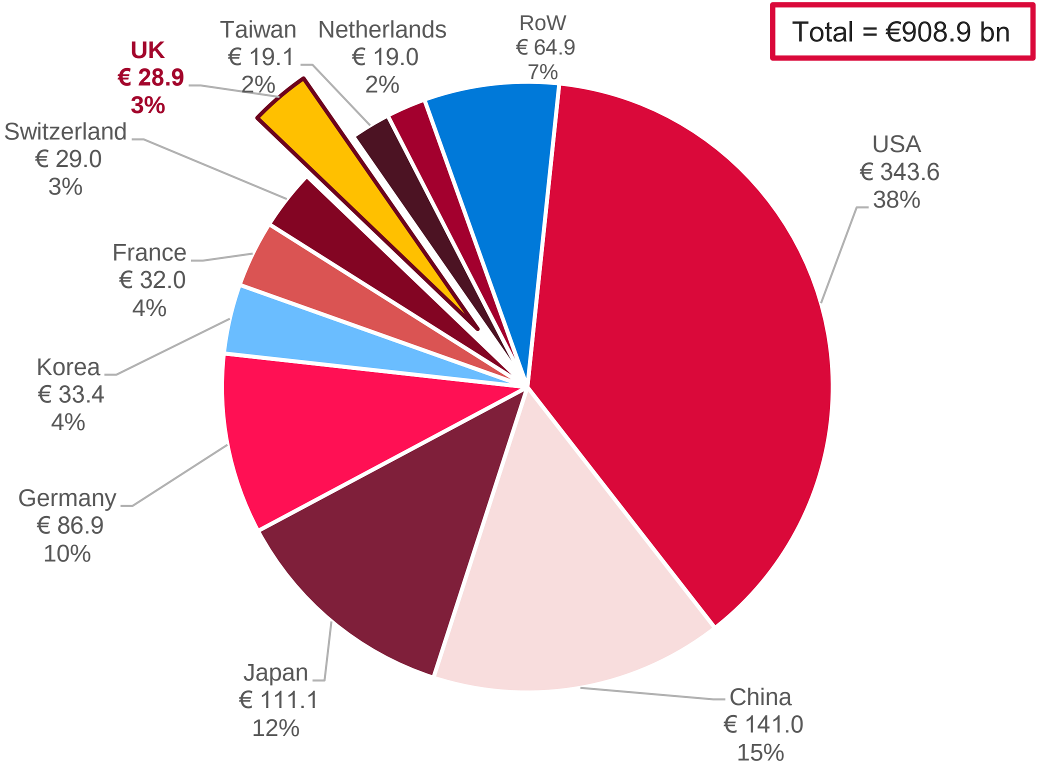


Note: R&D investing companies are the 2,500 firms that invested the largest sums in R&D worldwide in 2020, as defined in the *EU Industrial R&D Investment Scoreboard*. These companies have headquarters in 39 countries and represent 90% of the expenditure in R&D by the business sector in 2020.
Source: European Commission (2021). The 2021 EU Industrial R&D Investment Scoreboard.

- The chart shows how the 2,500 companies that invested the largest sum in R&D in 2020 are distributed across countries, focusing on the top 15 countries.
- There were 105 companies with headquarters in the UK among the top 2,500 R&D investing companies in 2020.
- Most of the top R&D investing companies have headquarters in the **USA** (779), **China** (597) and **Japan** (293), accounting for 66.8% of the total 2,500 R&D investing companies worldwide.
- **Germany** has 124 firms among the top R&D investing companies, accounting for 31% of the top R&D investing firms based in the **European Union**.

Chart 2.10. Expenditure of top R&D investing companies

€ billion, percentage, 2020



Note: RoW = rest of the world; R&D investing companies are the 2,500 firms that invested the largest sums in R&D worldwide in 2020, as defined in the *EU Industrial R&D Investment Scoreboard*. These companies have headquarters in 39 countries and represent 90% of the expenditure in R&D by the business sector in 2020.
Source: European Commission (2021). The 2021 EU Industrial R&D Investment Scoreboard.

- In 2020 the top 2,500 R&D investing companies worldwide invested a total of €908.9 billion in research and development activities, as reported in the EU Industrial R&D Investment Scoreboard.[1]
- Companies headquartered in the **USA** invested €343,6 billion, accounting for 38% of the total expenditure worldwide and more than what companies based in **China, Japan** and **Germany** invested all together.
- R&D investing companies based in the UK invested €28.9 billion, making the UK the eighth in the world country rank.

[1] The 2,500 R&D investing companies have headquarters in 39 countries and own around 800,000 subsidiaries around the world. The *EU Industrial R&D Investment Scoreboard,* however, reports R&D investment data, as reported by the 2,500 companies, regardless of where research and development activities are conducted.

Chart 2.11. Top 10 UK companies investing in R&D

R&D expenditure, € million, 2020

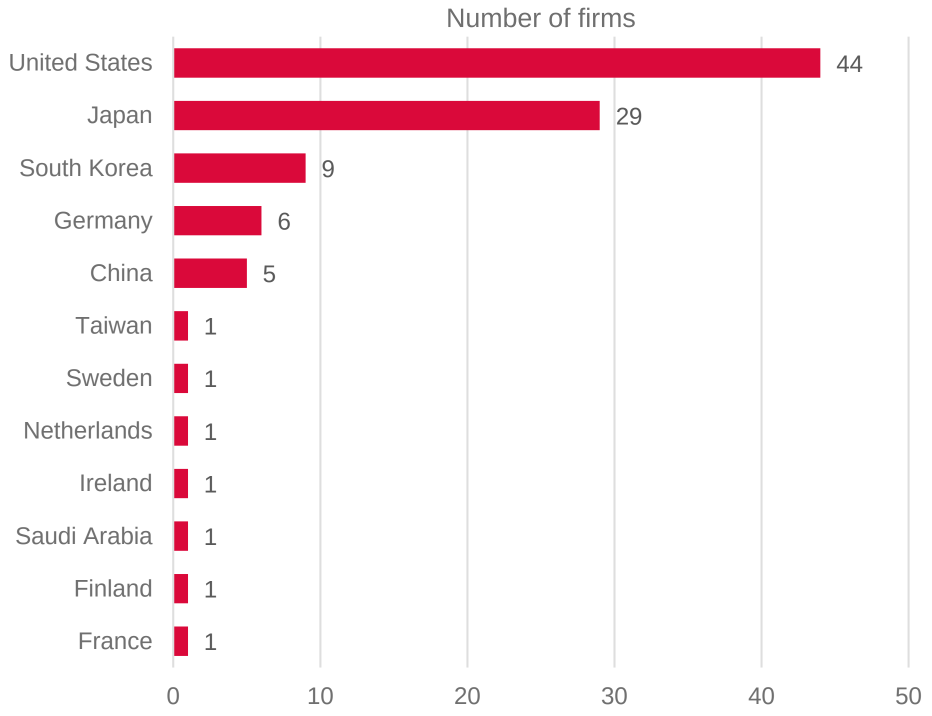
World rank	Company	Industry	R&D 2020 (€ m)
29	GLAXOSMITHKLINE	Pharmaceuticals and biotechnology	5,034
31	ASTRAZENECA	Pharmaceuticals and biotechnology	4,896
101	HSBC	Banks	1,576
145	LLOYDS BANKING	Banks	1,084
163	ROLLS-ROYCE	Aerospace and defence	983
193	APTIV	Automobiles and parts	834
207	UNILEVER	Food producers	800
214	ATLASSIAN CORPORATION	Software and computer services	785
227	ROYAL DUTCH SHELL	Oil and gas producers	739
238	BARCLAYS	Banks	706

Note: The 2021 edition of the *Scoreboard* covers 2,500 firms that invested the largest sums in R&D worldwide in 2020. These companies have headquarters in 39 countries and represent 90% of the expenditure in R&D by the business sector in 2020
Source: European Commission (2021). The 2021 EU Industrial R&D Investment Scoreboard.

- The chart shows the top 10 companies headquartered in the UK, which are among the 2,500 firms that invested the most in R&D in 2020, as reported by the 2021 EU Industrial R&D Investment Scoreboard.
- The first two UK-based firms among the world leaders investing in R&D in 2020 belong to the pharmaceuticals sector, with GSK and AstraZeneca ranking 29 and 31 worldwide, respectively.
- The UK top 10 R&D investing companies invested a total of €17.4 billion. However, those companies may have several subsidiaries around the world, while the 2021 EU Industrial R&D Investment Scoreboard reports data on R&D, regardless of where the research and development activities are conducted, whether in the UK or abroad.

Chart 2.12. Top 100 patent applicant firms at USPTO

Number of firms, country of headquarters, United States Patent and Trademark Office, 2020



Note: The analysis includes patents published with the USPTO in 2020.
Source: Patent data was retrieved from Lens.org (2021)

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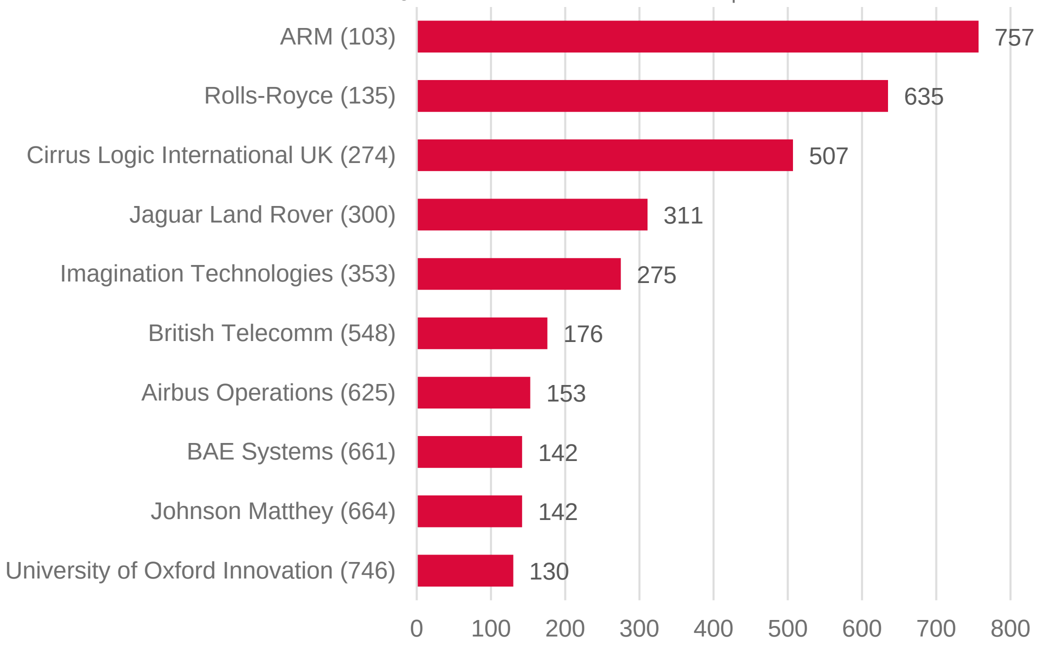
- The chart shows the top 100 patent applicant firms per country for patents published with the USPTO in 2020.[1]
- More than 70% of all top 100 patent applicants are represented by companies based in the **USA** (44) and **Japan** (29).
- Companies from **Korea** (9), **Germany** (6) and **China** (5) are also represented among the top 100 patent applicants in the USPTO in 2020.
- The top 10 patent applicants at the USPTO include the following firms: IBM, Intel, Apple, Microsoft, Qualcomm (USA); Samsung Electronics, LG Electronics (Korea); Canon (Japan), Huawei (China); and Taiwan Semiconductor (Taiwan).

[1] The United States Patent and Trademark Office (USPTO) is the second largest patent office globally, second only to the National Intellectual Property Administration of the People's Republic of China. USPTO data is widely used in academia and policy-making and makes analyses comparable. The USA is the country that best represents global technological developments, and therefore they would most naturally be considered when applicants want to protect their invention. USPTO data is also known to be of high quality and well accessible. For a comparison of patent data sources, see Kim J. and Lee S. (2015). Patent databases for innovation studies: A comparative analysis of USPTO, EPO, JPO and KIPO. *Technological Forecasting and Social Change,* Volume 92, pp. 332–345.

Chart 2.13. UK top 10 patent applicants at USPTO

Firms with headquarters in the UK, number of patents, United States Patent and Trademark Office, 2020



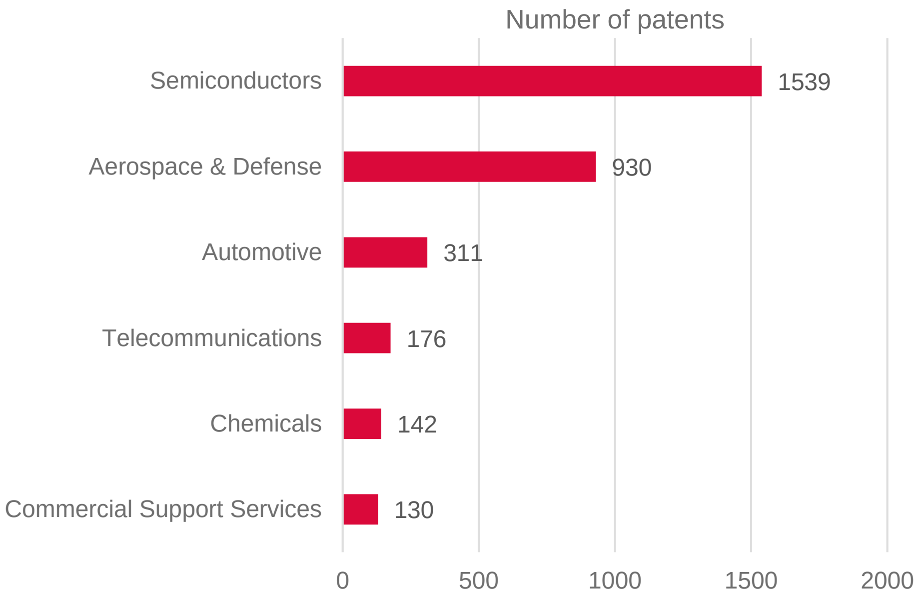
Note: The number in brackets indicates the world ranking; the analysis includes patents published with the USPTO in 2020.
Source: Patent data was retrieved from Lens.org (2021)

- The chart shows the UK top 10 patent applicant firms for patents published in 2020 with the USPTO.
- There is no company with headquarters in the UK among the top 100 patent applicants at USPTO for 2020.[1]
- ARM is the top UK patent applicant, ranking 103 globally among the top USPTO patent applicants in 2020.
- The second-best UK applicant is Rolls-Royce (635 patents), which ranks the company 135th among the top USPTO patent applicants.
- The presence of few companies with headquarters in the UK among the top patenting firms worldwide is consistent with analyses conducted by the European Commission and the OECD, covering the world's five largest patent IP offices.[2]

[1] A similar analysis was conducted for 2019 and 2018, and companies with headquarters in the UK were not among the top 100 applicants firms for patents published at the USPTO.
[2] Amoroso et al. (2021). World Corporate Top R&D investors: Paving the way for climate neutrality. A joint JRC and OECD report.

Chart 2.14. Top 10 UK patent applicants at USPTO by industry

UK firms, number of patents, United States Patent and Trademark Office, 2020



Note: The analysis includes patents published with the USPTO in 2020.
Source: Patent data was retrieved from Lens.org (2021)

- The chart shows the top 10 UK patent applicants for patents published in 2020 with the USPTO by industry.[1]
- The majority of top 10 UK patent applicants in the USPTO in 2020 were companies in the field of **semiconductors** and **aerospace and defence**.
- Semiconductor companies account for almost half of all USPTO published patents for the top 10 UK-based applicants, with 1,539 out of 3,228 patents.
- Companies in the field of **automotive** (Jaguar Land Rover), **telecommunications** (British Telecomm), **chemicals** (Johnson Matthey) and **commercial support services** (University of Oxford Innovation) are also represented among the top 10 UK-based USPTO patent applicants.

[1] The industry classification adopts the Bloomberg Industry Classification Standard (BICS). The displayed industries match the respective “sub-industry” level, as provided by Bloomberg.

Theme 3: Industrial performance – focus on the pharmaceutical and automotive manufacturing sectors

UK INNOVATION REPORT 2022

The pharmaceutical manufacturing sector

UK INNOVATION REPORT 2022

Theme 3: Policy questions and key messages

- Are UK sectors becoming more or less competitive internationally?
- How are UK sectors performing in terms of productivity, value added and employment?
- Are UK sectors investing enough in R&D compared to their international competitors?

THE PHARMACEUTICAL MANUFACTURING SECTOR

Key UK pharmaceutical manufacturing trends in the last decade	Drivers identified in literature review and sector expert consultations
The value added and productivity of the UK pharmaceutical manufacturing sector have declined significantly in the last decade ▪ Of the top 13 countries by pharmaceutical value added in 2018, the UK is the only one to have experienced a significant productivity decline, at a rate of -7.9% per year between 2008 and 2018. **The UK trade balance in pharmaceuticals has deteriorated significantly since 2014** ▪ The UK recorded deficits in pharmaceutical product trade in all years between 2014 and 2020, except in 2015. ▪ The UK's pharma trade balance went from a $9.6 billion surplus in 2010 to a deficit of over $1 billion in 2020. **Pharma business R&D expenditure in the UK has remained stagnant in the last decade and remains significantly lower than comparator countries** ▪ The business expenditure on R&D has only grown marginally in the last decade, both in manufacturing and non-manufacturing activities. Adjusting for inflation, R&D in the Pharmaceutical Product Group in 2020 was still only 83% of its peak in 2011. The sector spent only 6% more in 2018 than it did in 2008, compared to increases of around 30% in the US and Germany, and over 100% in Korea. ▪ On average, between 2014 and 2020, 50% of the pharmaceutical R&D performed in the UK was conducted by foreign-owned businesses.	➢ Company restructuring and site closures, including those by major sector employers; ➢ Increased offshoring of pharmaceutical manufacturing, including a large share of APIs; ➢ The UK's inability to capture the "second wave" of international manufacturing investments; ➢ Greater incentives (e.g. tax) offered by other countries to attract manufacturing; ➢ New entrants focusing on early-stage drug discovery and non-manufacturing activities; ➢ An inability to commercialise and scale up the manufacture of technologies developed in the UK; ➢ Caps on drug spending having an impact on the perception of the UK by investors; ➢ Increased use of generics pushing prices downwards and driving imports upwards; ➢ The 2016 EU membership referendum adding uncertainty to investment decisions; ➢ The large share of domestic business R&D expenditure decisions taken abroad; ➢ Competitor countries having greater incentives to attract R&D investment; ➢ Difficulties accessing scale-up funding locally, leading to firm decisions to migrate; and ➢ UK companies reducing in-house R&D investment in favour of acquiring small firms.

Chart 3.1. Pharmaceutical manufacturing – value added and employment

Value added in current US$, employment and labour productivity in pharmaceuticals and medicinal chemicals, top countries by value add in 2018

Rank	Country	Value added		Employment		Productivity Value added per employee	
		US$bn, 2018	CAGR (2008–18)	Persons, '000, 2018	CAGR (2008–18)	US$'000, 2018	CAGR (2008–18)
1	United States	160.9	1.3%	241	-0.3%	666.3	1.6%
2	Switzerland	27.7	7.1%	47	3.1%	590.3	3.9%
3	Germany	24.1	0.0%	157	2.3%	153.3	-2.2%
4	Ireland (2014)	16.8	-0.4%	16	0.0%	1042.9	0.4%
5	India	15.7	7.7%	740	7.7%	21.2	0.0%
6	France	14.4	0.3%	97	1.6%	148.3	-1.2%
7	Belgium	12.4	10.4%	28	4.8%	439.3	5.4%
8	Italy	10.9	0.4%	66	-0.2%	165.6	0.6%
9	Korea	10.1	5.9%	41	4.6%	245.5	-0.1%
10	Singapore	9.7	5.8%	8	6.9%	1206.6	-1.0%
11	Denmark	9.2	8.4%	25	4.0%	362.5	4.2%
12	**United Kingdom**	**7.9**	**-6.7%**	**50**	**1.2%**	**157.2**	**-7.9%**
13	Brazil	6.9	1.3%	108	1.2%	64.5	0.1%

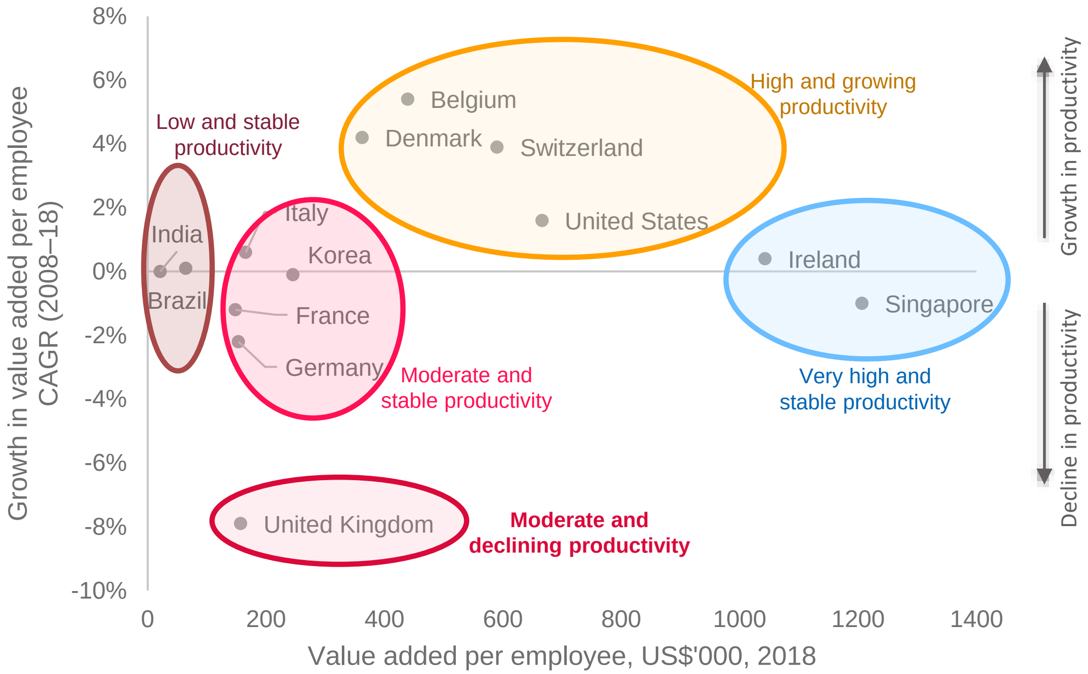
Note: Last available value-added (VA) data for Ireland from 2014, used and indicated in table above. Because of data unavailability, 2017 values for VA and employment are used instead of 2018 values for India and Korea; 2017 values for employment are used instead of 2018 values for France; 2009 values for VA and employment are used instead of 2008 values for Belgium and Switzerland; and 2011 value for VA and 2007 value for employees are used instead of 2008 value for Korea. CAGR (compound annual growth rate) calculations adjusted accordingly. Sector definition: "Manufacture of basic pharmaceutical products and pharmaceutical preparations". As per the International Standard Industrial Classification (SIC) of All Economic Activities, Revision 4, SIC 21.

Source: UNIDO (2021). INDSTAT 4, ISIC Revision 4.

- The **UK** was ranked twelfth in the world in the production of **pharmaceuticals** in 2018 by value added in current US$. The value added per employee metric showed that **UK** productivity within the **pharmaceutical sector** declined between 2008 and 2018 at a rate of 7.9% per year (CAGR), as a result of both decreases in value added and increases in employment over this period.
- Unlike top-performing countries, the **UK** has recorded negative growth rates in value added and value added per employee over the past decade.
- At ~$157 in 2018, UK value added per employee was at a similar level to **Germany, Italy and France** but lower than the productivity levels of most comparators, except **India** and **Brazil**.
- **Singapore** has the highest value added per employee of comparator countries. **Belgium, Denmark and Switzerland** are countries with high growth in value added per employee over the decade.

Chart 3.2. Pharmaceutical manufacturing – productivity growth

Productivity measured by value added per employee and productivity growth, top-performing economies in 2018



Note: See previous slide. Sector definition**:** "Manufacture of basic pharmaceutical products and pharmaceutical preparations". As per the International Standard Industrial Classification (SIC) of All Economic Activities, Revision 4, SIC Code 21.

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Source: UNIDO (2021). INDSTAT 4, ISIC Revision 4.

- Of the top 13 countries by value add in 2018, in billions of US dollars, the **UK** is the only one to have experienced a significant productivity decline between 2008 and 2018.
- Other countries, including **Belgium, Denmark, Switzerland** and the **United States**, saw productivity growth between 2008 and 2018, measured as growth per year in value added per employee.
- **France and Germany**, which have similar productivity to the **United Kingdom**, also experienced smaller declines in productivity during this time period; however, the decline in productivity in the **UK** was 4–8 times larger than these comparable nations.

Chart 3.3. Pharmaceuticals – trade balance (a)

Global ranking by trade balance in pharmaceutical products

2010		
Rank	**Country**	**US$bn**
1	Switzerland	27.9
2	Ireland	26.9
3	Germany	18.6
4	**United Kingdom**	**9.7**
5	France	8.5
6	Denmark	5.1
7	Israel	5.0
8	India	4.9
9	Belgium	4.8
10	Sweden	4.5
11	Singapore	3.4
162 of 162*	USA	-21.2

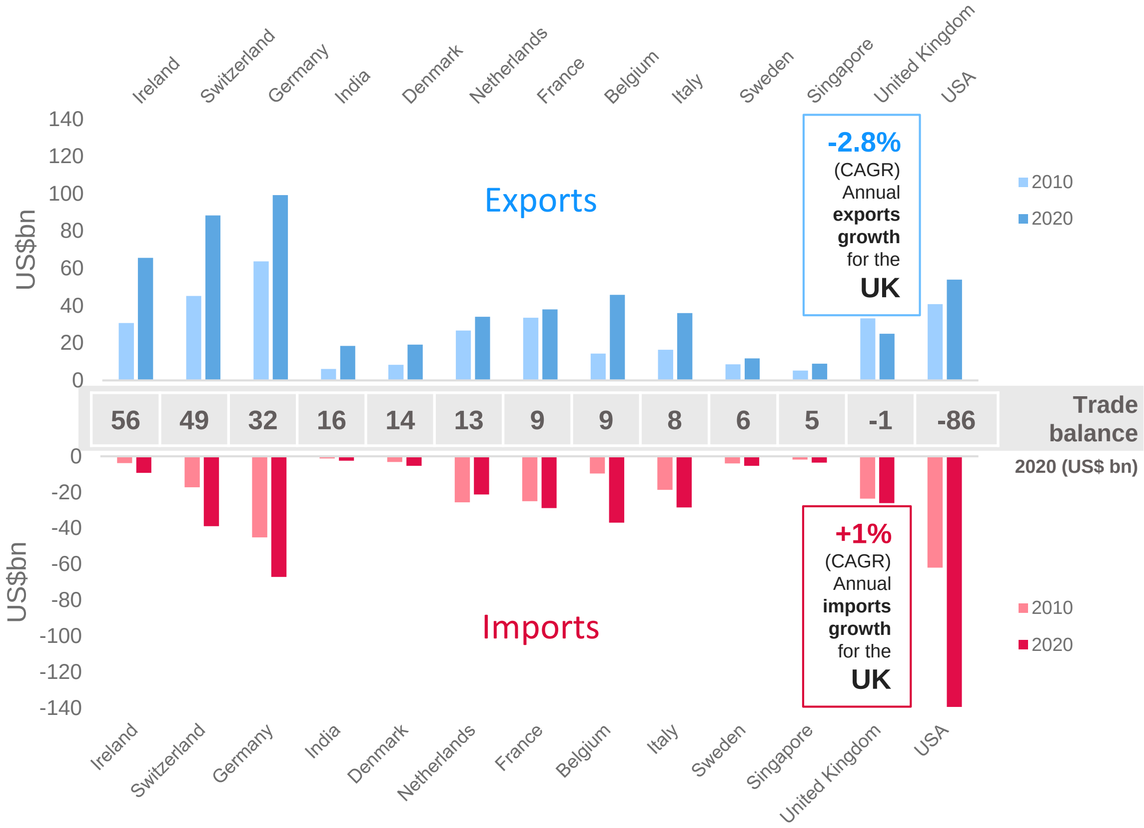
2020		
Rank	**Country**	**US$bn**
1	Ireland	56.4
2	Switzerland	49.4
3	Germany	32.1
4	India	15.9
5	Denmark	13.8
6	Netherlands	12.7
7	France	9.1
8	Belgium	8.9
9	Italy	7.5
10	Sweden	6.3
11	Singapore	5.3
98	**United Kingdom**	**-1.2**
133 of 133*	USA	-85.6

- The **UK** has suffered from a rapid loss in trade competitiveness in **pharmaceutical products** from the perspective of trade balance over the past decade.
- The **UK** was the fourth largest net exporter of **pharmaceutical products** in 2010, with a surplus of ~$10 billion.
- Since 2014 the **UK** has recorded deficits in **pharmaceutical product** trade in all years except 2015. Its trade deficit widened to ~$1 billion in 2020, placing it among the third quartile of countries according to trade balance.

Note: Trade balance is based on gross exports and gross imports of goods at HS 2-Digit level for HS 30 – Pharmaceutical Products.
*Global ranking excludes countries for whom data for the year in question is not available.

Source: UN Comtrade (accessed January 2022). HS 30 – Pharmaceutical Products

Chart 3.4. Pharmaceuticals – trade balance (b)



- This loss in trade competitiveness for the **UK** over the past decade, leading to a ~$1 billion trade deficit in 2020, is the result of an annual 1% increase in imports (CAGR) and an annual 2.8% CAGR decline in exports (CAGR) between 2010 and 2020.
- Of the comparator countries, the **UK** is the only country where exports were smaller in 2020 than they were in 2010.

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Source: UN Comtrade (accessed January 2022). HS 30 – Pharmaceutical Products

Note: Trade balance is based on gross exports and gross imports of goods at HS 2-Digit level for HS 30 – Pharmaceutical Products.
*Global ranking excludes countries for whom data for the year in question is not available.

Chart 3.5. Pharmaceuticals – UK top trade partners

UK trade of medicinal and pharmaceutical products, constant price in £ million, November–December 2021

Import			Export	
2010	**2020**		**2010**	**2020**
Spain	Netherlands	1	United States	United States
United States	Germany	2	Germany	Germany
Switzerland	Belgium	3	France	China
Germany	United States	4	Spain	Belgium
Belgium	Spain	5	Netherlands	Ireland
Ireland	Ireland	6	Italy	Netherlands
Netherlands	Switzerland	7	Ireland	France
France	Italy	8	Japan	Spain
Italy	France	9	Australia	Australia
Israel	India	10	Switzerland	Canada

Source: ONS (January 2022 and historical data). Trade in goods: country-by-commodity exports - Code 54: Medicinal and pharmaceutical products.; ONS (January 2022 and historical data), trade in goods: country-by-commodity imports - Code 54: Medicinal and pharmaceutical products.

- There have been some successes in the **UK pharmaceutical** trade over the past decade. The **UK** has exported more **medicinal and pharmaceutical products** to **China** and **Belgium**, with a 13% CAGR between 2010 and 2020, bringing in £1 billion more in exports in 2020 than 2010 from each country.
- Imports from **Italy** rose, while exports to this nation declined (5.8% rise in imports, -9.7% decline in exports), with a similar but smaller picture occurring with **France** (2.7% rise in imports, -6.3% decline in exports). This resulted in a net reduction of just over £1 billion in trade for the **UK** in 2020 than 2010 from **Italy and France.**
- The rise in imports outstripped the growth in exports from countries, including the **Netherlands** (14.4% vs 1.5%), to the tune of a £3.2 billion lower trade balance in 2020 compared to 2010, and to a lesser extent in **Germany** (4.4% vs 0.9%, with a £700 million difference between 2020 and 2010).
- This analysis identifies that, although some traditional markets for UK pharmaceuticals in the **EU** may be declining, new export markets with growth potential are also opening up **(e.g. China).**

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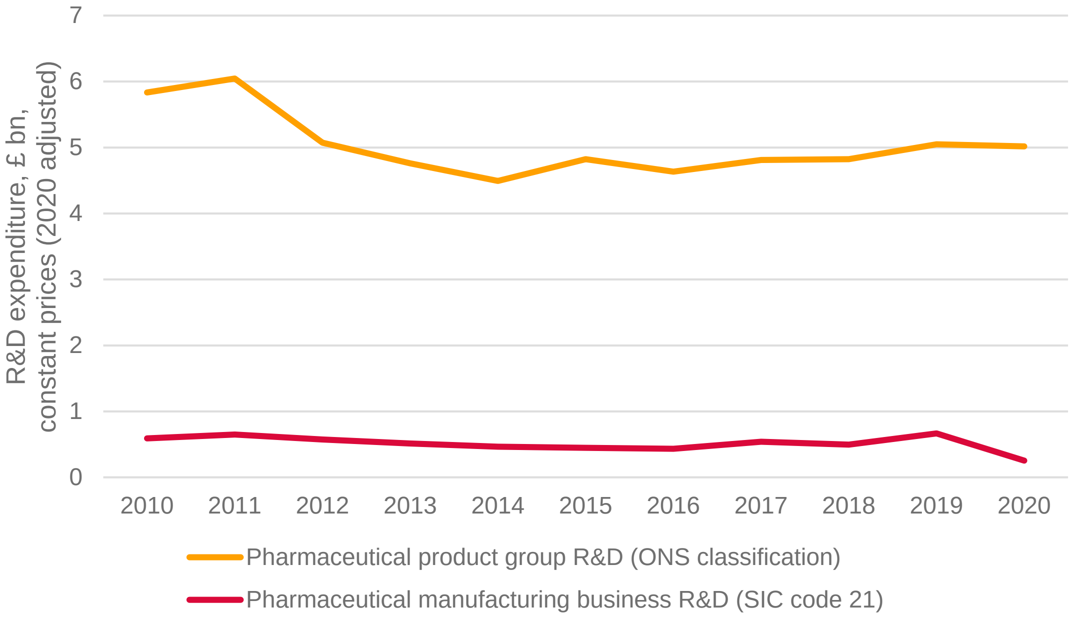
Chart 3.6. Pharmaceuticals – business spending on R&D (a)

Business enterprise R&D expenditure (BERD), various classifications, constant prices, £ billion (2020)



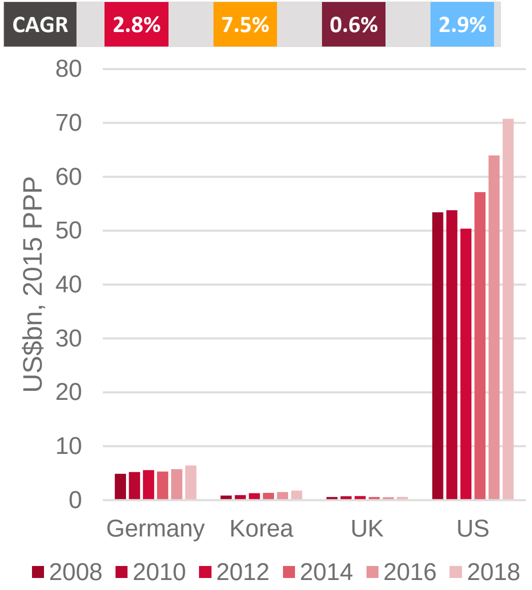
Note: Current prices adjusted using GDP deflator to 2020 prices.

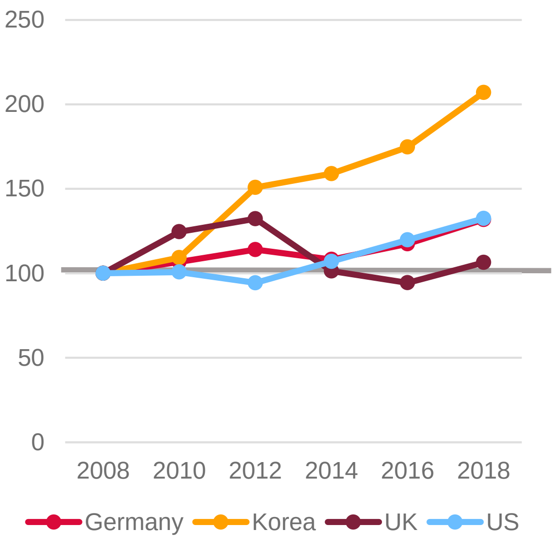
- Developed by the ONS, the term **"product group"** refers to business R&D expenditure allocated to the product group that best describes the subject type of R&D activities carried out by firms.
- This is in contrast to the "**industry classification**", where SIC codes are allocated based on the main activity of the business – in this instance, companies whose main activity is **pharmaceutical manufacturing**. These are more often used for international comparisons.
- The difference between these two measures indicates that only a fraction of all R&D in the **pharmaceutical** industry is conducted by businesses whose main activity is **pharmaceutical manufacture**. Companies that may account for the difference include contract R&D organisations and pre-commercial SMEs.
- Adjusting for inflation, R&D in the **Pharmaceutical Product Group** in 2020 was still only 83% of its peak in 2011.
- **While R&D in pharmaceutical manufacturing** (SIC Code 21) dipped to just 39% of its 2011 value in 2020, it had been relatively stable throughout the decade.

Source: ONS (2021). BERD Statistics.

Chart 3.7. Pharmaceuticals – business spending on R&D (b)

Business enterprise expenditure on R&D (BERD) in basic pharmaceutical products and pharmaceutical preparations, selected countries





- Comparing **pharmaceutical manufacturing**, the decline experienced by the sector in terms of GVA and productivity may have affected business R&D expenditure.
- The sector spent only 6% more in 2018 than it did in 2008, compared to increases of around 30% in the **US** and **Germany** and over 100% **in Korea**.
- In absolute terms, however, business enterprise R&D expenditure in the **UK** remains comparatively lower than that of **Korea, Germany** and **the US**.

Note: Compound annual growth rates for countries are based on data for the first and last available years within the 2008–16 range. Data from Industry: Manufacture of basic pharmaceutical products and pharmaceutical preparations (SIC Code 21).

Source: OECD (2021). Research and Development Statistics

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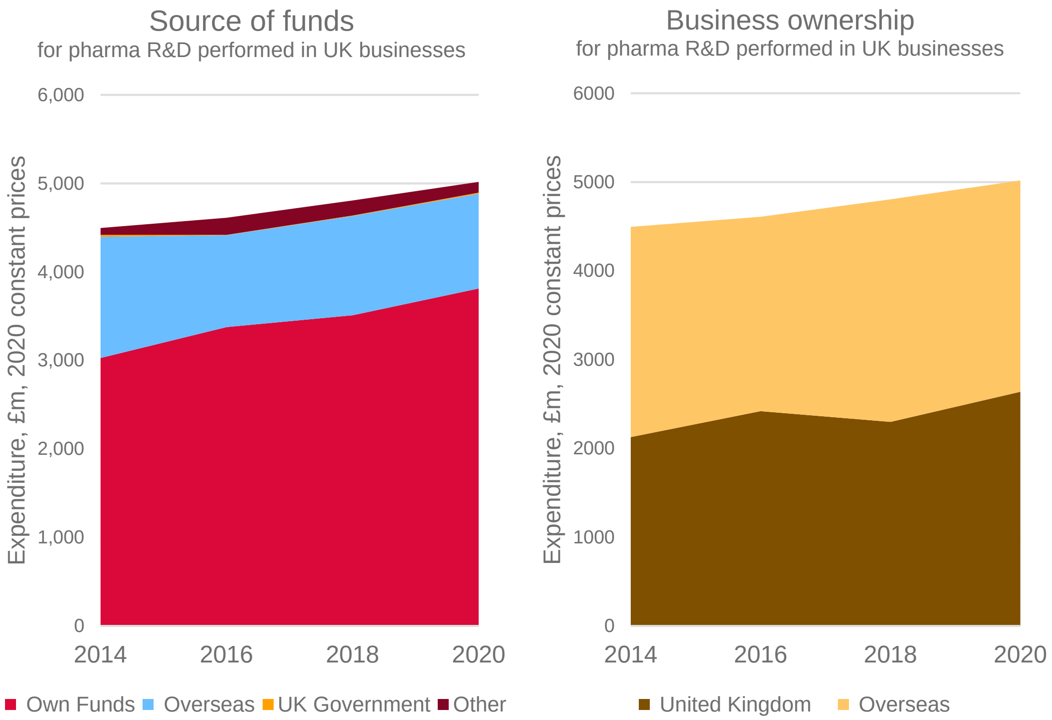
Chart 3.8. Pharmaceuticals – foreign R&D in the UK

Source of funds for R&D, and ownership of business, for businesses performing R&D in pharmaceuticals within the UK



Note: Current prices adjusted using GDP deflator to 2020 prices. ONS defined product grouping.

- Most **pharmaceutical** R&D conducted by businesses in the **UK** is funded by the companies themselves (~70%).
- Around 25% of **pharmaceutical** R&D performed by businesses in the **UK** is funded by overseas organisations. While overseas investment in R&D makes up a substantial portion of the total R&D, this has not been increasing.
- Only a small fraction of R&D performed by business is funded by the government (~£12 million in 2020).
- The graph on the right shows that, on average, 50% of the **pharmaceutical** R&D performed in the **UK** was conducted by businesses owned overseas.

Source: ONS (2021). BERD Statistics

Drivers behind the trends in the pharmaceutical manufacturing sector

Insights from literature review and consultations with sector experts

What is driving value added, productivity and trade trends in pharmaceutical manufacturing? (1)

Key trend identified	▪ The value added and productivity of the UK pharmaceutical manufacturing sector have declined significantly in the last decade ▪ The UK trade balance in pharmaceuticals has deteriorated significantly since 2014
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**Company restructuring and site closures, including those by major sector employers** ▪ Some top companies (e.g. Pfizer, GSK), who are major employers in the industry, completed reorganisations over the last decade, resulting in site closures [Bioscience and Health Technology Sector Statistics, 2019]. **Increased offshoring of pharmaceutical manufacturing** ▪ The consulted stakeholders highlighted that the last decade saw a move by UK pharmaceutical manufacturers towards the outsourcing of some manufacturing activities. ▪ There seems to be a greater degree of firm mobility in the pharmaceutical sector than in other industries as a result of shorter factory life cycles, lower-scale operations and lower capital embedded in facilities and the supply chain. ▪ Together with superior incentives from overseas markets, these traits may help to explain the closure and/or migration of some key operations outside the UK. ▪ Both the literature and interviewees suggest that a large share of advanced pharmaceutical ingredient (API) chemicals and materials production has moved offshore over the last 10–15 years, mostly driven by cost considerations [Medicines Manufacturing Industry Partnership, 2017]. ▪ The stakeholders consulted also highlighted that contract development and manufacturing companies (CDMOs) owned and located abroad, taking on tasks such as drug development and manufacturing, have become more common. **The UK's inability to capture the "second wave" of manufacturing investments** ▪ The second wave of manufacturing investments on new plant and equipment for the manufacture of biologics and other novel medicines has largely gone to Ireland, Singapore, Germany and the US, which together have attracted the bulk of US$ 125 billion investment between 2011 and 2017 [LSIS, 2017]. ▪ The 2017 Life Sciences Industrial Strategy therefore suggested that the UK should not miss the next wave of manufacturing opportunities in the sector in order to close the export gap and boost productivity [LSIS, 2017]. ▪ The 2021 Life Sciences Vision identifies areas in which the UK has, or could develop, a meaningful competitive advantage, including: cell and gene therapies, oligonucleotides, viral vectors, advanced diagnostics or wound care [HMG, 2021].

What is driving value added, productivity and trade trends in pharmaceutical manufacturing? (2)

Key trend identified	▪ The value added and productivity of the UK pharmaceutical manufacturing sector have declined significantly in the last decade ▪ The UK trade balance in pharmaceuticals has deteriorated significantly since 2014
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**Other countries provide greater incentives – particularly tax – to attract manufacturing investment** ▪ The 2021 Life Sciences Vision recognises that it is essential to provide incentives to support company growth, innovation and investment and to help new companies develop products and sales based in the UK [HMG, 2021]. ▪ Key competitors such as Germany, the US, Switzerland, Ireland and Singapore have all prioritised life sciences manufacturing, with Ireland landing manufacturing investments from 9 out of 10 top pharmaceutical companies and Singapore having 30 of the world's leading biopharmaceutical companies' HQs [LSIS, 2017]. ▪ The consulted stakeholders highlighted that lower business tax rates, including incentives for companies to locate headquarters and R&D facilities within countries, may out-compete the UK offering regarding international investment. This is seen particularly in the cases of Ireland and Singapore, which have highly attractive business tax structures, better rates of return of investment, access to capital and other financial incentives. ▪ There was a perception among the consulted experts that, although the UK has started to offer R&D grants and other innovation incentives, the total UK budget for R&D grants remains lower than that of competitor countries. ▪ There is also a concern that, although the UK has traditionally offered some advantages for R&D-intensive pharmaceutical companies to operate in the country, such as good access to skills and the presence of a vibrant innovation ecosystem, these might have eroded over time. ▪ Both the literature and interviewees identified difficulties in recruiting highly qualified workers in categories such as the core scientific disciplines of biological and chemical sciences; a wide range of computational disciplines; and clinical pharmacology [ABPI, 2019]. The consultees also mentioned that the UK has lower proportions of skilled technicians with specific knowledge of the sector than other competitor countries.

What is driving value added, productivity and trade trends in pharmaceutical manufacturing? (3)

Key trend identified	▪ The value added and productivity of the UK pharmaceutical manufacturing sector have declined significantly in the last decade ▪ The UK trade balance in pharmaceuticals has deteriorated significantly since 2014
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**New UK sector entrants focused on early-stage drug discovery and other activities outside manufacturing** ▪ While the sector has historically been dominated by a small number of large players (e.g. AstraZeneca and GSK), ONS data suggests that 65% of 610 companies registered as pharmaceutical manufacturing enterprises at the start of 2018 were micro-firms with fewer than 5 employees [Make UK, 2018]. ▪ The interviewees suggested that the UK has developed a strong presence of start-ups in the last decade, many of which focus on new discoveries and operate on loss-making models while these developments get to market. ▪ From the perspective of some interviewees, trade deficits could be a symptom of the UK focus on basic R&D but not commercialisation in recent years, which could be leading to UK innovation being exploited abroad and therefore lower exports. **Inability to commercialise and scale up the manufacture of technologies and products developed in the UK** ▪ Technologies and products that were originally developed in the UK have not been commercialised or manufactured in the UK, and globally mobile inward investments have tended to go to competitor countries [HMG, 2021]. ▪ For example, there is concern that, despite the discovery of monoclonal antibodies in the UK, the country has failed to capitalise on this by securing commercial manufacturing of these products [LSIS, 2017]. ▪ The UK government’s recognition that the high costs of developing a drug and getting it to market are prohibitive factors for many manufacturers has resulted in attempts to develop a streamlined pathway to bring products to market through programmes such as the Accelerated Access Collaborative [Make UK, 2018].

What is driving value added, productivity and trade trends in pharmaceutical manufacturing? (4)

Key trend identified	▪ The value added and productivity of the UK pharmaceutical manufacturing sector have declined significantly in the last decade ▪ The UK trade balance in pharmaceuticals has deteriorated significantly since 2014
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**Caps on drug spending may have an impact on the perception of the UK by investors** ▪ An opinion found in the literature and expressed by various interviewees is that, although drug spending decisions do not directly influence investments because companies operate in a global market, they might affect the perception that global companies have of the UK's commitment to the sector [Make UK, 2018]. ▪ In this regard, the Association of the British Pharmaceutical Industry [ABPI, 2020] suggests that the drive by the NHS to purchase the lowest-price product and single-supplier contracts has resulted in manufacturing being driven to low-cost labour markets, thereby weakening the resilience of UK supply. **Increased use of generics could be pushing prices downwards and driving imports upwards** ▪ The UK pharmaceutical industry has seen increased price pressures, both nationally and globally, from generics [Enterprise Ireland, 2020]. ▪ The consulted stakeholders highlighted that, in terms of generics manufacturing, other countries such as India and China are the preferred options to manufacture basic chemistry at a lower price. Increased generic use by the NHS may be driving imports upwards. **The 2016 EU membership referendum added uncertainty to investment decisions in the sector** ▪ There was a common perception among the stakeholders consulted that the 2016 EU membership referendum resulted in pharmaceutical companies becoming more cautious in their spending and putting larger capex on hold. ▪ In the view of some interviewees, the referendum decision created a perception that the UK could become a smaller domestic market, which reduced some of its attractiveness. IP protection considerations added to these concerns, as it became unclear whether the UK would remain part of the EU Unitary Patent Initiative and the European Patent with Unitary Effect (EPUE) scheme. ▪ There is also a perception that the UK's new trade relationship with the EU has reduced the attractiveness of producing final products in the country, as these would need to be re-released and approved in other markets. ▪ Both interviewees and literature sources suggest that longer lead times and increased paperwork caused by border and custom checks affect profit margins, particularly for products with a short shelf life, leading to companies transferring specific production lines outside the UK [Make UK, 2018].

What is driving business R&D expenditure trends in pharmaceutical manufacturing? (1)

Key trend identified	▪ Pharma R&D expenditure in the UK has remained stagnant in the last decade and remains significantly lower than comparator countries
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**A large share of domestic business R&D expenditure relies on decisions taken abroad** ▪ Around half of the UK's pharmaceutical R&D expenditure was performed in businesses owned by overseas companies in 2020. As a result, the investment decisions of multinational companies located in the UK may be made by headquarters located elsewhere. ▪ In the view of some interviewees, this may have impacted R&D expenditure decisions and has potentially lessened the UK's speed of innovation, particularly for technologies where the development process is highly iterative and requires proximity to the manufacturing base [HMG, 2021]. **Competitor countries offer greater incentives to attract R&D investment** ▪ There was a perception among the consulted stakeholders that firms receive more favourable grants and tax credits in other countries. ▪ Capital allowance regimes in the UK may be particularly disadvantageous for the pharmaceutical sector because of its high R&D intensity, making it relatively less attractive to invest in pilot and full-scale manufacturing facilities in comparison to other countries [LSIS, 2017]. ▪ For example, France and Canada offer capital allowance rates of 28% and 50%, respectively, in comparison with an annual rate of 18% on a reducing balance basis in the UK [LSIS, 2017]. ▪ Although the UK's current corporation tax is the lowest in the G20, the UK government recently announced significant rises from 19% to 25%, with effect from 1 April 2023.

What is driving business R&D expenditure trends in pharmaceutical manufacturing? (2)

Key trend identified	▪ Pharma R&D expenditure in the UK has remained stagnant in the last decade and remains significantly lower than comparator countries
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**UK companies may struggle to access scale-up funding locally and decide to migrate, impacting R&D expenditure** ▪ The access to scale-up funding in the UK has been identified as a constraint despite a strong performance in research and innovation, across a number of fields. The ease of accessing funding in the US is seen as greater than in the UK. **Decision of UK companies to reduce high-risk in-house R&D investment in favour of acquiring small companies** ▪ According to the consulted experts, large pharmaceutical companies are preferentially providing seed funding for small companies conducting R&D and then acquiring these companies if successful. This may be reducing the overall business R&D expenditure in the UK. ▪ The long lag times and costs between the research beginning and a drug being patented can be prohibitive for firms, leading to mergers and acquisitions across the industry in order to gain the economies of scale and financial capability to manufacture pharmaceuticals [Make UK, 2018]. **Smaller innovative companies tend to outsource R&D** ▪ As suggested by the UK Bioindustry Association, smaller innovative companies often operate on an outsourcing model, whereby they rely on universities and other companies to conduct R&D on their behalf [BIA, 2022]. ▪ In the view of some interviewees, this sectoral trait may be reducing the R&D identified as being done by manufacturing firms, while not necessarily reducing total R&D. ▪ Similarly, there was a view among the consulted stakeholders that foreign contract research organisations (CROs) servicing the pharmaceutical and biotechnology industries may be affecting domestic R&D expenditure statistics.

The automotive sector

UK INNOVATION REPORT 2022

Theme 3: Policy questions and key messages

- **Are UK sectors becoming more or less competitive internationally?**
- **How are UK sectors performing in terms of productivity, value added and employment?**
- **Are UK sectors investing enough in R&D compared to their international competitors?**

THE AUTOMOTIVE MANUFACTURING SECTOR

Key UK automotive manufacturing trends in the last decade

The value added and productivity of the UK automotive sector grew steadily between 2008 and 2018

- In 2018 the UK automotive industry was the eighth largest in the world in value-added terms, growing at around 2.3% annually from 2008 to 2018.
- The UK belongs to a group of nations where productivity was high and rising over the 2008–18 period, together with Germany, Korea and the US.

Despite being the ninth largest exporter of vehicles in 2020, the UK maintains a significant deficit in automotive product trade

- Since 2010 the UK has recorded a persistent trade deficit in automotive products, standing at $21.8 billion in 2020.
- Industry reports suggest that, given the ownership structure of the tier-1 supply base in 2017, 50% local content by value was regarded as a plausible target for the overall UK car industry. However, as the sector transitions to electrification, new opportunities and challenges will arise for UK auto-makers.

UK business expenditure on automotive R&D grew rapidly between 2009 and 2018 but has declined in recent years.

- UK business enterprise expenditure on R&D (BERD) for automotive grew by 11.7% (CAGR) between 2009 and 2018, with a slight decline in 2019 and 2020.
- Overall, total UK business enterprise expenditure on R&D in automotive remains an order of magnitude lower than in competitor countries.

Drivers identified in literature review and sector expert consultations

- Increased specialisation of the UK's automotive sector in premium product segments;
- Future sector growth dependent on the UK's ability to produce electric and hydrogen vehicles and components;
- High levels of automation influencing growth in employment in recent years;
- Skills' shortages, particularly in higher technical education reported by industry;
- Decisions by foreign original equipment manufacturers (OEM) favouring other locations;
- Increased competitive pressures from both established and upcoming nations;
- Increased uncertainty around trade and investment due to the 2016 EU membership referendum; and
- R&D investment decisions mostly driven by foreign OEMs

Chart 3.9. Automotive – value added and employment

Value added in current US$, employment and labour productivity in the automotive industry, top countries by value add in 2018

Rank	Country	Value added		Employment		Productivity Value added per employee	
		US$bn, 2018	CAGR (2008–18)	Persons, '000, 2018	CAGR (2008–18)	US$'000, 2018	CAGR (2008–18)
1	United States	186.9	5.0%	963	3.2%	194	1.7%
2	China	172.0	8.5%	4588	4.8%	37	3.5%
3	Japan	170.7	2.6%	1102	2.6%	155	-0.1%
4	Germany	128.3	3.5%	917	0.9%	140	2.6%
5	Korea	50.3	3.9%	326	2.2%	154	1.7%
6	Mexico	44.0	12.8%	975	18.1%	45	-4.5%
7	France	24.0	1.5%	238	0.2%	100	1.3%
8	**United Kingdom**	**22.4**	**2.3%**	**165**	**-0.6%**	**135**	**2.9%**
9	Indonesia	18.3	14.1%	244	10.9%	75	2.9%

Note: Data refers to ISIC 34 Motor vehicles, trailers, semi-trailers. CAGR = compound annual growth rate.

- In 2018 the **UK** automotive industry was ranked eighth in the world in value-added terms.
- This was supported by value added growing at around 2.3% annually from 2008 to 2018.
- Employment levels reduced at an annual rate of 0.6% between 2008 and 2018.
- From 2008 to 2018 **UK** automotive productivity grew at comparable rates to other world leaders (2.9% annually).
- With value added per employee of $135 in 2018, the **UK** had higher productivity than **France** but lower productivity than comparable high-income nations, including the **USA, Japan, Korea** and **Germany**.

Source: UNIDO (2021). INDSTAT 2 2021, ISIC Revision 3. ISIC 34.

Chart 3.10. Automotive – productivity growth

Productivity measured by value added per employee and productivity growth, top-performing economies in 2018

Note: Data refers to ISIC 34 Motor vehicles, trailers, semitrailers. CAGR: compound annual growth rate.

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Source: UNIDO (2021). INDSTAT 2 2021, ISIC Revision 3. ISIC 34.

- The **UK** belongs to a group of nations where productivity was high and rising over the 2008–18 period. Other nations with top-performing automotive sectors in this group include **Germany, Korea** and **the US.**
- Some countries are experiencing similar levels of productivity growth in the **automotive sector**, but from lower initial levels of productivity, including **China** and **Indonesia**.
- **Japan's** productivity was high and stable, while **Mexico's** was low and declining over the 2008–18 period.

Chart 3.11. Automotive – trade balance (a)

Global ranking by trade balance in automotive products

2010		
Rank	Country	US$bn
1	Japan	132.2
2	Germany	124.5
3	Mexico	45.6
4	Rep. of Korea	27.0
5	Czechia	13.1
6	Slovakia	12.6
7	Thailand	10.8
8	Spain	6.3
9	India	5.9
10	Hungary	5.3
162 of 164*	**United Kingdom**	**-22.2**
164 of 164*	USA	-86.8

2020		
Rank	Country	US$bn
1	Japan	102.8
2	Germany	87.0
3	Rep. of Korea	68.6
4	Mexico	35.9
5	Czechia	20.4
6	Spain	15.5
7	Thailand	14.8
8	Poland	13.9
9	Slovakia	8.7
10	India	8.6
134 of 136*	**United Kingdom**	**-21.8**
136 of 136*	USA	-149.3

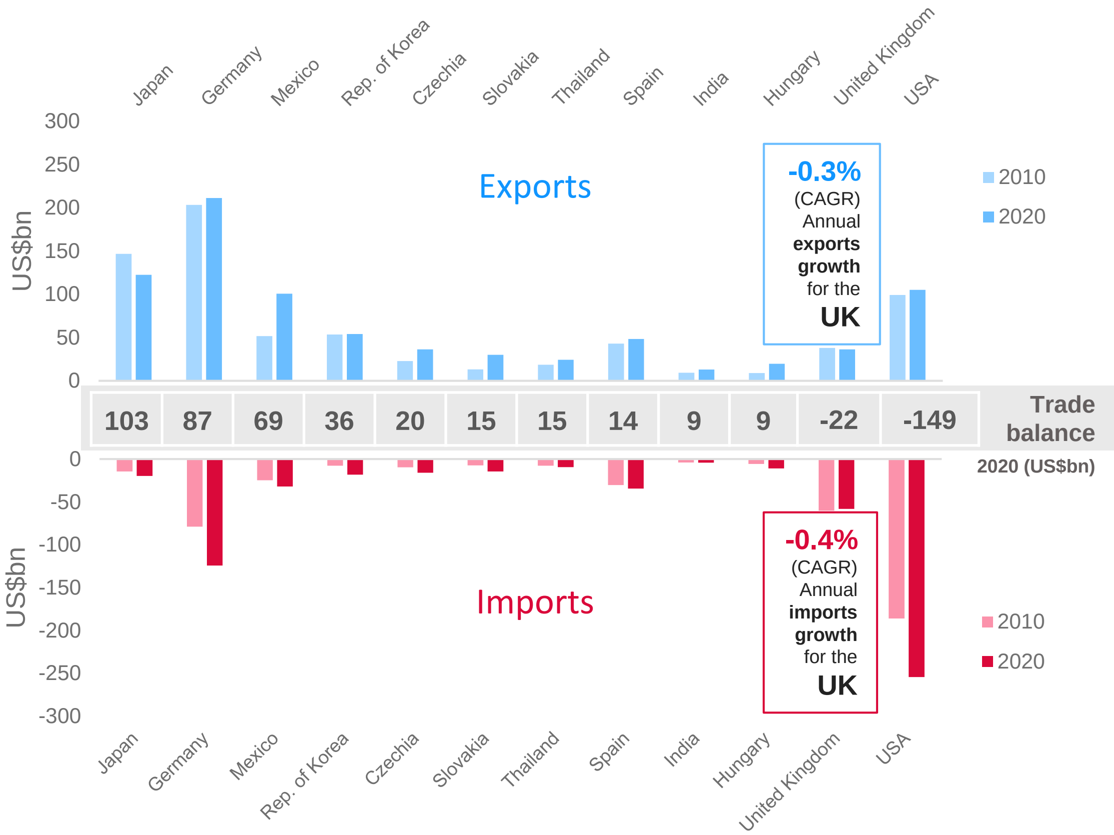
Note: Trade balance is based on gross exports and gross imports of goods at HS 1992 2-Digit level, for HS 87: Vehicles, other than railway or tram rolling stock, and parts and accessories thereof.
*Global ranking excludes countries for whom data for the year in question is not available.

Source: UN Comtrade (2010,2020). HS 1992 2-Digit level, for HS 87

- The **UK** was the ninth largest exporter of **vehicles** by value in 2020, with around 81% of cars made in the **UK** being exported.[1]
- It was also the fifth largest importer of **vehicles** by value in 2020.[1]
- However, when considering broader trade in **automotive components**, the country has consistently recorded trade deficits in recent years.
- There was very little change in the **automotive trade** balance between 2010 and 2020. Its deficit in **automotive products** trade reduced from ~$22.2 billion in 2010 to ~$21.8 billion in 2020.

[1] World's Top Exports https://www.worldstopexports.com/cars-imports-by-country/.

Chart 3.12. Automotive – trade balance (b)



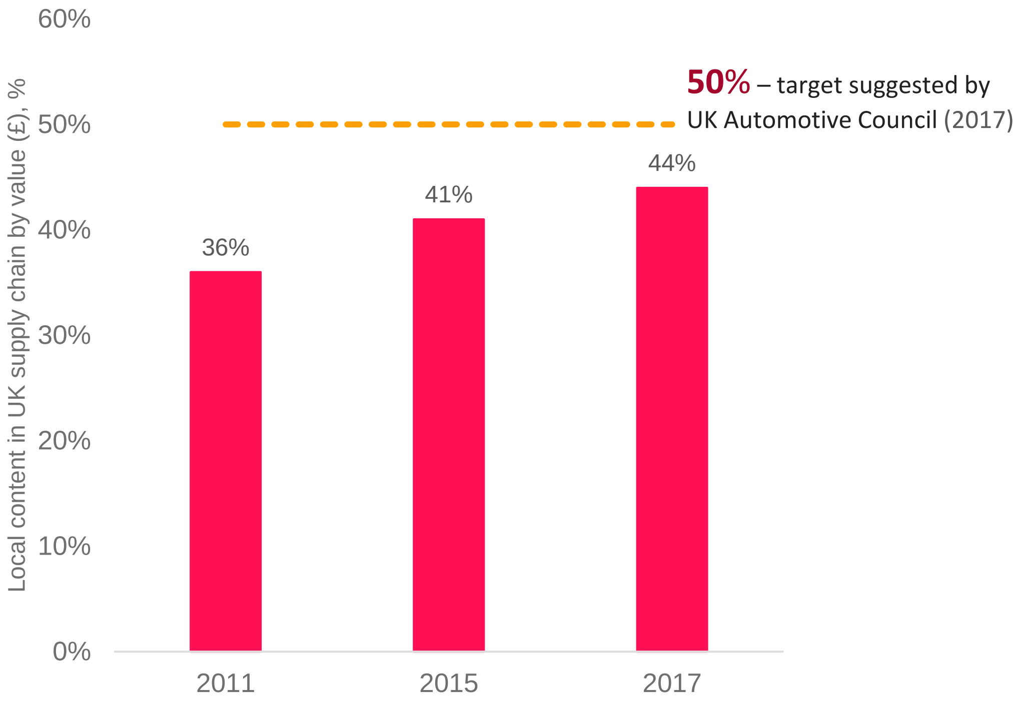
- Between 2010 and 2020 **UK** imports **of automotive products** shrank by 0.4%, while exports shrank by 0.3% per year on average (CAGR).
- Of the comparator countries, the **UK** is the only country where imports were smaller in 2020 than they were in 2010.
- Although the **US** had an even bigger trade deficit in automotive products in 2020 (~$149 billion), all other comparator countries in the top 10 global ranking by trade balance in **automotive products** presented positive trade balances in 2020.

Note: Trade balance is based on gross exports and gross imports of goods at HS 1992 2-Digit level, for HS 87: Vehicles, other than railway or tram rolling stock, and parts and accessories thereof.

Source: UN Comtrade (2010,2020). HS 1992 2-Digit level, for HS 87

Chart 3.13. Automotive – local content

Locally produced content within the automotive supply chain



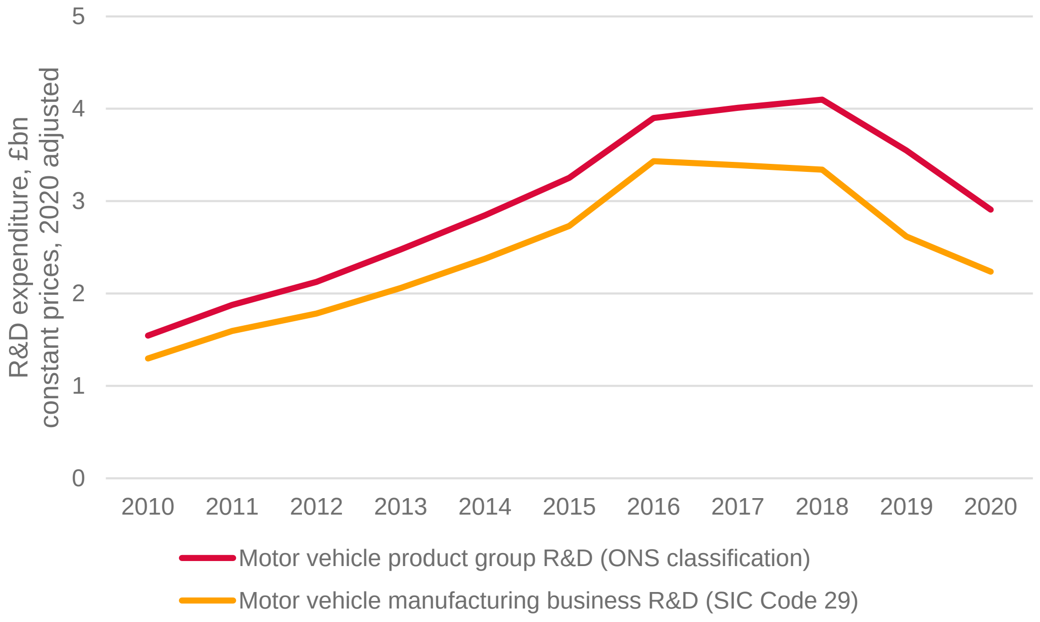
Source: Automotive Council UK (2015, 2017). Growing the Automotive Supply Chain – Local Vehicle Content Analysis.

- As explained by the **UK Automotive Council**, the amount of locally sourced parts is a key measure of success for the **UK** automotive industry, as the majority of the sector's value added is created in the upstream supply chain.[1]
- In value terms, the parts sourced by **UK** car manufacturers from **UK** first-tier suppliers increased from 36% in 2011 to 44% in 2017.[1]
- There are no reliable sources available to establish valid benchmarks, as the actual sourcing patterns of local manufacturing firms can only be established through surveys.[1]
- The **UK Automotive Council** suggests that, given the ownership structure of the tier-1 supply base in 2017, 50% local content by value was regarded as a plausible target for the overall **UK** car industry.
- However, as the sector transitions to electrification, new opportunities and challenges will arise for **UK** auto-makers. Deeper analysis is needed to understand which **UK** supply chain segments might be at risk during this transition, and what opportunities exist for capturing value in new areas.

[1] Automotive Council UK (2017). Growing the Automotive Supply Chain – Local Vehicle Content Analysis.

Chart 3.14. Automotive – business spending on R&D (a)

Business enterprise R&D expenditure (BERD), various classifications, constant prices, £ billion (2020)



Note: Current prices adjusted using GDP deflator to 2020 prices.

- Developed by the ONS, the term **"product group"** refers to business R&D expenditure allocated to the product group that best describes the subject type of R&D activities carried out by firms.
- This is in contrast to the "**industry classification**", where SIC codes are allocated based on the main activity of the business – in this instance, companies whose main activity is automotive manufacturing. These are more often used for international comparisons.
- The small difference between these two measures indicates that most R&D in the **automotive industry** is conducted by businesses whose main activity is manufacturing. Companies that may account for the difference include contract R&D organisations and pre-commercial SMEs.
- The peak in BERD spending in the **UK** appears to have occurred between 2016 and 2018.
- In 2020 BERD in motor vehicles and parts was at just 70% of its 2018 peak value.

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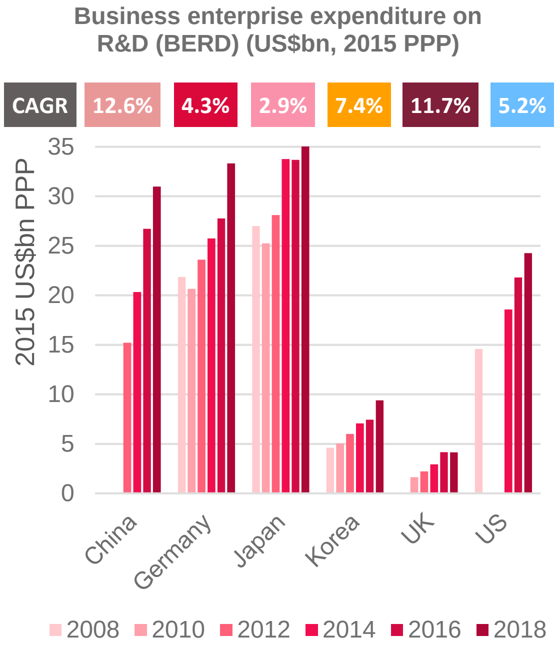
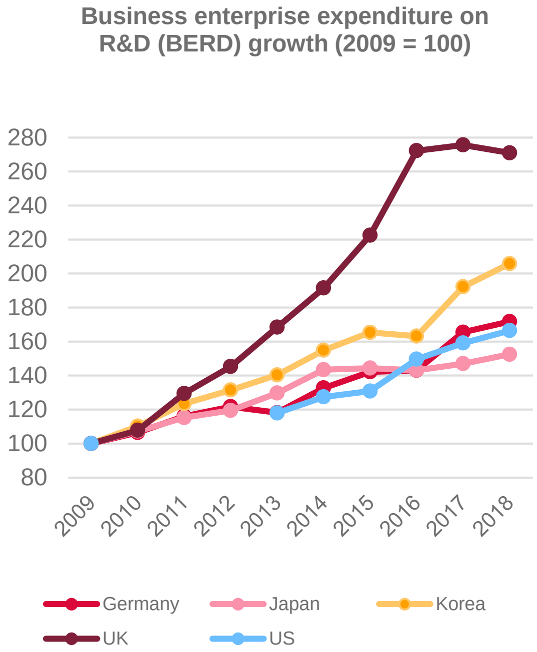
Source: ONS (2021). BERD Statistics.

Chart 3.15. Automotive – business spending on R&D (b)

Business enterprise R&D (BERD) expenditure in motor vehicles, trailers and semi-trailers, selected countries





Note: Compound annual growth rates for countries are based on data for the first and last available years within the 2008–18 range. UK CAGR is based on the period 2009–18. For BERD expenditure growth, the base year for the US is 2008.

Source: OECD (2020). Research and Development Statistics.

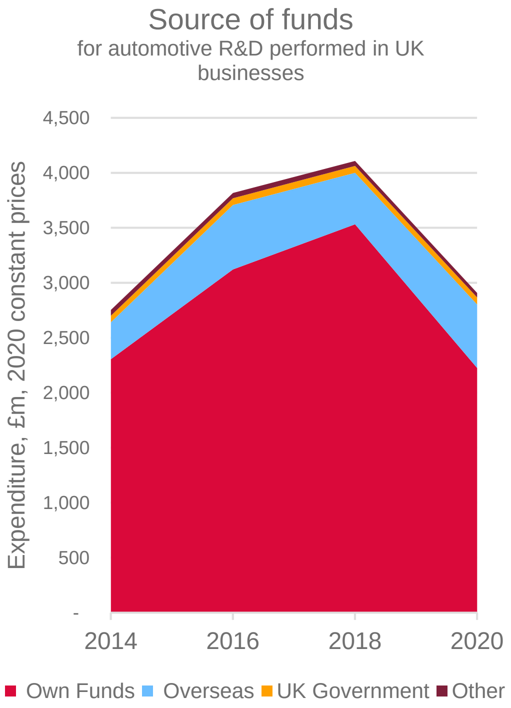
- In 2018 the **automotive industry** accounted for almost 15% of overall business R&D expenditure in the **UK**, second only to the pharmaceutical industry.[1]
- In 2018 the **UK automotive sector** had an R&D intensity (as measured by the sector expenditure on R&D as a percentage of sales) of 6.6%, behind sectors such as pharmaceuticals, electronics and communication equipment, and computers.[2]
- **UK** business enterprise expenditure on R&D (BERD) for **automotive** grew by 11.7% (CAGR) between 2009 and 2018.
- Although **UK** BERD showed a high growth rate between 2009 and 2016, growth became stagnant after 2016.
- Despite its high growth, total **UK** business enterprise expenditure on R&D in **automotive** remains an order of magnitude lower than in competitor countries.

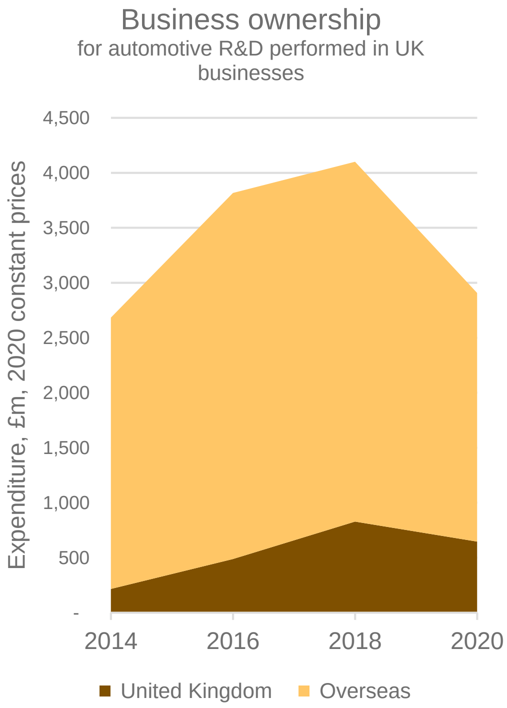
(1) OECD (2020). Business enterprise R&D expenditure by industry database.

(2) ONS (2020). Research and Development in UK Businesses, 2018 Datasets.

Chart 3.16. Automotive – foreign R&D in the UK

Source of funds for R&D, and ownership of business, for businesses performing R&D in the automotive sector within the UK





Note: Current prices adjusted using GDP deflator to 2020 prices. The 2014 and 2016 values for "UK government" and "other" extrapolated from 2016 and 2020 values.

- Most **automotive** R&D conducted by businesses in the **UK** is funded by the companies themselves (~76% in 2020).
- Around 20% of **automotive** R&D performed by businesses in the **UK** in 2020 was funded by overseas organisations and was relatively constant between 2014 and 2020.
- Only a small fraction of the R&D performed by business is funded by the government (~£64 million in 2020, or 2%).
- The graph on the right shows that 78% of the **automotive** R&D performed in the **UK** in 2020 was conducted in businesses owned overseas.

Source: ONS BERD Statistics, 2021.

Drivers behind the trends in the automotive sector

Insights from literature review and consultations with sector experts

What is driving value added, productivity and trade trends in automotive manufacturing? (1)

Key trend identified	▪ The value added and productivity of the UK automotive sector grew steadily between 2008 and 2018 ▪ Automotive employment levels reduced at an annual rate of -0.6% between 2008 and 2018 ▪ Despite being the ninth largest exporter of vehicles in 2020, the UK maintains a significant deficit in automotive products' trade
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**The UK's automotive sector has increased its specialisation in premium product segments** ▪ There is broad agreement among the stakeholders consulted that over the last decade UK automotive manufacturers moved into higher value-added products. Data for 2018 shows that 45.8% of all cars produced were premium products, while 1.7% were luxury and sports cars [SMMT, 2019]. ▪ Data from SMMT suggests that in 2019 there were six mainstream volume car manufacturers in the UK, eight major premium and sports car manufacturers, four commercial vehicle manufacturers and eight bus and coach manufacturers, with more than 2,500 suppliers to the sector [SMMT, 2019]. **Future sector growth is likely to depend on the UK's ability to produce electric and hydrogen vehicles and components** ▪ The UK has set a target for phasing out internal combustion engine (ICE) vehicles by 2030. The interviewees consulted highlighted that the transition to electric and hydrogen vehicles represents both an opportunity and a challenge for UK automotive. Electrical motors are expected to dominate light commercial vehicle sales, and hydrogen fuel cells are anticipated to be the preferred technology for heavy-duty vehicles. This transition means that some of the UK's strengths in traditional powertrain design and engine manufacturing could become less important [SMMT, 2021]. ▪ There was a perception among the consulted stakeholders that developing battery manufacturing operations in the UK is essential to ensuring that existing and new OEMs can be anchored to the country. Increased use of digital technologies within cars will also play a key role, with estimates that embedded software could make up to 30% of total vehicle value by 2030 [SMMT, 2021]. ▪ A key argument expressed by interviewees is that the heavy weight of electric batteries means that it is not economically feasible to transport them around the world as a result of the logistics costs. Therefore, it might be advantageous to have the final vehicle assembly located near battery production facilities. ▪ Although the UK has made significant recent announcements in this space (e.g. Britishvolt "gigafactory"), there is a perception that more could be done to back this ambition with a matching level of investment in battery production incentives [SMMT, 2021]. ▪ The SMMT predicts that by 2025 the UK might lag behind its key competitors in terms of lithium-ion battery production capacity, with just 12 GWh compared to 164 GWh in Germany, 91 GWh in the US or 32 GWh in France [SMMT, 2021].

What is driving value added, productivity and trade trends in automotive manufacturing? (2)

Key trend identified	▪ The value added and productivity of the UK automotive sector grew steadily between 2008 and 2018 ▪ Automotive employment levels reduced at an annual rate of -0.6% between 2008 and 2018 ▪ Despite being the ninth largest exporter of vehicles in 2020, the UK maintains a significant deficit in automotive products' trade
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**High levels of automation might be partly behind the moderate growth in employment in recent years** ▪ When discussing employment levels in the sector, the consulted stakeholders highlighted the push for automation as a potential reason for the observed trend, with a move towards high-value, low-labour and heavily automated operations in recent years. ▪ At 101 robots per 10,000 workers, the UK ranked 24th in the world in terms of industrial robot density in 2020 for all industrial sectors, a growth of 77% from 2015 [International Federation of Robotics, 2021]. ▪ It is yet to be seen how this trend will pan out during the transition to low-carbon vehicles. However, some interviewees suggest that the labour content of electric vehicles might be lower at vehicle assembly plant level. **Despite increased automation, the industry is reportedly facing skills' shortages, particularly in higher technical education** ▪ Data from the OECD presented in Theme 4 of this report shows that the UK supply of both STEM graduates and higher technical education lags behind other competitor countries [OECD, 2021]. ▪ The consulted stakeholders expressed concerns about the lack of apprenticeships and technical education programmes to supply future workers and upskill existing ones in preparation for the transition to low-carbon vehicles. ▪ SMMT analysis suggests that the industry is likely to require new skills in industrial chemistry, electrical engineering, virtual modelling, software design, cyber-security and digital science, engineering and architecture, with many of these skills likely to be delivered by retraining rather than new employees [SMMT, 2021]. **Future productivity gains may depend on the ability of firms to further adopt digital manufacturing practices** ▪ Some interviewees believe that the digitalisation of manufacturing operations in the sector could unlock significant productivity gains in the future at firm level. ▪ There was a perception among the consulted stakeholders that the digitalisation of production processes is not yet a general trend in the sector. However, this might change as firms are forced to do more with less as a result of cost pressures related to energy, input materials and labour, which could be partly addressed through digitalisation.

What is driving value added, productivity and trade trends in automotive manufacturing? (3)

Key trend identified

- The value added and productivity of the UK automotive sector grew steadily between 2008 and 2018
- Automotive employment levels reduced at an annual rate of -0.6% between 2008 and 2018
- Despite being the ninth largest exporter of vehicles in 2020, the UK maintains a significant deficit in automotive products' trade

Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)

Decisions taken by foreign original equipment manufacturers (OEM) may be favouring other countries as manufacturing locations

- The consulted stakeholders share the view that decisions taken by foreign original equipment manufacturers (OEM) have favoured other countries for new manufacturing investments and supply chain sourcing decisions.
- As stated by Make UK, over 6% of automotive firms (both OEMs and suppliers) were foreign-owned in 2018, over double the average for the manufacturing sector as a whole. The biggest non-domestic investors in 2018 were the US (31% of foreign-owned companies), Japan (15%) and Germany (14%) [Make UK, 2019]. As suggested by the interviewees, this could have investment location implications.

Increased competitive pressures from both established and upcoming manufacturing nations

- Competitive pressures affecting the UK automotive industry come from both countries with well-known OEMs (e.g. Japan, Germany, Korea) and lower-cost locations (e.g. Mexico, Thailand, Poland, India).
- Both interviewees and industry reports agree that while the UK retains a strong research and engineering base, it is increasingly falling behind in other elements of competitiveness, with some of the highest energy and tax costs. The UK government recently announced significant rises to corporation tax while the super allowance for capital investment is currently set to expire in 2023 and tax incentives for R&D lag behind global leaders [SMMT, 2021].

However, the transition to electric and hydrogen vehicles offers opportunities to increase local automotive content

- The development of electric and hydrogen vehicles may open the door for new players in the market, including high-technology start-ups from outside the automotive sector.
- Interviewees suggested that new entrants with strong ICT technical know-how (not necessarily from the automotive industry), as well as companies from the chemical industry, could become important players in future electric and hydrogen vehicle supply chains.
- Although not all existing auto firms are expected to survive the transition to low-carbon vehicles, this is still perceived as an opportunity to leverage UK advantages to support new and existing businesses diversifying into the sector. These advantages include a vibrant entrepreneurial ecosystem and strong research, innovation and commercialisation know-how.

What is driving value added, productivity and trade trends in automotive manufacturing? (4)

Key trend identified	▪ The value added and productivity of the UK automotive sector grew steadily between 2008 and 2018 ▪ Automotive employment levels reduced at an annual rate of -0.6% between 2008 and 2018 ▪ Despite being the ninth largest exporter of vehicles in 2020, the UK maintains a significant deficit in automotive products' trade
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**Rules of origin may increase the urgency to develop local suppliers to ensure tariff- and quota-free exports in the future** ▪ Rules of origin, which describe which goods can be counted as being made in the UK, may become a source of uncertainty for the UK automotive sector in the future, according to the consulted stakeholders. ▪ Interviewees agree that the rules of origin included in the UK–EU trade agreement can potentially be replicated for other markets in the future, including Japan, China, North America and Australia, among others. ▪ Rules of origin in these markets would require UK auto OEMs to uplift UK content in vehicles to meet rule-of-origin targets. **The 2016 EU membership referendum added uncertainty to future trade and investment** ▪ As suggested by the SMMT, sector output fell after 2016 following weaker domestic demand surrounding political and economic uncertainty, the slowdown in demand in key export markets such as the EU and China, combined with weaker demand for diesel cars. Overall, output in 2018 was 9.1% lower than 2017 levels, at 1.60 million units [SMMT, 2019]. ▪ The consulted stakeholders agreed that the EU membership referendum had created uncertainty for investment decisions in the automotive sector. In particular, it was mentioned that a number of tier-1 and 2 supply investment decisions were put on hold after 2016, only to be later consolidated to Europe based on the fear of the UK becoming an isolated market. ▪ The exit from the EU meant that some tier-1 and 2 investments could no longer justify large-scale operations in the UK and may have had an impact on the expansion of the sector and trade.

What is driving business R&D expenditure trends in automotive manufacturing?

Key trend identified	▪ UK business expenditure on automotive R&D grew rapidly between 2009 and 2016 but has declined in recent years
Potential drivers identified from literature review and consultations with sector experts (see Appendix 3.1 for details)	**Although the UK has strong R&D and innovation capabilities, investment decisions are mostly driven by foreign OEMs** ▪ When asked about the potential reasons for the low level of business enterprise expenditure on R&D in the automotive sector compared to other leading nations, the consulted stakeholders highlighted two potential factors: the size of the sector as a whole; and the ownership structure of UK-based OEMs. ▪ It is believed that R&D investment decisions by foreign-owned OEMs are often made from European or global headquarters against a wide range of criteria that may not favour the UK (e.g. tax incentives for R&D lag behind global leaders), with new developments taking years before being deployed across their international operations (e.g. Nissan, Ford). **However, strong R&D capabilities remain a key instrument to attract high value-added manufacturing into the UK** ▪ Despite OEMs driving R&D investment, there was a view among the consulted stakeholders that the UK has a strong record in design engineering and university collaboration, supported by its premium product manufacturers and its motorsports industry. ▪ This, in addition to innovation capabilities in industries that can diversify into new electric and hydrogen automotive supply chains, could offer powerful instruments to support the UK's attempt to capture high value-added segments of the automotive supply chain. ▪ In 2017 the UK government launched a new Industrial Strategy aiming to boost productivity and earning power throughout the UK, including an automotive sector deal at the start of 2018, to improve supply chain competitiveness, reduce the sector's environmental impact and boost investment in emerging technology to ensure that the sector remains competitive during the transition to low-carbon vehicles [Make UK, 2019]. ▪ The Industrial Strategy Challenge Fund (ISCF) was developed to support this aim, with three waves launched between 2017 and 2019, committing funding to the "Faraday Challenge" to develop world-leading batteries, designed and manufactured in the UK, leading to the establishment of the Faraday Institution and the UK Battery Industrialisation Centre [UKRI, 2021].

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Appendix 3.1

Stakeholder consultation – the pharmaceutical and automotive manufacturing sectors

In an attempt to understand the reality behind the data, Theme 3 was informed by a reduced number of interviews with key UK stakeholders from industry and government – including R&I funding programme management agencies, innovation centres, industry associations and key private-sector organisations. The consultation included representatives from the following organisations:

Pharmaceutical manufacturing sector analysis

- Office for Life Sciences (OLS)
- Innovate UK
- Confederation of British Industry (CBI)
- UK Bioindustry Association (BIA)
- CPI (High Value Manufacturing Catapult)
- National Physical Laboratory (NPL)
- Medicines Manufacturing Innovation Centre (MMIC)
- Medicines Manufacturing Research Centre (University of Strathclyde)
- Alnylam Pharmaceuticals
- Siemens
- AstraZeneca

Automotive sector analysis

- BEIS automotive team
- BEIS advanced manufacturing team
- North East Automotive Alliance
- Advanced Propulsion Centre (APC)
- Innovate UK (Faraday Battery Challenge)
- Society of Motor Manufacturers and Traders (SMMT)
- Ford
- Autocraft

Theme 4: Science and engineering workforce

UK INNOVATION REPORT 2022

Theme 4: Policy questions and key messages

- **Is the UK producing enough scientists and engineers?**
- **Is the UK government investing enough in technical and vocational education?**
- **How does this compare with other countries?**

Tertiary education attainment in the UK is well above the OECD average – and a comparatively larger share of graduates is found in science, technology, engineering and mathematics (STEM) disciplines

- In 2020 the level of tertiary education attainment in the UK (49.4%) was above the OECD average (39%) and countries such as Italy (20.1%), Germany (31.3%) and France (39.7%).
- In 2019 graduates in STEM disciplines accounted for 43.4% of the total number of graduates in the UK, above comparator countries such as France (36.8%), Canada (37.8%) and the United States (37.6%).
- Within STEM disciplines the share of graduates in "engineering, manufacturing and construction" remains relatively low in the UK, at 8.4%, especially compared to countries such as Germany (27.8%) and Korea (20.7%).

Women are under-represented in STEM disciplines

- In 2019 women represented 25% of new entrants in "engineering, manufacturing and construction" degrees in the UK and 21% of new entrants in "ICT" degrees - these levels are similar to the OECD average.
- Only 27% of the STEM workforce in the UK is female, compared with 52% in the total workforce.
- For UK engineers a gender pay gap exists but it is smaller than the pay gap for all UK workers.

Higher technical education enrolment is comparatively low in the UK

- Enrolment rates in post-secondary education courses, below the standard three-year Bachelor's degree, are comparatively low in the UK compared with countries such as the US, Korea and France.
- Following publication of the government's White Paper, *Skills for Jobs*, new government programmes have been announced with the intention of addressing the "significant shortage of vital technician-level STEM skills".

Chart 4.1. Tertiary education attainment

Share of population, 25–64 years old, by sex, selected countries, 2020

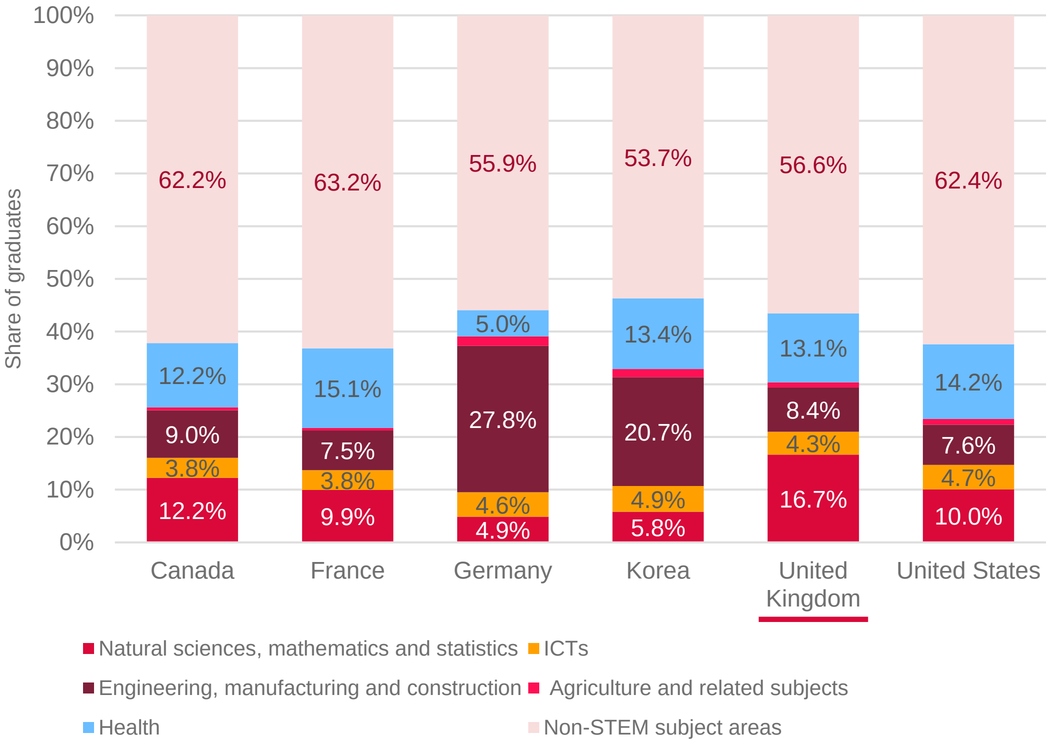
Source: OECD (2022). Adult education level (indicator).

- In 2020 the UK presented a level of tertiary education attainment (49.4%) that was well above the **OECD average** (39%) and countries such as **Italy** (20.1%), **Germany** (31.3%) and **France** (39.7%).
- Similarly to the **OECD average**, in the UK women's tertiary education attainment level (51.8%) was higher than men's attainment level (46.9%).
- Significant differences in tertiary education attainment levels exist across UK regions, ranging from 38% in **North East England** to 68% in **Greater London**, this being one of the highest regional variations across OECD countries.[1]
- In 2019 the share of foreign students enrolled in tertiary education courses in the UK was among the highest in the world (18.7%), only after **Luxemburg** (48.6%), **Australia** (28.4%) and **New Zealand** (20.8%).[2]
- The share of foreign students enrolled in tertiary education courses in 2019 was: 10.1% in **Germany**; 9.2% in **France**; and 5.2% in the **USA**. [2]

[1] OECD (2021) Education at Glance 2021 – United Kingdom Country Note.
[2] OECD (2022) International student mobility (indicator).

Chart 4.2. Graduates by subject areas

Bachelor degrees or equivalent, selected countries, 2019



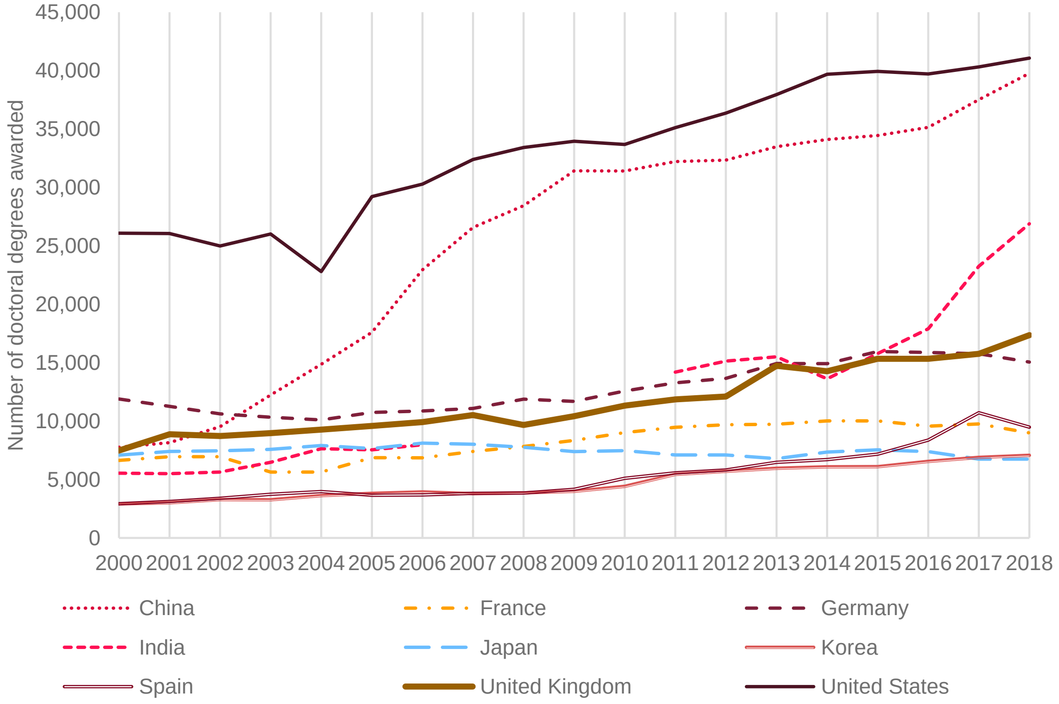
Note: Non-STEM subject areas include: arts and humanities; social sciences, journalism and information; business, administration and law; education; generic programmes and qualification; field unknown.
Source: OECD (2021). Education at a Glance database.

- Although innovation encompasses several disciplines, graduates in STEM disciplines (science, technology, engineering and mathematics) are of particular importance to innovation activities.
- The importance of boosting STEM skills has also been recognised in the UK Innovation Strategy.[1]
- In 2019, 431,820 students obtained a Bachelor degree from the UK's higher education institutions.
- Graduates in STEM disciplines accounted for 43.4% of the total graduates in the UK in 2019. This value was above that for comparator countries such as **France** (36.8%), **Canada** (37.8%) and the **United States** (37.6%).
- The share of graduates in engineering, manufacturing and construction remains relatively low in the UK, at 8.4%, especially compared to countries such as **Germany** (27.8%) and **Korea** (20.7%).

[1] BEIS (2021). UK Innovation Strategy – Leading the future by creating it.

Chart 4.3. STEM PhDs

Number of doctoral degrees awarded, selected countries, 2000–2018

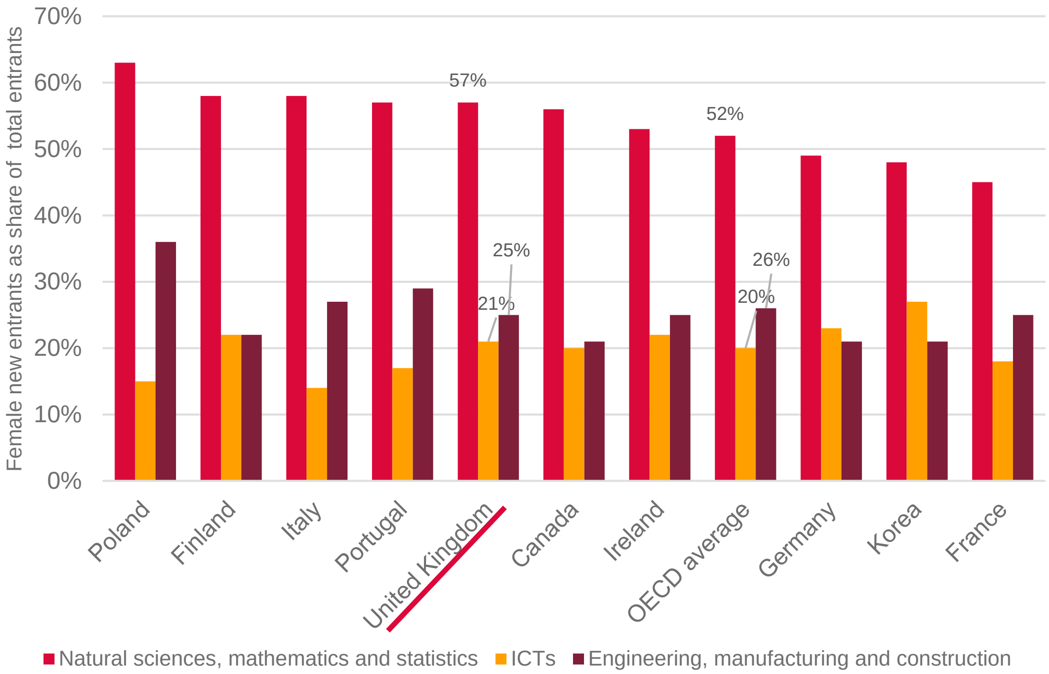


- In 2018 the UK's higher education institutions awarded 17,366 PhDs in STEM disciplines.
- The UK is among the countries with the highest number of STEM PhDs awarded per year, even compared to countries with larger populations.
- The **United States** has historically been the country with the highest number of STEM PhDs awarded per year (41,071 in 2018).
- **China** is rapidly catching up with the **USA** in awarding STEM PhDs, from 7,766 doctoral degrees awarded in 2000, to 39,768 in 2018, representing an increase of 412% in 18 years.

Notes: STEM PhDs include doctoral degrees awarded in the following fields: natural sciences, mathematics and statistics; ICTs; engineering, manufacturing and construction; agriculture and related subjects; health.
Source: NSF (2022). The State of US Science and Engineering 2022.

Chart 4.4. Women in STEM tertiary education

Female new entrants, share of total entrants, selected countries, 2019



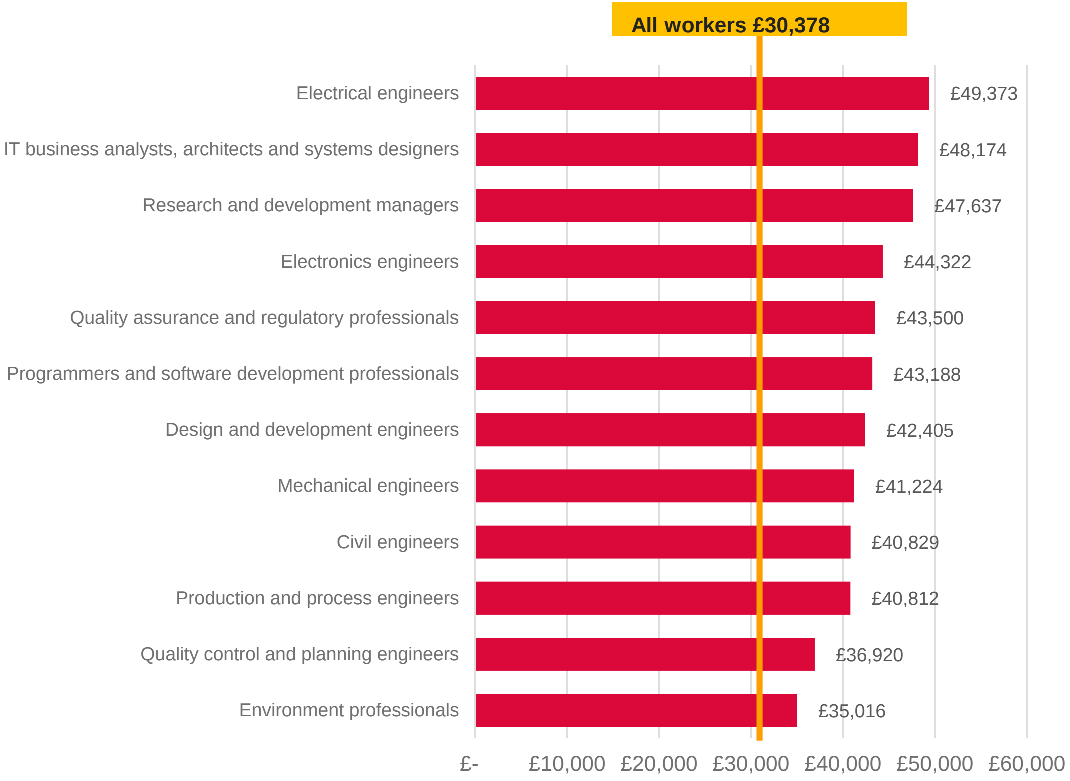
Source: OECD (2021). Education at a Glance.

- Similarly to the **OECD average**, in the UK women are under-represented in some STEM fields of study.
- In the UK women represented 25% of new entrants in engineering, manufacturing and construction degrees (against the 26% **OECD average**) and 21% of new entrants in ICT degrees (against the 20% OECD average).
- Gender disparities in accessing STEM degrees are reflected in the labour market composition. Against 52% of the total workforce:[1]
  - 27% of the STEM workforce is female;
  - 40% of the science and maths workforce is female;
  - 21% of the technology workforce is female; and
  - 9% of the engineering workforce is female.

[1] British Science Association (2020). The State of the Sector: Diversity and representation in STEM industries in the UK.

Chart 4.5. Engineering profession salaries

Gross annual salary, median salary, full-time employees, 2019



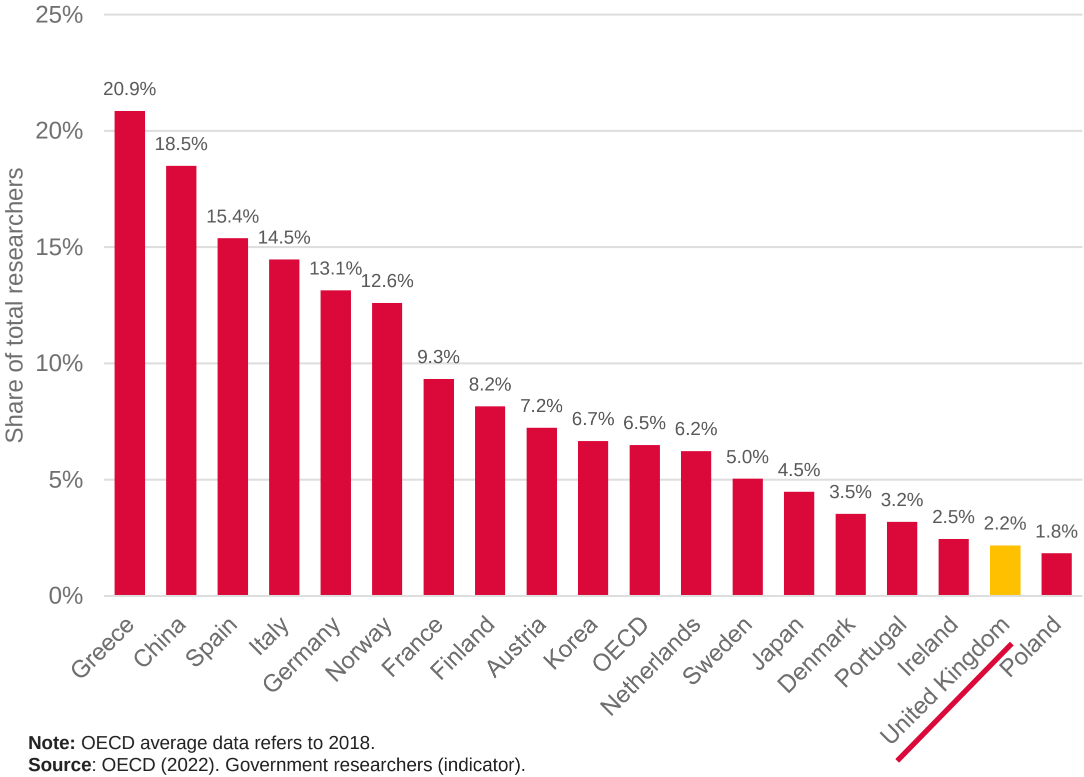
Notes: Standard Occupational Classification (SOC) codes for the engineering professions based on Engineering UK (2018). The State of Engineering 2018.
Source: ONS (2020). Earnings and hours worked, occupation by four-digit SOC: ASHE Table 14.

- In the UK the median salaries for engineering occupations are higher than the average in the job market.
- In 2019 the median gross annual salary for an engineering professional was £42,634, against the £30,378 median gross annual salary of all UK workers.[1]
- For UK engineers, the gender pay gap is smaller than the pay gap for all UK workers and is mainly due to the under-representation of women in senior and higher-paid roles.[2]

[1] Although more recent data is available, the comparison of salaries by occupation in 2020 and 2021 may be impacted by job market support programmes implemented during the COVID-19 pandemic.
[2] The gender pay gap is defined as “the difference in average hourly earnings for all men and all women across an organisation, a sector, or the economy as a whole”. See Royal Academy of Engineering (2020). Closing the engineering gender pay gap.

Chart 4.6. Government researchers

Share of total researchers, 2019 or latest available



Note: OECD average data refers to 2018.
Source: OECD (2022). Government researchers (indicator).

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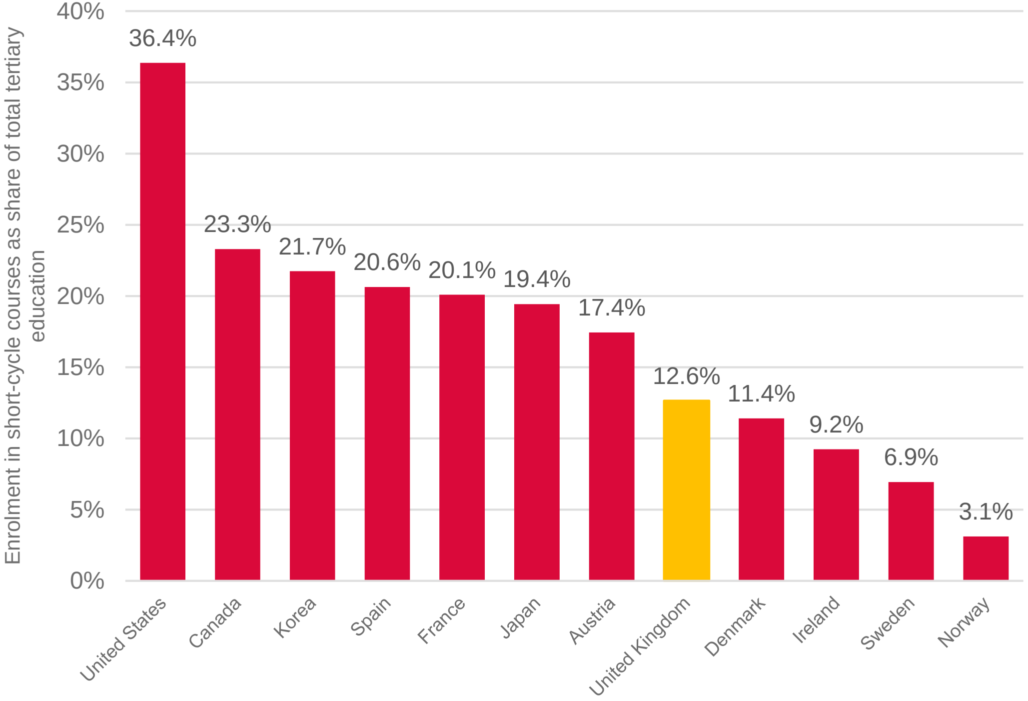
- The UK is among the OECD countries with the lowest proportion of researchers working for the government.[1]
- In 2019 the share of UK government researchers out of total researchers was 2.2%, against 6.5% of the OECD average.
- There have been calls for more people with STEM qualifications to be employed within the UK civil service for reasons connected to, for example, their ability to better understand specific policy issues related to science and technology.
- Analysis finds that the UK may be expected to have a relatively lower proportion of STEM-trained individuals within the civil service, potentially because of the lower starting salaries and the lower likelihood of undertaking skilled work in their area of training.[2]

[1] The OECD defines government researchers as "*professionals working for government institutions engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned*"
[2] Policy Links (2021). STEM professionals in the UK civil service: an international comparative study. IfM Engage, Institute for Manufacturing, University of Cambridge, Cambridge.

Chart 4.7. Higher technical education

Enrolment in short-cycle tertiary education, percentage of total tertiary education, 2019



Notes: Tertiary education includes: short-cycle tertiary education; Bachelor degrees; Master's degrees; PhD degrees.
Source: OECD (2021). Education at a Glance database.

- The UK has a shortage of people qualified in higher technical education (HTE), that is, in those qualifications awarded between A level and undergraduate degrees.[1]
- In 2019 students who were enrolled in short-cycle tertiary education in the UK made up 12.6% of the total tertiary education, compared to 36.4% for the **USA**, 23.3% for **Canada** and 21.7% for **Korea**.
- Further to the 2019 *Independent Review of Post-18 Education and Funding,* in January 2021 the UK government published the further education White Paper, *Skills for Jobs: Lifelong Learning for Opportunity and Growth.*
- To tackle the "*significant shortage of vital technician-level STEM skills*", the White Paper made proposals such as expanding the Institutes of Technology programme, continuing with the T level programmes and, more generally, reforming the post-A-level education system.[2]
- In June 2021 the government also announced a £30 million investment to support higher technical education in 2022. The funding has been allocated, among others, to the Institutes of Technology – consortia of further education colleges, universities and employers with a focus on STEM HTE – that will also work with the High Value Manufacturing Catapult.[3]

[1] In the Frameworks for Higher Education Qualifications of UK Degree-Awarding Bodies, HTE corresponds to Level 4 and Level 5, both corresponding to UNESCO ISCED Level 5. See Foster D. (2019). Level 4 and 5 education. House of Commons Library Briefing paper 8732.
[2] Hubble S. et at (2021). FE White Paper: *Skills for Jobs: Lifelong Learning for Opportunity and Growth.* House of Commons Library Briefing paper 9120.
[3] Donnelly A. (2021). Higher technical education gets a boost. Gatsby Charitable Foundation.

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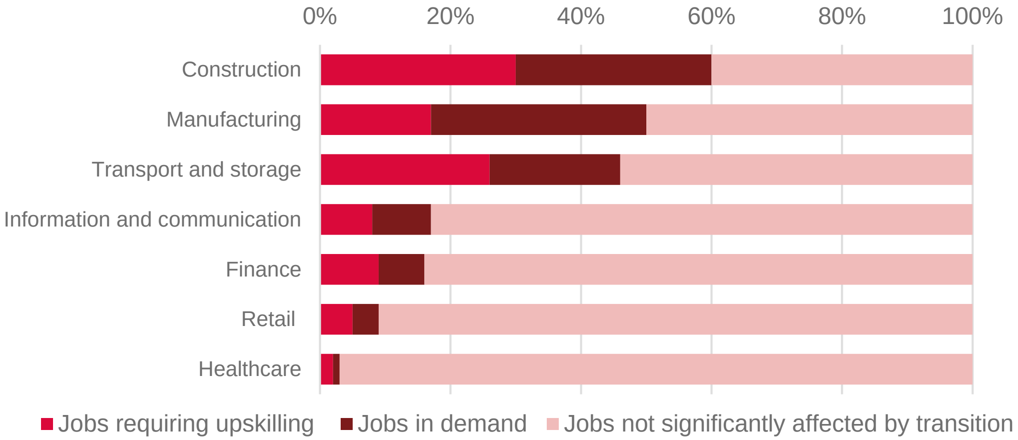
Chart 4.8. Green skills for net-zero transition

Percentage, selected sectors, based on 2019 job market data



Jobs requiring upskilling: Jobs that require significant changes in skills and knowledge. These include specialised jobs in the manufacturing and extractive sectors, such as petroleum engineers and heavy-equipment operators, whose skills need to be adapted to a net-zero economy.

Jobs in demand: Existing jobs that are expected to be in high demand as a result of their important role in the net-zero economy. These include specialised positions in the green economy, such as wind turbine installers, but also the skills and expertise of welders, builders and engineers already working to build the infrastructure of a green economy.

Source: Robins, N., Gouldson, A., Irwin, W. and Sudmant, A. (2019). *Investing in a just transition in the UK – How investors can integrate social impact and place-based financing into climate strategies.* London.

- The transition to a net-zero economy may impact 6.3 million jobs in the UK, with around 3 million workers requiring upskilling and 3 million in high demand.[a]
- Construction, manufacturing and transport have been identified as the sectors that will be more impacted in terms of job upskilling: it is projected that between 17% and 30% of the jobs in these sectors will require upskilling.[1]
- As highlighted by the independent report of the *Green Jobs Taskforce* announced by the UK government, "*to set the direction for the job market as we transition to a high-skill, low-carbon economy*", STEM skills will underpin jobs that are critical for the net-zero transition.
- The *Green Jobs Taskforce* has also identified "cross-cutting" skills as important to transitioning to net zero, including: digital and data skills; project management; education communication and change management; and leadership, management and communication skills.
- The *Green Jobs Taskforce* has also highlighted the expected increase in demand for engineering technicians in sectors such as **offshore wind** and in **electric vehicles' manufacturing**.

[1] PCAN (2021). *Tracking Local Employment In the Green Economy: The PCAN Just Transition Jobs Tracker.* Place-based Climate Action Network.

Theme 5: Net-zero innovation

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For many, the greatest challenge of the 21st century is climate change. Net zero refers to achieving a balance between the carbon emitted into the atmosphere and the carbon removed from it. Markets for new technologies that can help businesses and countries to achieve net zero are expanding, and therefore they are a key area in which innovative activity has the potential to contribute to national economic growth and competitive advantage.

Our *UK Innovation Report 2022* has chosen net-zero innovation as a topic in focus, to highlight how the UK is performing in what has the potential to be a high-growth economic sector. While climate-change mitigation technologies are not clearly classified within typical economic indicators, this section brings together the available data from global patent data and the so-called low-carbon and renewable-energy economy (LCREE) sectors within the UK. These allow us to provide a snapshot of whether net-zero innovation is translating into economic growth in the UK.

Theme 5: Policy questions and key messages

- How does the UK compare in low-carbon and renewable-energy technology research and development (R&D) investment?
- How is R&D expenditure translating into patenting performance?
- Is the UK capturing the economic potential of the transition towards net zero?

Although the UK's public R&D budget in low-carbon and renewable-energy technologies is comparable to other leading nations, the country underperforms slightly in terms of patenting

- The International Energy Agency (IEA) estimates that in 2020 the UK's public R&D budget in low-carbon and renewable-energy technologies was $1.2 billion (USD $2020), lower than the US ($8.1 billion), Japan ($2.9 billion) and France ($2.1 billion), but ahead of Germany ($1.1 billion) and Canada ($0.8 billion).
- In the period of 2013–17, the UK ranked eighth in the development of climate-change mitigation technology (CCMT) patents, behind Japan, the US, Germany, Korea, China, France and Taiwan but ahead of Italy and Canada. Key technology fields covered in this ranking include buildings, carbon capture and storage (CCS), energy, information and communication technology (ICT), manufacturing, transportation and waste management.

Most of the low-carbon and renewable-energy sectors in the UK have been declining over the last five years

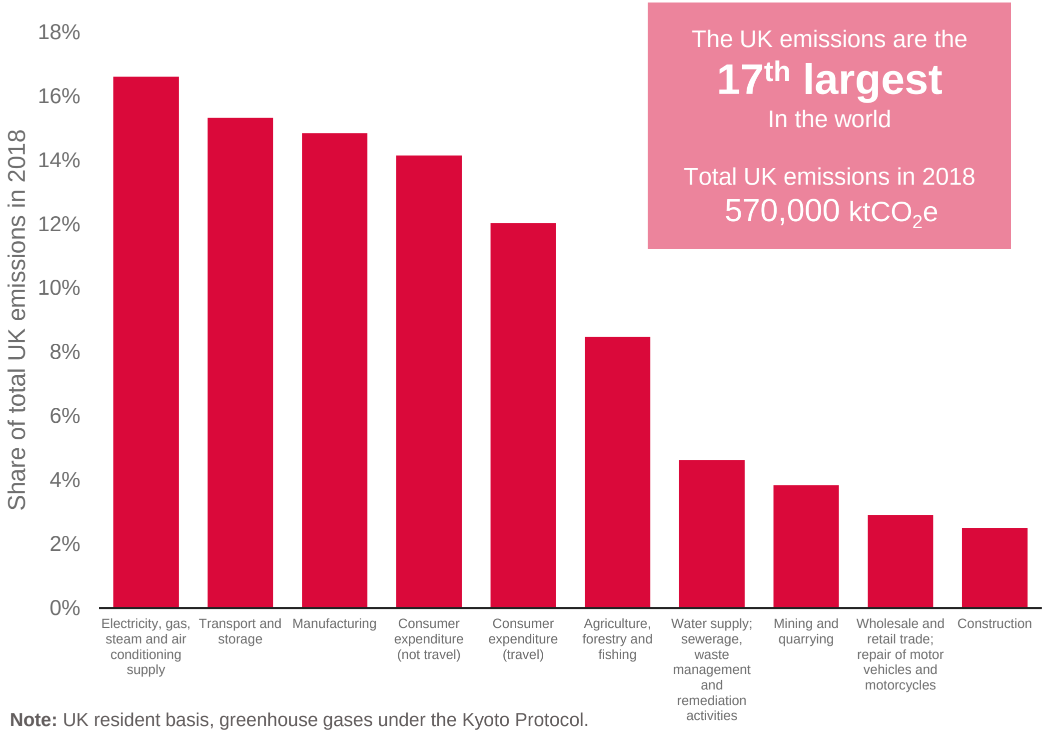
- The ONS defines the low-carbon and renewable-energy economy (LCREE) as 17 low-carbon sectors, including wind, renewables, PV, CCS, nuclear and energy-efficient products. Most of the low-carbon and renewable-energy sectors in the UK have been declining over the last five years, except for a small number of activities such as offshore wind. A total of 10 out of 17 sectors showed a decline in turnover between 2014 and 2019.
- Overall, there were 27,000 fewer LCREE business and 33,800 fewer jobs in LCREE sectors in 2019 than in 2014.

There are some national disparities, with Scotland performing strongly

- At £1.073 million turnover, 4.1 jobs and 2.2 businesses per 1,000 inhabitants, Scotland performed above the UK annual average for all categories between 2014 and 2019.
- Similarly, Wales performs above the national average for LCREE businesses and jobs, at 2.46 businesses and 3.35 jobs per 1,000 inhabitants.
- In contrast, Northern Ireland is under-performing relative to its size on turnover and employment in LCREE sectors, whereas England has a lower turnover (£605,000 per 1,000 inhabitants) than the national average (£643,000 per 1,000 inhabitants).

Chart 5.1. UK carbon emissions by sector

UK emissions of greenhouse gases by industry, share of total emissions in 2018



Note: UK resident basis, greenhouse gases under the Kyoto Protocol.

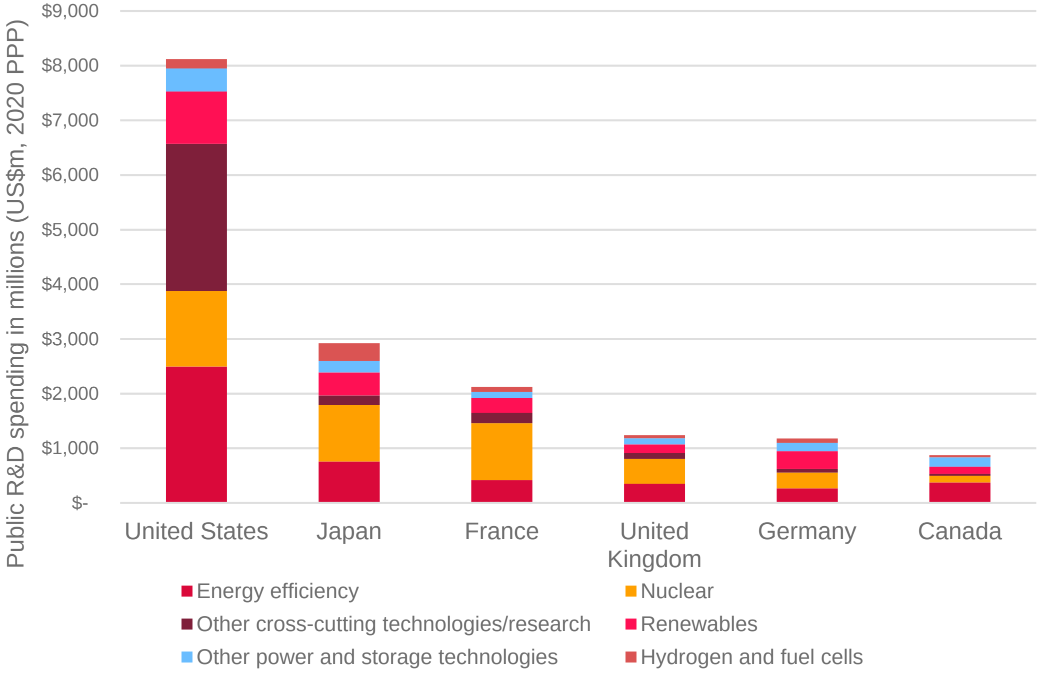
Source: ONS (2021). Atmospheric emissions: greenhouse gases by industry. Industry definitions provided in Appendix 5.1.

- Climate change is a current and pressing global challenge. The **Intergovernmental Panel on Climate Change's (IPCC)** most recent report identified that, unless there are immediate, rapid and large-scale reductions in greenhouse-gas emissions, limiting warming to **1.5°C** or even **2°C** will be beyond reach.[1]
- The **UK** is one of the top 20 emitters globally and has above-average emissions per capita, even before accounting for emissions embedded in imported goods. The **UK's** emissions are the 17th largest in the world,[2] with 1% of global emissions produced by 0.9% of the global population.
- The **UK's** high emissions represent a significant challenge but also a significant opportunity for innovation under regulatory constraints.

[1] IPCC (2021). Climate Change widespread, rapid, and intensifying.
[2] World Bank (2021). Total greenhouse gas emissions (kt of CO2 equivalent), 2018 figures.

Chart 5.2. Public R&D spending on low-carbon and renewable-energy technologies

USD$ million, 2020 PPP



Source: IEA (2021). IEA Energy Technology RD&D Budgets - October 2021 - Selected data.

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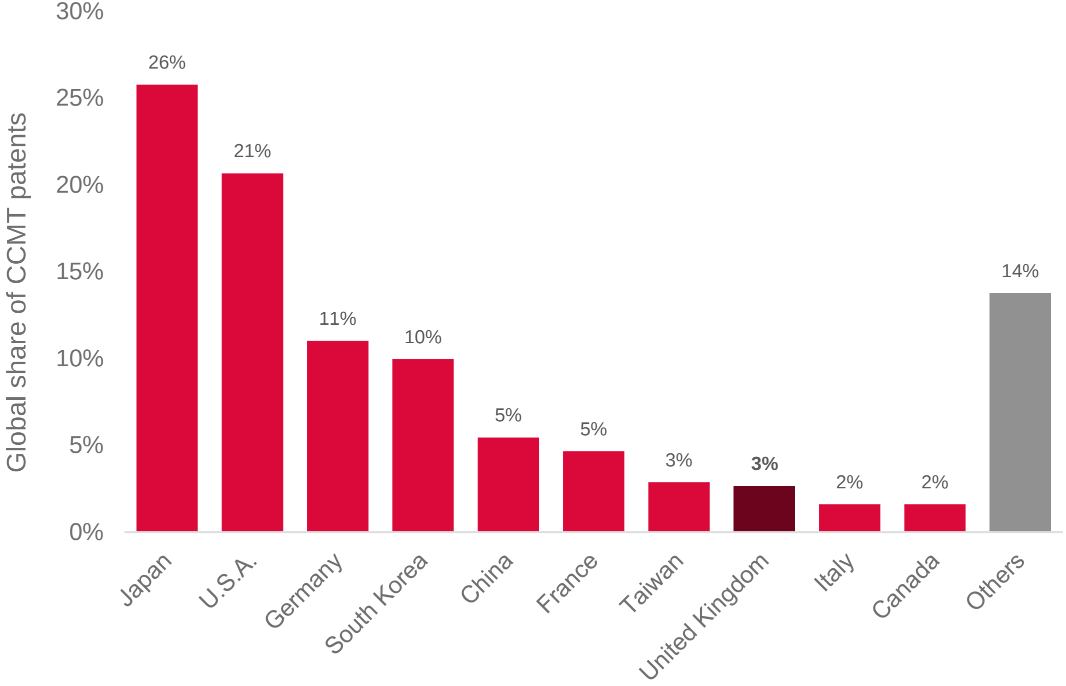
- Climate-change mitigation is an international priority. At COP26, countries worldwide reaffirmed their mitigation targets, including the **UK's** targets for a reduction in emissions of 78% by 2035 compared to 1990 levels and net-zero emissions by 2050.[1]
- This is reinforced by significant spending on innovation, including the £1 billion Net Zero Innovation Portfolio announced in March 2021.[2]
- The **International Energy Agency (IEA)** estimates that in 2020 the **UK's** public R&D budget in low-carbon and renewable-energy technologies was $1.2 billion (USD $2020), lower than France ($2.1 billion), Japan ($2.9 billion) and the US ($8.1 billion) but ahead of Germany ($1.1 billion) and Canada ($0.8 billion).[3]
- Categories included in the IEA's analysis include: **energy efficiency**; **renewables**; **nuclear**; **hydrogen and fuel cells**; other **power and storage technologies**; and other **cross-cutting technologies**.

[1] UK Government (2021). UK enshrines new target in law to slash emissions by 78% by 2035.
[2] UK Government (2021). Net Zero Innovation Portfolio.
[3] IEA (2021). IEA Energy Technology RD&D Budgets - October 2021 - Selected data.

Chart 5.3. Top 10 countries by global share of patents in climate-change mitigation technology (CCMT)

Worldwide inventions, 2013-2017



Source: Probst et al. (2021). Global trends in the invention and diffusion of climate change mitigation technologies.

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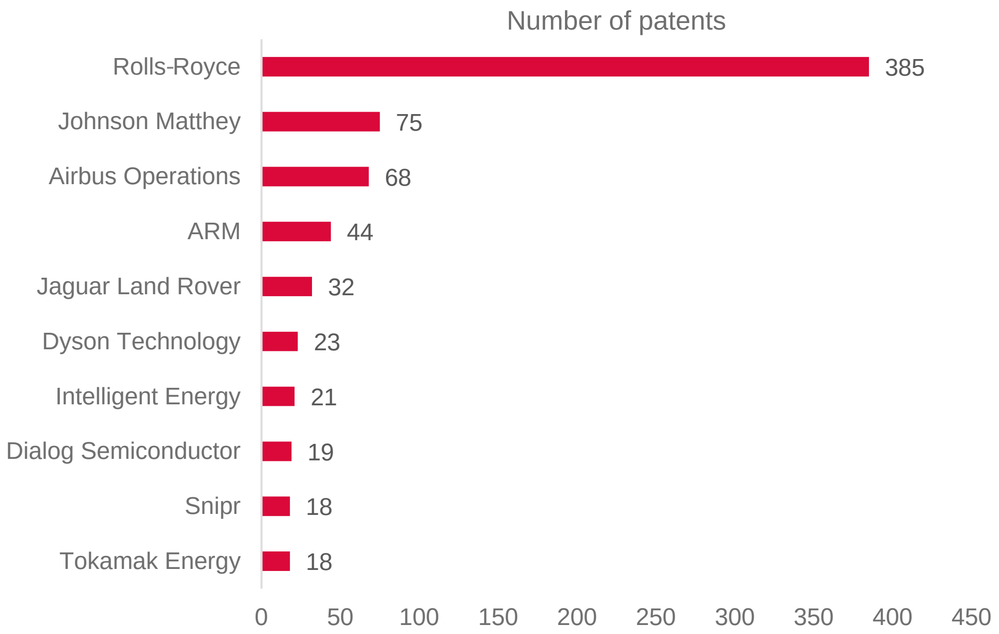
- The **UK** ranks eighth in the registration of climate-change mitigation technology (CCMT) patents, behind **Japan, the US, Germany, Korea, China, France and Taiwan** but ahead of **Italy** and **Canada.**[1][2]
- Technologies covered under the CCMT group include: **buildings**, **carbon capture and storage**, **energy**, **information and communication technology**, **manufacturing**, **transportation,** and **waste management**.
- It is unclear, however, whether this strength in patents is translating into economic performance for the **UK** or if the economic benefits are being exploited elsewhere.

[1] Climate-change mitigation technologies (CCMT) are defined as patents classified as "Y02" patents within the CPC classification scheme. The Y02 classification covers technologies for mitigation or adaptation against climate change and is a cross-sectional tagging scheme for new technological developments, particularly with the goal of highlighting patents in the field of climate-change mitigation. The classification was jointly developed by the USPTO and European Patent Office (EPO). See Appendix 5.2 for more detail.

[2] Probst et al. (2021). Global trends in the invention and diffusion of climate change mitigation technologies. Compiled with global data from the Worldwide Patent Statistical Database (PATSTAT) maintained by the European Patent Office (EPO). It contains bibliographical data relating to more than 100 million patent documents from leading industrialised and developing countries

Chart 5.4. Top 10 UK patent applicants in the field of climate-change mitigation technologies (CCMT)

UK firms, number of patents, United States Patent and Trademark Office, 2020



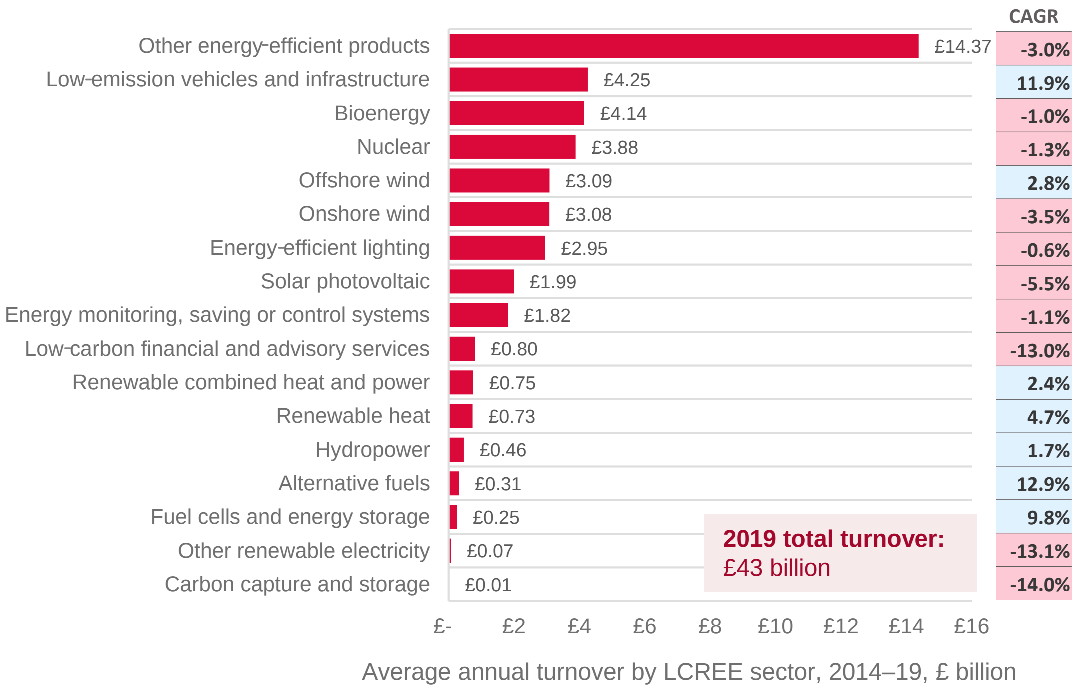
Note: The analysis includes patents published with the USPTO in 2020.
Source: Patent data was retrieved from Lens.org.

- The chart shows the top 10 **UK-based** patent applicants for climate-change mitigation technology patents published in 2020 with the **USPTO**.[1]
- The top patent applicant in the field of climate-change mitigation technologies is **Rolls-Royce**, with 385 patents.
- **Johnson Matthey** (75 patents), **Airbus Operations** (68 patents) and **ARM** (44 patents) follow in the ranking of climate-change mitigation technology patents.
- The top 10 **UK-based** companies patented a total of 703 patents.
- **UK-based** companies patented a total of 1,578 climate-change mitigation technology patents in 2020 with the **USPTO**.

[1] Climate-change mitigation technologies (CCMT) are defined as patents classified as “Y02” patents within the CPC classification scheme. The Y02 classification covers technologies for mitigation or adaptation against climate change and is a cross-sectional tagging scheme for new technological developments, particularly with the goal of highlighting patents in the field of climate-change mitigation. The classification was jointly developed by the USPTO and European Patent Office (EPO). See Appendix 5.2 for more detail.

Chart 5.5. UK low-carbon and renewable-energy economy (LCREE) sector performance

Average turnover (£ billion) and CAGR, 2014–2019



Note: This analysis uses results from the low-carbon and renewable-energy economy (LCREE) survey, run by the ONS (2021), which identifies 17 low-carbon sectors within the UK economy (see Appendix 5.2 for full detail).

Source: ONS (2021). Low Carbon and Renewable Energy Economy (LCREE) survey estimates, UK, 2014 to 2019.

- The overall turnover of the LCREE sectors showed a slight decline from £44 billion in 2014 to £43 billion in 2019 (for context, the overall **automotive industry** turnover is estimated at approximately £80 billion).[1]
- Activity captured within the largest sector – **other energy-efficient products** – is extremely broad. Examples include the design, manufacture or installation of energy-efficient doors, windows and insulation.
- Ten sectors showed a decline in turnover between 2014 and 2019. The largest growth industry between 2014 and 2019 was the **low-emission vehicles and infrastructure sector**, with a growth in turnover of just under £2.6 billion, or 12% p.a., between 2014 and 2019. Other growth sectors included **offshore wind, renewable heat and hydropower**.
- Despite the similar sizes of the **onshore and offshore wind sectors**, between 2014 and 2019 **offshore wind** was growing, while **onshore wind** was declining, in approximately equal proportions. There was a net decrease in turnover in **wind** between 2014 and 2019 (~-£65 million turnover difference).

Note: This analysis uses results from the low-carbon and renewable-energy economy (LCREE) survey, run by the ONS (2021), which identifies 17 low-carbon sectors within the UK economy (see Appendix 5.2 for full detail).

[1] SMMT (2021). Economy – Automotive's Economic Contribution – Key Industry Indicators.

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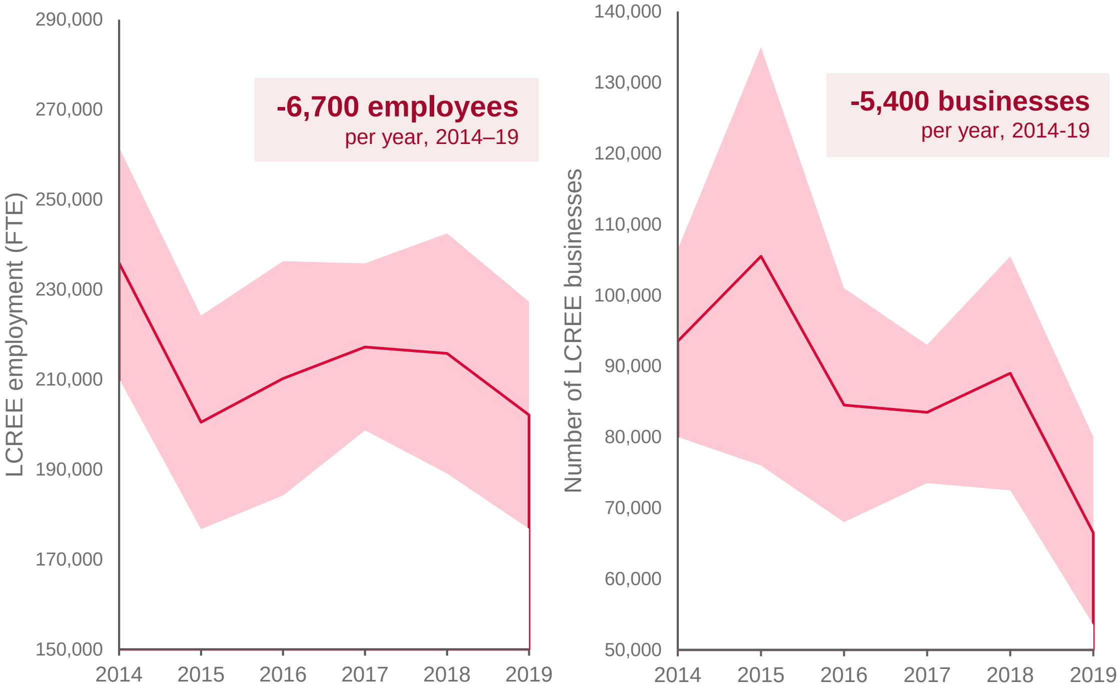
Chart 5.6. Employment and number of businesses in the low-carbon and renewable-energy economy (LCREE)

Number of employees and businesses between 2014 and 2019



Source: ONS (2021). Low Carbon and Renewable Energy Economy (LCREE) survey estimates, UK, 2014 to 2019.

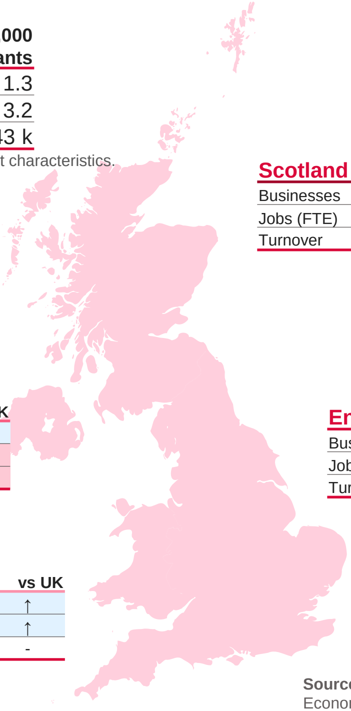
- Despite the potential for LCREE to represent a growth sector within the **UK** economy during a period of increasing policy importance, the number of **businesses** and **employees** within these sectors in the **UK** declined from 2014 to 2019.
- There were 27,000 fewer businesses in 2019 than in 2014, a net loss of ~5,400 businesses per year.
- Similarly, there were 33,800 fewer jobs in the LCREE sectors in 2019 than in 2014, a net loss of ~6,700 jobs per year.
- SMEs employed the vast majority (69% FTE) of individuals working in the LCREE sectors between 2014 and 2019.
- Total employment has been falling within SMEs in the LCREE sector, at an average rate of 9,860 fewer jobs in SMEs per year between 2014 and 2019. While employment has been increasing in larger companies, at an average rate of 3,100 jobs per year, this still results in a net decline.

Chart 5.7. Low-carbon and renewable-energy economy (LCREE) sectors comparison by country

Proportion of total UK LCREE turnover, both total and compared to UK performance on a per capita (‘000) basis, annual average for 2014–2019

The UK	Total	per 1,000 inhabitants
Businesses	87,000	1.3
Jobs (FTE)	214,000	3.2
Turnover	£43 bn	£643 k

Note: National figures do not add up due to data-set characteristics.



Scotland	Total	per 1,000 inhabitants	vs UK
Businesses	12,000	2.2	↑
Jobs (FTE)	22,600	4.1	↑
Turnover	£5.9 bn	£1.073 m	↑

Northern Ireland	Total	per 1,000 inhabitants	vs UK
Businesses	3,500	1.9	↑
Jobs (FTE)	5,600	2.9	↓
Turnover	£1.0 bn	£524 k	↓

England	Total	per 1,000 inhabitants	vs UK
Businesses	74,000	1.3	-
Jobs (FTE)	174,000	3.1	-
Turnover	£34.1 bn	£605 k	↓

Wales	Total	per 1,000 inhabitants	vs UK
Businesses	7,800	2.46	↑
Jobs (FTE)	10,600	3.35	↑
Turnover	£2.0 bn	£642 k	-

Source: ONS (2021). Low Carbon and Renewable Energy Economy (LCREE) survey estimates, UK, 2014 to 2019.

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- Analysing LCREE data by country indicates that **Scotland** punches above its weight, while **Northern Ireland** is under-performing relative to its size on turnover and employment in the LCREE sectors.
- While **England** has the highest total turnover in LCREE businesses, **Scotland** has a higher performance on a per-capita basis.
- Relative to the other countries, **Scotland** has the highest proportion of its average turnover generated by onshore wind. It also has above-average input from nuclear and hydropower and below-average input from low-emission vehicles and infrastructure.
- Perhaps surprisingly, offshore wind makes up only 5% of **Scotland’s** average turnover – less than **England** (8%) or **Wales** (6%) but above **Northern Ireland** (0.5%).
- **Northern Ireland** performs poorly on turnover on a per capita basis. **Northern Ireland** has the highest per capita share of employment within the low-emission vehicles and infrastructure sector, at 25% of all LCREE employment in **Northern Ireland**, compared to no more than 5% in other countries. Overall, **Northern Ireland** has fewer employees in the LCREE sectors despite having more businesses on a per capita basis.

Appendix 5.1

Sectoral breakdown for ONS (2021) atmospheric emissions: greenhouse gases by industry and gas [1]

Sector	Sub-sector
Electricity, gas, steam and air-conditioning supply	Electricity production – coal
	Electricity production – gas
	Electricity production – nuclear
	Electricity production – oil
	Electricity production – other
	Manufacture of gas; distribution of gaseous fuels through mains and steam and air-conditioning supply
Transport and storage	Air transport services
	Buses, coaches, trams and similar public urban transport n.e.c
	Freight transport by road and removal services
	Postal and courier services
	Rail transport
	Taxis and other renting of private cars with driver
	Transport via pipeline
	Underground, metro other non interurban rail services
	Warehousing and support services for transportation
	Water transport services
Consumer expenditure	Consumer expenditure – not travel
	Consumer expenditure – travel
Agriculture, forestry and fishing	Fish and other fishing products; aquaculture products; support services to fishing
	Products of agriculture, hunting and related services
	Products of forestry, logging and related services
Water supply; sewerage, waste management and remediation activities	Natural water; water treatment and supply services
	Remediation services and other waste management services
	Sewerage services; sewage sludge
	Waste collection, treatment and disposal services; materials recovery services
Mining and quarrying	Crude petroleum and natural gas
	Mining of coal and lignite
	Mining of metal ores
	Mining support services
	Other mining and quarrying products
Wholesale and retail trade; repair of motor vehicles and motorcycles	Retail trade services, except of motor vehicles and motorcycles
	Wholesale and retail trade and repair services of motor vehicles and motorcycles
	Wholesale trade services, except of motor vehicles and motorcycles
Construction	Buildings and building construction works
	Constructions and construction works for civil engineering
	Specialised construction works

Sector	Sub-sector	Sub-sector
Manufacturing	Aluminium production	Motor vehicles, trailers and semi-trailers
	Basic pharmaceutical products and pharmaceutical preparations	Other manufactured goods
	Building of ships and boats	Other nitrogen compounds
	Computer, electronic, communication and optical products	Paper and paper products
	Electrical equipment	Plastics products
	Fabricated metal products, except machinery and equipment, excluding weapons and ammunition	Printing and recording services
	Fertilisers	Processing and preserving of fish, crustaceans, molluscs, fruit and vegetables
	Furniture	Processing and preserving of meat and production of meat products
	Leather and related products	Processing of nuclear fuel
	Machinery and equipment n.e.c.	Repair and maintenance of aircraft and spacecraft
	Manufacture of air and spacecraft and related machinery	Repair and maintenance of ships
	Manufacture of alcoholic beverages, including spirits, wine, cider, beer and malt	Rest of repair; Installation
	Manufacture of articles of concrete, cement and plaster	Rubber products
	Manufacture of bakery and farinaceous products	Textiles
	Manufacture of basic Iron and steel	Tobacco products
	Manufacture of cement	Wearing apparel
	Manufacture of cleaning and toilet preparations	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials
	Manufacture of coke oven products	
	Manufacture of dairy products	
	Manufacture of dyestuffs, agro-chemicals	
	Manufacture of glass, refractory, clay, other porcelain and ceramic products, stone and abrasive products	
	Manufacture of grain mill products, starches and starch products	
	Manufacture of industrial gases and non-nitrogen-based inorganic chemicals	
	Manufacture of lime	
	Manufacture of other basic metals and casting (excl. nuclear fuel and aluminium)	
	Manufacture of other chemical products and man-made fibres	
	Manufacture of other food products	
	Manufacture of other transport equipment, excluding ships, boats, air and spacecraft	
	Manufacture of paints, varnishes and ink	
	Manufacture of petrochemicals	
	Manufacture of plaster	
	Manufacture of prepared animal feeds	
	Manufacture of refined petroleum products	
	Manufacture of soft drinks: production of mineral waters and other bottled waters	
	Manufacture of vegetable and animal oils and fats	
	Manufacture of weapons and ammunition	

[1] ONS (2021). Atmospheric emissions: greenhouse gases by industry and gas.

Appendix 5.2

Key definitions

Defining climate-change mitigation technologies (CCMT) within patent analysis globally

- High-value climate-change mitigation technologies (CCMT), compared to other similar countries.
- This analysis is based on the Y02 classification scheme, which provides the most comprehensive and standardised low-carbon patent classification. It covers most technology fields, buildings, carbon capture and storage (CCS), energy, information and communication technology (ICT), manufacturing, transportation and waste management.
- This analysis uses international patent families for high-value inventions (which comprise the top ~25% of all patented CCMT inventions).
- Analysis compiled with global data from the Worldwide Patent Statistical Database (PATSTAT) maintained by the European Patent Office (EPO). It contains bibliographical data relating to more than 100 million patent documents from leading industrialised and developing countries.

More information at:

- https://www.uspto.gov/web/patents/classification/cpc/html/cpc-Y.html#Y02
- https://www.epo.org/searching-for-patents/business/patstat.html

Defining low-carbon and renewable-energy economy (LCREE) sectors within the UK

The low-carbon and renewable-energy economy (LCREE) survey, run by the ONS (2021), identifies 17 low-carbon sectors, as follows:

- offshore wind
- onshore wind
- solar photovoltaic
- hydropower
- other renewable electricity
- bioenergy
- alternative fuels
- renewable heat
- renewable combined heat and power
- energy-efficient lighting
- other energy-efficient products
- energy monitoring, saving or control systems
- low-carbon financial and advisory services
- low-emission vehicles and infrastructure
- carbon capture and storage
- nuclear
- fuel cells and energy storage

Activity captured within the largest sector – other energy-efficient products – is extremely broad. Examples include the design, manufacture or installation of energy-efficient doors, windows and insulation.

Within this report, these sectors are used as the best available proxy to understand the dynamics of the UK's climate-change mitigation technology economy.