INNOVATION & RESEARCH CAUCUS

GLOBAL REACH, LOCAL ROOTS:

UNDERSTANDING THE INTERNATIONALISATION OF R&D AMONG UK FIRMS

IRC Report No: 042

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About the Innovation and Research Caucus

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Executive Summary

This report presents new evidence on the UK innovative landscape with special attention on the internationalisation of research and development (R&D) among UK firms, drawing from patent data and firm-level records spanning 2000 to 2021. The country shows a robust growth in R&D investment and a consistently strong position in global innovation rankings whilst navigating major global shocks. The report highlights both achievements and structural weaknesses in the UK's R&D system and proposes policy directions to enhance global engagement and innovation capacity.

- The UK consistently ranks among the top 10 innovators in the world for life sciences technologies. However, emerging technologies show mixed results. The UK excels in green technologies and semiconductors but lacks global competitiveness in AI, quantum, and robotics. Patenting is dominated by a few actors, raising concerns about depth and inclusivity.
- International collaboration, long a cornerstone of UK innovation, has weakened since 2014 - particularly with EU partners. While deep ties with the US and select Asian economies persist, the overall collaboration base is narrowing, limiting access to diverse global knowledge pools.
- In the last decade UK-China research links grew significantly, accounting for over 10% of UK joint output.
- Pharmaceuticals, ICT and Original Equipment Manufacturing are the top 3 innovative sectors over time with OEM firms increasingly shifting from the EU to the US and China.
- Domestic companies are more likely to engage in domestic collaboration, which means that international R&D is mainly done by multinationals or foreign owned companies, particularly from the US and Canada.

1. Introduction and research motivation

There are large and persistent gaps in understanding the internationalisation of research and development (R&D) between firms, particularly in the context of advanced economies such as the UK (Castellani and Du, 2023). As innovation becomes increasingly globalised, it is vital to examine how firms and countries position themselves in global knowledge networks, and how this affects their economic and technological resilience.

For the UK, this issue has become especially salient in the wake of recent geopolitical and economic shocks. As recently outlined in the UK Government Industrial Strategy (June 2025), collaboration and support R&D are key to achieve growth and economic security.

The UK's hiatus from EU programmes such as Horizon 2020 led to a decline in international research funding—from £5.6 billion in 2014 to £5.0 billion in 2017 (Garas et al., 2019; Resolution Foundation, 2022). Recent evidence shows a decline in UK firms' R&D since the Brexit referendum (Pichler and Pisera, 2023), while the UK's exit from the EU and the recent geopolitical tensions have also posed challenges to international R&D. Inward investment patterns also shifted, favouring research offices and facilities over production and export-oriented platforms (The Economist, 2019; Driffield et al., 2023).

Despite an overall increase in the UK public and private R&D expenditure after 2016 (Resolution Foundation, 2022, see also Figure 1 and 2 in section 4), these gains were in part compensatory—reflecting efforts to replace lost EU-based support. At the same time, venture capital inflows into UK biotech and tech startups rose sharply, contributing to record funding rounds in areas like AI and life sciences. However, systematic evidence on how firms responded to these shifts—especially at the level of collaboration patterns and international linkages—remains scarce.

This report addresses that evidence gap. It provides a comprehensive, data-driven analysis of how UK firms have internationalised their R&D over the period 2000–2021, focusing on the structure, scale, and evolution of cross-border innovation activity. The study combines two analytical perspectives. First, it uses the full universe of global patent applications from the PATSTAT database to assess system-level trends in technological specialisation, international collaboration, and global innovation positioning. Second, it draws on a linked dataset integrating PATSTAT with Orbis Intellectual Property data to examine firm-level heterogeneity—by ownership, size, sector, and collaboration mode. This dual approach allows the report to capture both the macro-structure of UK innovation and the micro-level behaviours of the firms that underpin it.

The report addresses two core research objectives:

- RO1: To examine the structure and evolution of collaborative international R&D, and how these vary across industrial sectors and technological domains.
- RO2: To investigate how different types of firms-particularly multinationals versus SMEs-responded to recent shocks in their R&D internationalisation strategies.

This study makes two principal contributions. First, it introduces a robust data infrastructure that enables longitudinal and disaggregated analysis of UK firms' international R&D activity. Drawing on a novel linkage of global patent data with firm-level financials, ownership structures, and cross-border investment records, the analysis captures both established technological fields (e.g. mechanical engineering, instrumentation, chemistry) and strategically important emerging domains (e.g. AI, green technologies, quantum, semiconductors), in line with national priorities outlined in the UK Science and Technology Framework (2023, 2024) and very recently in the UK Government Industrial Strategy (2025).

Second, the report generates new empirical insights into the heterogeneity of UK innovation actors - by firm size, ownership, sector, and international collaboration mode. It extends existing literature that has primarily focused on large multinationals, shedding light on the roles of SMEs and domestically embedded firms in the global innovation system (Rodríguez and Nieto, 2016; Nieto and Rodríguez, 2022).

The findings contribute directly to UKRI's strategic goals - including advancing future technologies and building a green innovation economy - and support the ESRC's commitment to data-driven, evidence-informed policy. As the UK repositions itself in a shifting global innovation landscape, this report offers timely evidence on how firms are adapting, where comparative strengths are emerging, and how policy can support sustained international R&D engagement.

2. Conceptual and policy context

2.1 Theoretical foundations of R&D internationalisation

The internationalisation of research and development (R&D) plays a central role in driving innovation and technological progress. It offers firms strategic advantages for several reasons. First, cross-border collaboration grants access to diverse knowledge bases and complementary capabilities, which can accelerate innovation (Kafouros & Forsan, 2012; Narula, 2001). Second, international partnerships enable cost sharing and risk mitigation, allowing firms to conduct R&D more efficiently (Sampson, 2005). Third, global R&D networks enhance firms' ability to enter new markets and gain exposure to emerging technologies (Narula, 2001).

However, despite these benefits, firms often exhibit a strong "home bias" in R&D location choices. This reflects several constraints. Coordination costs and the complexity of managing geographically dispersed teams are significant (Belderbos et al., 2013). Intellectual property risks also deter firms from pursuing international collaboration (Patel & Pavitt, 1991). In addition, challenges in integrating knowledge across locations can limit the effectiveness of cross-border innovation efforts (Belderbos et al., 2013).

The success of international R&D collaborations depends critically on firms' absorptive capacity, the strength of institutional frameworks, and the degree of cultural and geographic proximity between partners (Castellani & Du, 2023; Tojeiro-Rivero & Moreno, 2019). As innovation becomes increasingly transnational, understanding the broader economic, social, and environmental implications of R&D internationalisation is essential (Castellani & Du, 2023).

2.2 Global R&D landscape and emerging trends

Global R&D activity has long been dominated by multinational enterprises (MNEs) from advanced economies, which have leveraged extensive international networks to strengthen their innovation capacity (Alcácer et al., 2016). In recent years, however, this landscape has been reshaped by the growing influence of MNEs from emerging markets, particularly China and India.

China has rapidly transitioned from a peripheral player to a central hub in global innovation networks. It now leads the world in both the volume and connectivity of patent filings, having risen from 8th in global rankings before 2005 to 1st after 2015 (Scherngell et al., 2020). More importantly, emerging economies like China and India are increasingly becoming the sources of knowledge (Lundvall & Rikap, 2022).

These shifts are reflected in global patent trends, which show intensifying international competition. Although the UK remains among the top ten patenting countries - especially in fields such as medical technology and biotechnology - its growth has been modest relative to the rapid expansion observed in China and South Korea since the mid-2000s (Scherngell et al., 2020).

2.3 UK context: policy shifts and Brexit impacts

The internationalisation of UK R&D has evolved within a shifting policy and structural context, profoundly influenced by the UK's departure from the European Union in 2016. Brexit marked a turning point, disrupting long-established mechanisms for funding and collaboration. The UK's withdrawal from the Horizon research framework led to a sharp reduction in international research funding, which fell from £5.6 billion in 2014 to £5.0 billion by 2017 (Bloom et al., 2018). UK firms and universities encountered growing barriers to EU collaborative projects, diminished access to skilled researchers, research facilities and increasing uncertainty over talent mobility (Garas et al., 2019).

These disruptions also affected patterns of inward investment. Post-referendum, investment flows increasingly favoured the establishment of offices and research facilities rather than production or export-oriented platforms (The Economist, 2019; Driffield et al., 2023). Firm-level data indicate a broader decline of about 6% in R&D expenditure among UK firms in the years following the Brexit vote[1] (Pichler & Pisera, 2023).

In response to the Brexit referendum (2016), the UK government took steps to reinforce its national innovation ecosystem and maintain crucial international research and development (R&D) linkages. The government set an ambitious goal to raise R&D investment to 2.4% of GDP by 2027. By 2019, they had successfully achieved this target, with R&D reaching 2.6%

[1] After 2021, the HM Revenue and Customs data identified a 2.4% real terms decrease in R&D expenditure in forms of tax credits. For further details on the use of tax credits and other Research & Innovation policy tools see Ribaudo, Marin-Cadavid & Macbryde (2024).

of GDP. These efforts were further reinforced, and in the 2021 Spending Review, the government confirmed its plans to increase public R&D by £20 billion annually from 2024 to 2025. Central to this effort is the UK Science and Technology Framework (2023–2024), which outlines strategic priorities across five critical technologies: artificial intelligence, semiconductors, quantum technologies, engineering biology, and future telecommunications. The framework also places strong emphasis on accelerating commercialisation, fostering international partnerships, and upgrading national research infrastructure. These objectives have been reiterated in the just published industrial strategy that sets £670 million to drive the adoption of quantum computers, and £500 million to develop AI Growth Zones.[2]

2.4 Comparative perspective and challenges

The UK's innovation system remains globally significant but faces intensifying competitive pressures. In 2021, the UK's total R&D expenditure reached 2.91% of GDP - a notable improvement, yet still trailing innovation leaders such as South Korea and Japan, both of which invest over 3% of GDP. The UK also lags behind the United States and Germany in terms of investment intensity and the robustness of commercialisation ecosystems (OECD, 2021).

Within the private sector, business enterprise R&D (BERD) rose to 2.05% of GDP, a positive trajectory but one that remains below comparative benchmarks set by the US and Germany. In terms of innovation output, the UK continues to rank among the global top ten in patenting across key technological fields, particularly in medical and biotech domains. However, it has not matched the exponential growth in patent filings seen in China and South Korea since the mid-2000s.

Broader structural challenges persist. Geopolitical tensions and institutional fragmentation - exacerbated by the UK's temporary exclusion from EU R&D programmes such as Horizon - have imposed additional costs. These have been particularly acute in domains of strategic importance, such as climate change and Industrial Digital Technologies (Garas et al., 2019). Together, these pressures underscore the need for sustained policy effort to secure the UK's position in a rapidly evolving global innovation landscape.

[2] See also The UK's modern Industrial Strategy

2.5 Research gap and report objectives

While the UK's R&D internationalisation is well-documented pre-Brexit, there is a lack of comprehensive analysis on post-Brexit inter-firm R&D internationalisation. This report addresses this gap by examining the extent, impact, and challenges of R&D internationalisation across sectors, technologies, and firm types. It situates the UK within a shifting global innovation landscape, where national systems are increasingly interdependent yet vulnerable to fragmentation. Understanding these dynamics is essential for informing policies that strengthen the UK's innovation system, safeguard its comparative advantages, and broaden firm participation in global research networks.

3. Methodology and data sources

The empirical analysis draws on patent-level and firm-level data from multiple sources. Core data are obtained from PATSTAT Global (Autumn Edition 2023), a comprehensive patent database managed by the European Patent Office, covering over 100 million patent documents worldwide. The dataset includes detailed information on patent applicants, inventors, jurisdictions, and technology classifications[3].

To identify UK-based innovation, we selected patents with at least one applicant located in the UK between 2000 and 2021[4]. To account for multiple filings of the same invention across jurisdictions, we adopted the DOCDB patent family definition, treating each family as a unique innovation unit. This approach avoids duplication and aligns with international research practice (Amendolagine et al., 2023; Dechezleprêtre et al., 2015). The patent dataset was linked to firm-level records from ORBIS Intellectual Property, provided by Moody's Bureau van Dijk. This database offers extensive information on firms' financials, sector classifications, and ownership structures, enabling detailed analysis of the characteristics of R&D-active firms. Matching was performed using applicant names and identifiers. In total, we identified over 270,000 unique patent families with UK applicants, covering 658 CPC technological classes

[3] We use the Cooperative Patent Classification (CPC) at the 6-digit level from PATSTAT and concordance tables from CPC.org to retrieve International Patent Classification from the World Intellectual Property Organisation to build indicators consistently. Concordance table between IPC and CPC codes are available at CPC.org
[4] We take the application year of the first patent in the family.

and 173 countries. We further harmonised CPC subclasses into broader technological fields using the Schmoch (2008) classification, resulting in five aggregate categories: Electrical Engineering, Instruments, Chemistry, Mechanical Engineering, and Other Fields. Special attention was given to emerging technologies such as AI, green technologies, semiconductors, and quantum, consistent with UK policy priorities.

Firms were categorised by industry (NACE Rev.2), size, ownership, and collaboration status (solo, domestic, or international). We distinguish between patents filed by individual UK firms, those involving UK-based collaboration, and those reflecting international joint activity. This methodology enables a granular and longitudinal analysis of the UK's innovation landscape, capturing both national trends and cross-border linkages in R&D activity.

4. The UK Innovation Landscape: Trends and Global Position

The UK has maintained a significant position in global innovation rankings over the past two decades, with strong scientific output and steady growth in R&D investment. The UK excels in academic research, producing 16% of the world's highest-quality scientific publications despite having less than 1% of the global population (Cambridge Industrial Innovation Policy, 2024). This strong knowledge base has driven the UK's rise in global innovation rankings, climbing from 10th in 2011 to 2nd in 2015 in the Global Innovation Index (GII)[5], and maintaining a top-tier position post-2016. As a result, the UK's overall innovation performance (as measured by research output, startup activity, etc.) was robust through the 2010s (DSIT, 2015). However, it faces rising competitive pressures and ongoing challenges in commercialisation, collaboration, and innovation scaling.

4.1 R&D investment and system-level patent performance

From 2000 to 2021, the UK's R&D intensity - measured as gross domestic expenditure on R&D (GERD) as a share of GDP- increased from 1.6% to 2.91%. This upward trajectory peaked in 2020, a figure partly inflated by a temporary pandemic-related GDP contraction. Despite this

[5] See also wipo.int

progress, the UK still lags behind top-performing countries such as South Korea (~4.5%), the US (~3.4%), and Japan and Germany (above 3%), and remains marginally below the OECD average of 2.95% (UK Innovation Report, 2023).

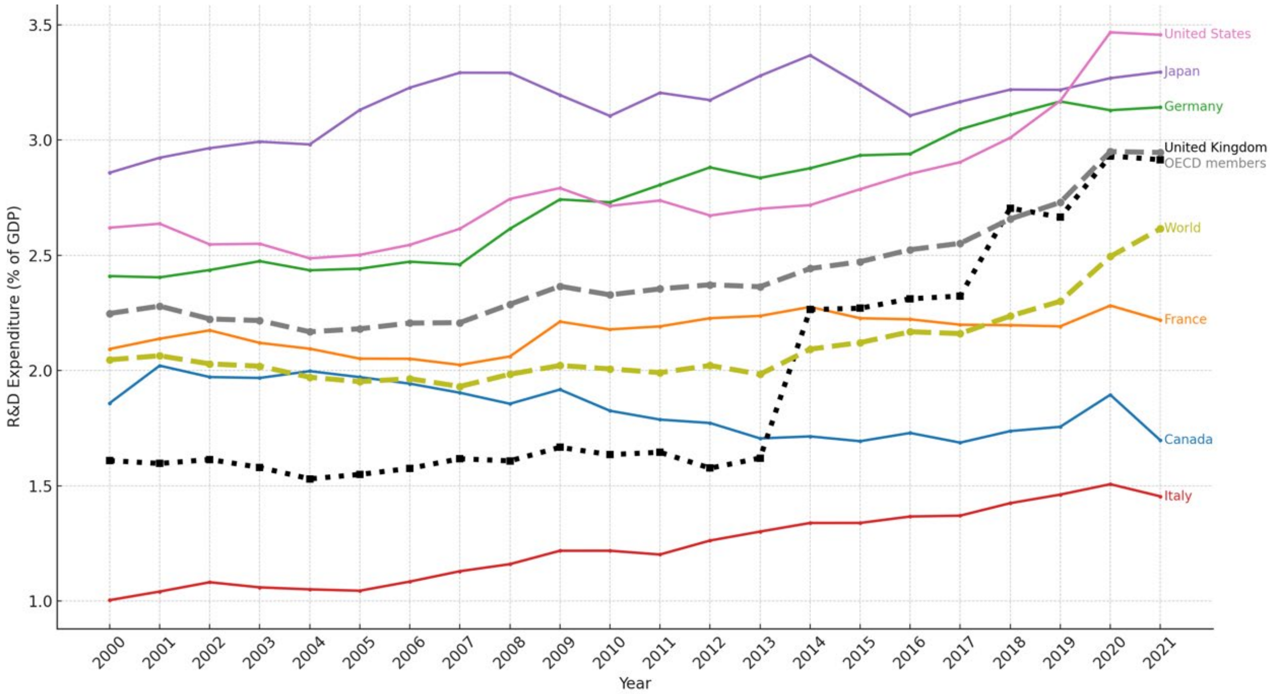

Figure 1. GERD. R&D Expenditure (% GDP) over time.

Source: Authors' elaboration based on World Bank Indicators.

To address long-standing underinvestment, the UK government set a 2.4% R&D intensity target by 2027, which was reached early in 2019. Business enterprise R&D (BERD) followed a similar trend, rising from 1.05% in 2000 to 2.05% in 2021 - slightly above the OECD average of 1.99% but still behind other R&D-intensive economies. While the private sector drives most R&D activity, persistent challenges in commercialisation and innovation diffusion limit the translation of investment into globally competitive outcomes. These issues are explored further in Section 5.

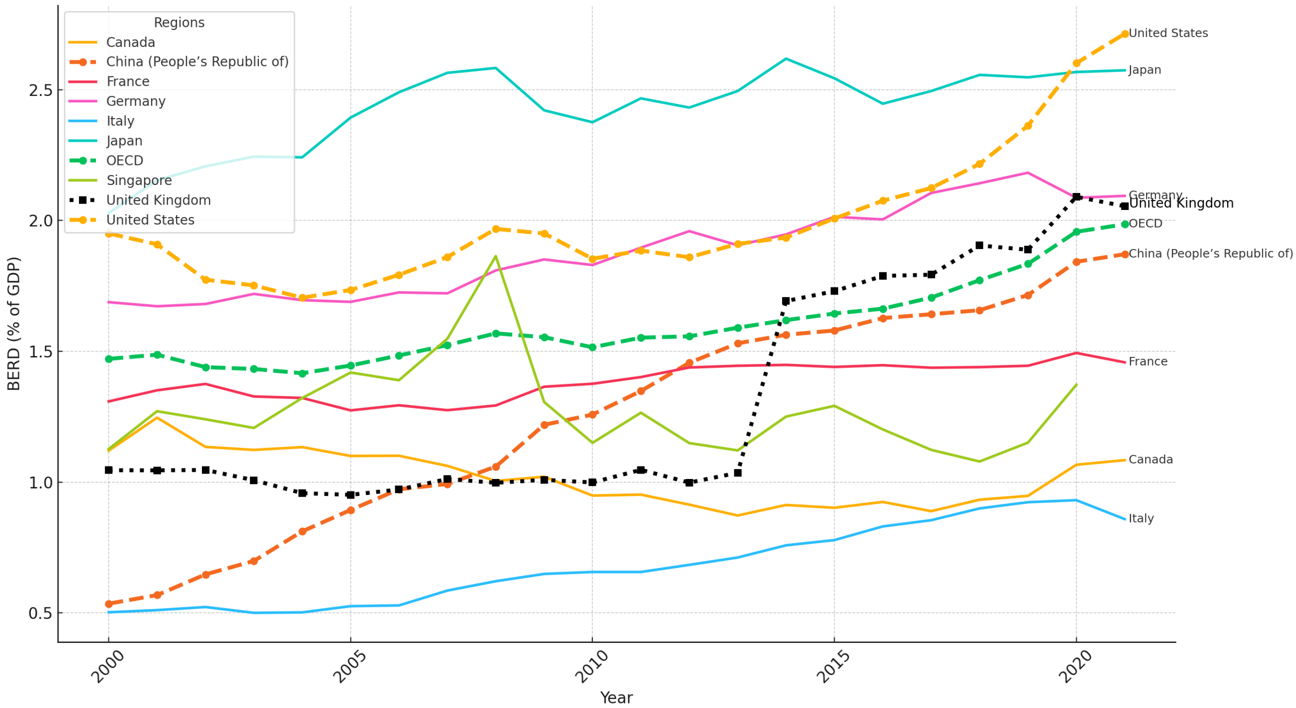

Figure 2. BERD. Business R&D expenditure (% GDP) over time.

Source: Authors' elaboration based on OECD data.

In terms of innovation output, the UK has consistently ranked among the top 10 patenting countries worldwide, particularly in fields such as medical technology, biotechnology, and mechanical engineering. However, the growth rate of UK patenting has been modest when contrasted with the rapid expansion observed in East Asian economies - most notably China and South Korea.

Patent data from the World Intellectual Property Organization indicate that UK firms tend to specialise in sectors such as services and software, where patenting is inherently less intensive. This partly explains the slower pace of growth in patent volume. Despite this, the UK's research base remains globally influential: UK researchers produce 16% of the world's most highly cited scientific publications, underscoring the strength of its academic and research institutions.

Nevertheless, global patenting trends reveal a relatively weakening UK's position. Between 2008 and 2016, global patent filings nearly doubled, driven largely by China's emergence as the leading innovator and additional growth from the US and Korea. UK filings rose less rapidly, and as a result, its relative global ranking slipped. By the late 2010s, China had overtaken all other countries in patent volume, while the UK had fallen behind Germany and stood roughly on par with France (Resolution Foundation, 2022).

4.2 Technological specialisation

The UK's patenting profile is concentrated in a limited number of technological fields. Table 1 summarises UK patenting activity from 2000 to 2021 across six broad technological fields, reporting the number of patents, their share of total UK patenting (excluding other fields), and the UK's global ranking in each field. Over the past two decades, UK mechanical and electrical engineering fields consistently recorded the highest volumes of patents, with mechanical engineering reaching a peak share of 26.1% in 2015–19.

The period 2020–21 shows a sharp drop in patenting activity, likely due to the shorter timeframe and pandemic-related disruptions. There has also been a modest shift in technological focus: while traditional strengths like chemistry have declined, medical and biotech fields have become more prominent. Overall, the data reflect a gradual contraction in patenting activity, coupled with sustained global competitiveness in selected high-value sectors.

Table 1. UK patenting across broader technological areas*

Period	Biotech	Chemistry	Electrical Engineering	Instruments	Mechanical Engineering	Medical Tech
2000-04	898	5301	8288	6800	10173	3356
	2.0%	*12.0%*	*18.7%*	*15.4%*	*23.0%*	*7.6%*
WIPO ranking	4	5	7		6	4
2005-09	646	4910	10441	7037	10285	4064
	1.4%	*10.4%*	*22.1%*	*14.9%*	*21.8%*	*8.6%*
WIPO ranking	8	7	8		7	8
2010-14	538	3775	9507	6371	10228	3690
	1.3%	*8.8%*	*22.1%*	*14.8%*	*23.8%*	*8.6%*
	6	8	9		7	8
2015-19	686	3265	7559	5236	9642	3310
	1.9%	*8.8%*	*20.4%*	*14.2%*	*26.1%*	*9.0%*
	8	8	9		7	9
2020-21	320	1200	2505	1512	2635	997
	2.3%	*8.5%*	*17.7%*	*10.7%*	*18.6%*	*7.0%*
	8	9	8		8	9

Source: Authors' elaboration based on PASTAT Autumn Edition 2023. **Shares* are as a percentage of total patenting by period. In bold we report the WIPO world ranking in each technological field. The *instruments* area includes various technological class such that a specific ranking for this field is not directly identifiable. For details, see Table A1 in Appendix for a definition and CPC codes used to identify these technological fields. In the table figures do not add up to 100 because we excluded the technological fields left. According to Schomcs (2008) they can be grouped into 'Other Fields', these represent on average 20% of the overall patenting activity.

The UK's technological footprint remains broad and diversified, with a consistent presence in the top 10. It is also notable that before the global financial crisis (GFC), the US, Japan, and Germany consistently occupied the top three spots globally, while China ranked 8th. By 2005 - 2009, China had risen to 4th and, by the period after 2015, emerged as the global leader in patenting activity. One area of concern is the underrepresentation of UK innovation in digital and electrical engineering - domains that are critical for the future of industry and infrastructure. This weakness suggests a disconnect between the UK's research strength in computing and its capacity to commercialise innovations in high-growth digital sectors.

4.3 Readiness in Emerging Technologies

Building on its legacy strengths, the UK has made strategic efforts to position itself in a set of emerging technologies designated as priorities under the UK Science and Technology Framework (2023–2024). These include artificial intelligence (AI), green technologies, semiconductors, robotics, quantum technologies, and electric vehicles (EVs). The new Industrial Strategy (2025) sets out R&D expenditure and commercialisation objectives in Green, AI and Quantum technologies. As summarised in Table 2, the UK shows relatively robust performance in green technologies and semiconductors, ranking 6th and 7th globally, respectively. These results reflect ongoing policy attention, net zero commitments, and targeted public investment in decarbonisation and digital resilience.

In AI, the UK ranks 9th - behind China, the US, and several East Asian economies - despite strong academic expertise and vibrant startup activity. Quantum technologies and robotics remain relatively niche, with innovation concentrated in a few university spinouts and multinational subsidiaries. EV-related patenting places the UK 8th globally, with innovation concentrated in a small number of firms tied to the automotive sector and investments increasingly located in Canada, China, Mexico and Brazil.

Table 2 Emerging Technologies in UK innovative activities

Period	AI	EV	Green	Robotics	Semiconductors	Quantum
2000-2004	150	18	200	2	420	47
WIPO World Rank	0.23%	0.03%	0.30% **7**	0.003%	0.626% **8**	*0.07%*
2005-2009	202	32	338	7	705	54
	0.28%	0.04%	0.47% **8**	0.01%	0.99% **9**	*0.07%*
2010-2014	152	103	464	5	551	35
	0.24%	0.16%	0.72% **8**	0.01%	0.85% **9**	*0.05%*
2015-2019	125	123	260	13	487	51
	0.23%	0.23%	0.48% **8**	0.024%	0.892% **10**	*0.09%*
2020-2021	64	54	74	4	233	34
	0.30%	0.25%	0.34% **8**	0.02%	0.16% **8**	0.18%

Source: Authors' elaboration based on PATSTAT Autumn 2023 Edition data.

Note: Shares are over the total number of UK patents for the 5-year period. In bold we report WIPO world ranking whenever available for those specific technological fields.

4.4 International collaboration and network position

International collaboration has long been integral to the UK's innovation system, enhancing knowledge exchange and research efficiency. However, recent data indicate both resilience and retraction in international R&D connectivity, particularly following the UK's exit from the EU.

As shown in Table 3 the share of UK patents involving international co-inventors declined significantly after 2014. This drop coincides with reduced participation in EU-funded research programmes, notably Horizon 2020, and growing institutional uncertainty around collaboration frameworks. While domestic collaboration has remained relatively stable, the contraction in international partnerships raises concerns about the UK's integration into global innovation networks.

Table 3. Patterns of Collaboration in the UK

5Y Period	#Patents	UK Single Applicant	Domestic Collaboration	International Collaboration
2000-2004	67070 (6th)	34.2%	33.6%	26%
2005-2009	71301 (7th)	29.5%	23.9%	38%
2010-2014	64592 (7th)	26.5%	27.9%	32%
2015-2019	54608 (7th)	30.2%	39.2%	11%
2020-2021	20166 (7th)	21.0%	58.4%	12%

Source: Authors' elaboration based on PATSTAT Global Edition 2023. The shares are over the total number of patents for each year. World rank in parentheses. We aggregate patent application IDs at the DOCDB family level to avoid double counting across different patent offices. The patent is classified as a UK single invention if there is one single applicant, and they are based in the UK. Domestic collaboration is detected if for every DOCDB with at least two applicants, both based in the UK. Finally, International Collaboration represents the share of patents that have at least two applicants, one in the UK and one in a foreign country. For about 1.8% of the patents, we do not have any information on the applicant and therefore the total number of patents may not sum up to 100%.

Figure 3 illustrates the UK's most prominent international collaborators. The United States remains the dominant partner, followed by key EU economies such as Germany, France, and the Netherlands. China's role as a UK R&D partner has grown substantially—particularly in digital and green technologies—reflecting its rising centrality in global innovation systems. Japan and South Korea continue to feature, though their relative shares have declined slightly.

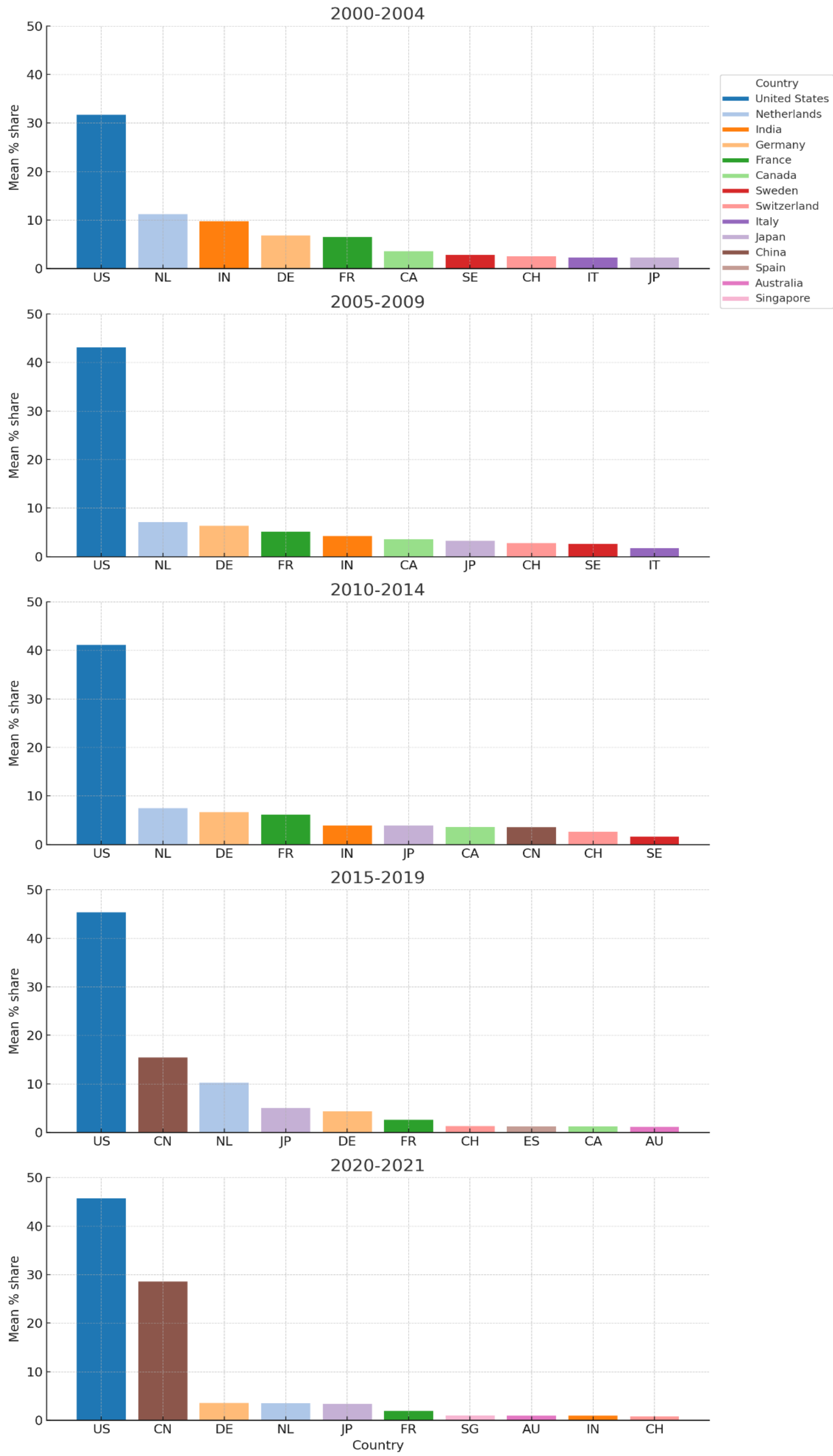

Figure 3. Share of International R&D Collaboration for the top 10 UK International Partners

Source: Authors' elaboration based on ORBIS IP and PATSTAT Autumn edition 2023.

Collaboration intensity varies by sector. International co-patenting is most prevalent in chemistry, biotechnology, and electrical engineering, whereas domestic co-patenting dominates in mechanical engineering and instrumentation (see Table 4). This variation underscores the bifurcated structure of the UK's innovation system: domestic capabilities remain strong in life sciences, while global linkages are more critical in and technology frontier areas.

In sum, the UK retains a well-established international innovation network, but this base has narrowed, particularly with Europe. Strategic renewal and diversification of research partnerships will be essential to maintaining global competitiveness and resilience.

Table 4. Collaboration Modes by Technological Domain: Domestic and International Co-Invention Shares (2000–2021)

	Broader Technological Area					
	Biotech	Chemistry	Electrical Engineering	Instruments	Mechanical Engineering	Medical Tech
Domestic R&D Collaboration	%	%	%	%	%	%
2000-2004	0.6	3.6	3.9	3.5	6.3	1.4
2005-2009	0.3	2.6	3.8	3.4	6.8	1.6
2010-2014	0.4	2.3	5.0	4.3	9.0	1.9
2015-2019	0.8	3.4	7.7	5.9	12.3	2.9
2020-2021	0.9	3.7	6.5	4.9	9.0	2.8
International R&D Collaboration						
2000-2004	0.26	2.4	2.5	0.74	1.08	0.35
2005-2009	0.13	2.25	3.2	1.14	0.97	0.5
2010-2014	0.15	1.96	2.8	1.67	1.15	0.49
2015-2019	0.21	1.5	2.4	0.92	1.04	0.37
2020-2021	0.27	1.38	2.9	0.91	0.73	0.302

Source: Authors' elaboration based on ORBIS IP and PATSTAT Autumn edition 2023.

Collaboration intensity also varies significantly across technological domains. Table 4 shows that domestic co-patenting dominates in more established sectors such as mechanical engineering and instrumentation. In contrast, internationally co-invented patents are more common in chemistry, electrical engineering, and biotechnology - fields that are more science-intensive and often require access to globally distributed knowledge networks.

On one hand, the UK retains strong domestic capabilities in established technologies with relatively self-contained collaboration structures.

4.5 Summary of system strengths and constraints

This section has assessed the performance of the UK innovation system through the lens of investment trends, technological focus, emerging capabilities, and international collaboration. The analysis highlights a number of structural strengths alongside persistent challenges:

- **R&D investment** has increased substantially, with the UK achieving and exceeding its 2.4% R&D intensity target ahead of schedule. Yet, the overall intensity remains below that of global innovation leaders, and growth has partly reflected cyclical factors such as the GFC and the COVID-19-induced GDP contraction.
- **Technological specialisation** continues to favour life sciences. In contrast, digital and electrical engineering remain relatively underdeveloped in the UK's patenting portfolio.
- **Emerging technologies** represent a mixed picture. The UK shows relative strength in green technologies and semiconductors but has yet to establish a globally competitive footprint in areas such as AI, quantum, and robotics. Patenting is dominated by a small number of actors, raising questions about depth and inclusivity.
- **International collaboration**, long a cornerstone of UK innovation, has weakened since 2014 - articularly with EU partners. While deep ties with the US and select Asian economies persist, the overall collaboration base is narrowing, limiting access to diverse global knowledge pools.

Taken together, these patterns point to an innovation system with robust foundations but constrained adaptability. Maintaining global competitiveness will require strategic investment in emerging technologies, expanded support for international R&D engagement, and targeted efforts to diffuse innovation capacity across a broader range of firms and sectors.

5. Disaggregating the UK Innovation Landscape: A Firm-Level Perspective on Local and International R&D

While Section 4 provided a system-wide view of UK innovation based on the full universe of patent applications from the PATSTAT database, this section adopts a firm-level perspective using linked data from PATSTAT and Orbis Intellectual Property. This shift in analytical lens enables a more granular exploration of firm heterogeneity in innovation activity - distinguishing between domestic and foreign ownership, firm size, sectoral specialisation, and collaboration profiles. Whereas PATSTAT allows us to characterise macro-level trends in technological specialisation and international positioning, the linked dataset reveals which types of firms are driving or lagging in the UK's innovation system, and how their strategies differ across domains. Together, these perspectives offer a comprehensive and complementary account of the UK's evolving innovation landscape.

To provide figures on firms' innovative activities we start from the step described in section 3 and restrict the sample to companies for which we can have a BVD identifier (see also Appendix for details on the matching keys between the two databases). Our starting sample includes 281,459 patents applied for by 46,792 applicants from 2000-2021. Once we clean our database for applicants for which we have information on their location i.e. country, we have a final sample of 280,254 patents filed by 46,077 applicants. A small percentage of about 1.17% (1,205 patents) are individuals that are also applicants in the patent, while about 3.25% are UK based public institutions, research centres and universities (7,399 patents). This subset of innovators is responsible for 4.6% of the total patents filed in the 21 years of observation. Finally, around 1.3% (466 patents) is innovation made in collaboration with foreign institutions that we could identify and that are not private firms.

As a final step, we decided to keep not only applicants for which we have information on their location, that are not individuals or institutions for which we have no other information than a name and country (243,462 patents), but also those for which we have information on their industrial sector, to be able to highlight which are the most innovative sectors in the UK (Cambridge Industrial Innovation Report, 2024 and 2025). After completing this step, we end up with 233,964 patents made by 46,076 companies. In terms of patenting trends, it does come with no surprise that 99% of our firms did not patent every year, while there is a 0.5% that did[6].

5.1 Ownership and the role of foreign firms

A defining feature of the UK innovation landscape is the high degree of concentration in patenting activity, both in terms of firm ownership and technological output. A relatively small number of firms, many of them foreign-owned multinationals, account for a disproportionate share of the UK's patented innovations. These firms are often embedded in global R&D networks and use the UK as a base for research, development, and design activities. Their presence is particularly pronounced in pharmaceuticals, electronics, and automotive sectors.

Table 5a and 5b, reports the share of patenting by foreign ownership for a sample of firms for which we are able to retrieve detailed ownership links (see section 6 for details). While the UK's openness to inward investment has long been a strength, providing access to global knowledge and financing, it raises concerns about domestic capability development and long-term value retention. UK-headquartered firms tend to be more active in patenting with US, Canada and EU-27 partners, with a staggering 60% of patents that are made by UK based companies. In appendix we provide a breakdown by manufacturing and service industry by technology intensity and the location of the parent company. What it stands in lower-patenting sectors such as services and software, where innovation is under-measured by standard patent metrics. The result is a dual dependence on foreign multinationals and a narrow domestic innovator base, which is much more prevalent across manufacturing sectors.

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[6] In terms of age profile, the median age is 29, whilst 5% of the sample is made by start-ups (less than 5 years old). The top 10% is made by firms that are more than 100 years old. Firms that do engage in R&D collaboration are on average 52 years old, while those that engage in international R&D are on average 62 years old. Only 1% of start-ups engage in international R&D.

Table 5a Firms' International R&D by ownership region

Parent Company location	# Patents	Overall %
EU27	714	9.1%
North America	866	11.1%
BRICS	39	0.5%
ASEAN	12	0.2%
Africa	46	0.6%
MENA (no North Africa)	0	0.0%
UK	5392	68.9%

Source: Authors' Elaboration based on PATSTAT Autumn Edition 2023 and Orbis Financial. Number of patents filed with international applicants. Shares do not add up to 100 because firms that are pure domestic, have no assigned parent company. A company is considered an owner if it has at least 10% ownership share.

Table 5b Firms' International R&D by ownership region

UK company with Subsidiary's location in:	# Patents	Overall %
EU27	387	5%
North America	120	2%
BRICS	77	1%
ASEAN	60	1%
Africa	14	0.18%
MENA (no North Africa)	10	0.13%
UK	2063	26%

Source: Authors' Elaboration based on PATSTAT Autumn Edition 2023 and Orbis Financial. Number of patents filed with international applicants. Shares do not add up to 100 because firms that are pure domestic, have no assigned parent company. A company is considered an owner if it has at least 10% ownership share.

5.2 Size distribution of patenting firms

Firm size significantly shapes the intensity and geography of innovation. Larger firms—especially multinationals—dominate UK patenting. They benefit from scale economies, access to capital and talent, and are well-positioned within international research networks. SMEs, while critical contributors in niche and emerging areas, face constraints in internationalising their R&D due to limited resources and institutional linkages.

As shown in Table 6, a small number of large firms account for the bulk of patent applications, while SMEs are underrepresented. Larger firms are more likely to engage in international co-patenting, reflecting deeper integration into global value chains. SMEs tend to collaborate domestically - often with universities, research institutes, or local partners - primarily in life sciences, advanced manufacturing, and energy. The limited international engagement of

SMEs also reflects challenges in coordination, IP management, and access to global knowledge networks.

Further, large firms dominate international R&D, with participants averaging 62 years in age and employing over 1,000 people. Only 1% of UK startups engage in cross-border R&D. Firms with international R&D links also exhibit higher productivity growth. About 32% of patenting firms are foreign owned, reflecting the embeddedness of the UK in global value chains.

Table 6 Firms' Size over time

Size	Overall Freq.	Overall %	Between %	Within %
Micro	15,659	15.96%	34.35%	54.37%
Small	11,905	12.14%	21.83%	53.32%
Medium	12,276	12.51%	17.86%	68.84%
Large	5,543	5.65%	7.96%	63.71%
Very Large	52,711	53.74%	74.54%	70.20%

Source: Authors' Elaboration based on PATSTAT Autumn Edition 2023 and Orbis Financial. The 'Between' column shows how much variation exists between firms. The 'Within' columns measures the variation within a firm across time.

5.3 Industrial and technological composition

The technological and sectoral profile of UK patenting is concentrated in a few dominant sectors, with notable differences by ownership. Foreign multinationals dominate patenting in pharmaceuticals and automotive, whereas UK-owned firms are more active in business services and software.

In terms of industrial sectors 37.7% of the firms in the sample operate in the manufacturing sector, whilst the vast majority is in services (61.7) and 0.93 are in the primary sector. Although there is a minor decline in firms' patenting the gap between manufacturing and services increases over time and particularly after 2014-2015 (see Figure 4).

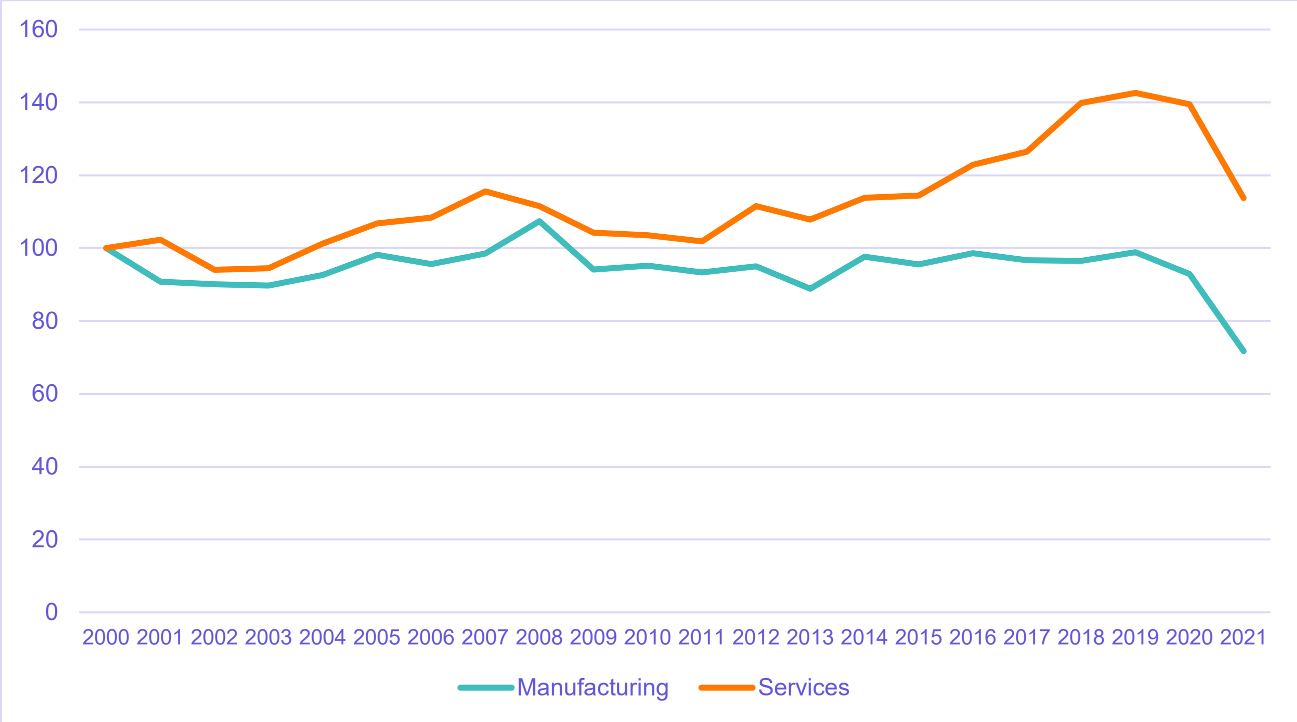

Figure 4. Innovation across main industrial sectors

Source: Authors' elaboration based on PATSTAT Global Edition 2023 and Orbis IP. Industrial sectors are at the NACE Rev. 2. Manufacturing includes NACE 2-digit codes 10 -33, whilst services include sectors 44-99. Base year 2000=100

This is consistent with the shift in R&D private spending in software and IT (House of Commons, 2023). Manufacture of chemicals, computer and equipment are consistently in the top are consistently in the top 3 over the last 20 years of observation. This insight may not come as a surprise. In terms of value added and strategic role, the Manufacturing and Equipment (M&E) sector alone accounts for £22.2 billion of value added (Cambridge Innovation Report, 2024). According to ONS figures[7], these sectors have the highest shares of foreign owned firms. This can mean that part of UK R&D in manufacturing is carried out by subsidiaries whose HQs is overseas, and therefore strategic decisions for the sector, are made abroad. This resonates with our data too. Around 22% of companies in the top 3 patenting sectors are foreign owned.

The Manufacture of Chemicals holds the lion share of international R&D, but the three sectors combined account for 69% of collaborative R&D, and 44% of international R&D. The countries

[7] See BERD UK 2017

(regions) with whom these UK companies collaborate the most within these three are US, EU and post GFC, China. For the latter, the share of collaboration is substantial in the manufacturing of Computer, electronic and optical products. Over 2000 - 2021, the balance of UK R&D partnerships across the OEM, Chemical, and Computer/Optical sectors became more diversified. EU reliance was high in 2000–2015, especially for manufacturing and automotive, but declined by 2021. All three sectors still collaborate with Europe, but the weight has fallen (Europe’s own share of global R&D in key industries declined, and UK firms now engage more with emerging players. Each sector displays a different partnership profile: OEM has historically been EU-centric but is now closer to US and Chinese partners, perhaps in the aim of reducing uncertainty; Pharmaceuticals are heavily transatlantic (US-linked) with growing ties to Asia, while Europe’s role diminishes in relative terms.

Looking at technologies, Table 7 shows patenting across time and technological fields. Patenting activity is heavily clustered in a limited number of high-tech and life sciences sectors. Patterns of R&D collaboration also vary substantially across sectors. In medical technologies and biotechnology, for example, international collaboration is frequent, often facilitated by clinical research networks and multinational supply chains. In contrast, more traditional manufacturing sectors such as mechanical engineering are characterised by domestic co-invention, often with local suppliers or research institutions.

This asymmetric distribution highlights that while the UK is present in many emerging areas, the depth of activity remains limited. Broadening technological engagement and supporting domestic participation in high-value sectors is essential.

Table 7 Number of patents by broader technological area.

Period	2000-2004	2005-2009	2010-2014	2015-2019	2020-2021
Broad Technological fields					
Biotech	1.90%	2.00%	2.00%	1.70%	3.90%
Chemistry	12.50%	13.20%	12.60%	11.00%	25.60%
Electrical Engineering	18.80%	19.90%	19.10%	16.70%	38.60%
Instruments	15.20%	16.00%	15.40%	13.40%	31.10%
Mechanical Engineering	23.90%	25.30%	24.30%	21.20%	49.10%
Medical Tech	7.60%	8.10%	7.70%	6.80%	15.70%
Other Fields	22.29%	23.57%	22.60%	19.73%	45.74%
Emerging Technologies					
AI	0.29%	0.46%	0.32%	0.29%	0.42%
EV	0.04%	0.06%	0.17%	0.24%	0.29%
Green	0.46%	0.94%	1.45%	0.96%	0.97%
Robotics	0.00%	0.02%	0.01%	0.03%	0.02%
Semiconductors	0.86%	1.45%	1.17%	0.87%	1.10%
Quantum	1.22%	1.45%	1.10%	1.07%	1.26%

Source: Authors' elaboration based on PATSTAT Autumn Edition 2023. For a breakdown of the CPC codes used to extract specific technological field see Appendix 1. Table include both collaborative and non-collaborative patents. Each cell represents the share for each technology over the total number of patents produced each time period.

5.4 Collaboration modes and innovation behaviour

Collaboration is essential for innovation, particularly in complex or globalised domains. Firms engaged in international co-patenting tend to be larger, foreign-owned, and highly integrated into international R&D networks. These firms often co-develop technologies with partners abroad, benefiting from diverse expertise and distributed innovation capabilities.

Domestic SMEs, by contrast, are less present in these global collaborations. As shown in Table 8, they typically collaborate within national boundaries, often with universities, public research institutes, or value chain partners. While these domestic networks are important for foundational R&D, they often lack the scale and international exposure needed to compete in emerging global technologies.

Table 8 Firms' Size in International R&D

Size	Overall Freq.	Overall %	Between %	Within %
Micro	2325	14.36	20.26	84.55
Small	2190	13.53	15.45	79.44
Medium	2291	14.15	14.26	87.45
Large	1116	6.89	5.96	85.5
Very Large	8266	51.06	57.94	91.51

Source: Authors' Elaboration based on PATSTAT Autumn Edition 2023 and Orbis Financial. The 'Between' column shows how much variation exists between firms. The 'Within' columns measures the variation within a firm across time.

Startups and small firms contribute to innovation, particularly in emerging technology domains. These firms typically face structural barriers, including limited access to global networks, financing constraints, and a lack of absorptive capacity for international knowledge.

The most R&D-active firms often span multiple sectors and countries, holding diverse patent portfolios. They are disproportionately located in knowledge-intensive sectors such as pharmaceuticals, digital technologies, and advanced manufacturing. These firms also report higher productivity growth, supporting existing literature linking global engagement to performance gains.

Interestingly, the geography of R&D engagement varies by firm size and ownership. Foreign-owned subsidiaries show strong international patenting ties with their home countries, while UK-headquartered firms often focus on partnerships with the US and Europe. SMEs, when involved in international activity, are more likely to co-patent with firms in similar industries or with universities.

Overall, the firm-level evidence suggests that internationalisation of R&D is highly selective and stratified. Policies aiming to broaden participation will need to address capability gaps among SMEs, reinforce absorptive capacities, and foster international connections beyond incumbent and foreign-owned leaders.

R&D collaboration is also influenced by firm sector. For instance, international co-invention is common in chemistry, biotechnology, and electrical engineering - sectors that are research-intensive and rely on access to global knowledge. In mechanical engineering and instrumentation, domestic collaboration dominates, pointing to more nationally embedded innovation ecosystems.

This segmentation of collaboration modes by firm type, size, and sector underscores the need for tailored policy support. Enabling SMEs and domestic firms to expand their international R&D linkages will be crucial to ensuring a more inclusive and globally integrated innovation system.

5.5 Summary of firm-level dynamics

The analysis presented in this section reveals a deeply segmented UK innovation landscape at the firm level. Patenting activity and participation in international R&D collaboration are highly concentrated among a relatively small group of large, often foreign-owned firms. These firms play a dominant role in the country's innovation system, particularly in high-value sectors such as pharmaceuticals, automotive engineering, and high-tech manufacturing. Their embeddedness in global innovation networks enables them to co-develop technologies across borders and benefit from extensive knowledge flows.

In contrast, UK-headquartered firms - especially small and medium-sized enterprises (SMEs) - exhibit a more limited presence in patent-driven innovation. These firms are generally more active in sectors like digital services, software, and business innovation where patents are not the primary measure of innovation output. Their innovation activity tends to be more domestically embedded and reliant on national partnerships, often with universities, research institutes, or supply chain actors.

The sectoral and technological composition of UK innovation also mirrors these divides. While the UK maintains strong capabilities in life sciences and engineering fields, its footprint in digital, AI, and quantum technologies remains small and highly concentrated. Emerging technologies are disproportionately led by a handful of specialised firms and university spinouts, suggesting that the system may lack sufficient breadth and diffusion of capabilities.

R&D collaboration patterns reinforce these structural asymmetries. Larger and foreign-owned firms lead in international co-patenting, while domestic SMEs tend to collaborate within national boundaries. This segmentation raises concerns about inclusiveness, as access to global knowledge and markets is unevenly distributed.

Taken together, these findings underscore the dual structure of the UK innovation system. On one side is a globally integrated, patent-intensive tier of innovation led by large multinationals, while on the other, a domestically oriented, undercapitalised segment driven by SMEs. Bridging this divide - by strengthening domestic innovation capacity, enhancing SME access to international collaboration, and broadening participation in emerging technologies - will be essential for building a more resilient, inclusive, and competitive innovation system.

5.6 Typologies of R&D Internationalisation

Building on the preceding analysis, and also drawing on linked firm-patent data, we categorise firms along two key dimensions: (i) the nature of their ownership (domestic vs foreign) and (ii) the breadth and depth of their international collaboration (none, domestic-only, or international co-patenting), we identify four stylised types of firms based on ownership and collaboration profile:

- **Multinational R&D Hubs**: Large, predominantly foreign-owned firms with extensive global collaboration. Dominant in pharmaceuticals, automotive, and electronics, they are embedded in international research portfolios.
- **Domestically Oriented Innovators**: UK-owned firms with limited or purely domestic collaboration, active in business services, software, and niche manufacturing. Innovation is often process-based and less patent-intensive.
- **Internationalising SMEs and Scale-Ups**: Dynamic, high-growth UK firms that selectively engage in global R&D, often via university links or targeted joint ventures. Active in AI, green tech, and materials.
- **Non-Collaborative Patent Generators**: Firms with patent activity but no co-inventors. Often subsidiaries or firms pursuing defensive IP strategies.

6. Firm-Level Insights: Who Internationalises R&D?

Building on the aggregate patterns described in Section 5, this section examines the firm-level determinants of R&D collaboration choices. Understanding which firms engage in international collaboration, and why, is essential for designing policies that can strengthen UK firms' participation in global innovation networks whilst addressing the structural challenges identified in earlier sections. The internationalisation of R&D offers strategic advantages through access to diverse knowledge bases and complementary capabilities (Kafouros & Forsan, 2012), yet firms often exhibit strong "home bias" in their innovation activities, reflecting coordination costs and the complexity of managing geographically dispersed partnerships (Belderbos et al., 2013).

We employ econometric analysis to identify the factors that influence whether UK firms collaborate domestically, internationally, or pursue mixed strategies. The analysis covers 16,252 UK firms over the 2000 - 2021 period, drawing on the integrated patent-firm dataset described in Section 3 and 5. We cover more than one third of our total sample of applicants, and on average 12% of patenting activity, with coverage being the highest among those that collaborate. We cover on average 25% of domestic collaborative patents and about 15% of international R&D. In terms of industrial sectors, coverage is very similar, being 37% of firms in the manufacturing sector, while 62 are in services and 0.5% in the primary sector. In terms of industrial structure, our subsample of firms is very much representative of the overall population of firms that patent in the UK.

In terms of ownership, the subsample is representative of the population of applicants with around ~40% being foreign owned companies. Three types of models are estimated: probit models for binary collaboration outcomes, ordered probit for collaboration intensity, and multinomial logit to distinguish between domestic-only, international-only, and joint collaboration strategies. Results prove robust across estimators and specifications, with standard errors remaining stable as additional controls are introduced.

6.1 Innovation capability and firm maturity

Patent stock emerges as the strongest predictor of international collaboration, whilst R&D expenditure *per se* shows no significant effect once capability measures are included (Table 9). This indicates that *demonstrated* innovation capacity matters more than research investment levels alone, aligning with research on absorptive capacity in cross-border partnerships (Castellani & Du, 2023). Experience matters more than capital intensity for international R&D.

Firm age exhibits striking differential effects across collaboration types. Older firms show substantially higher propensity for international collaboration but *lower* propensity for domestic-only collaboration. This suggests collaboration capabilities accumulate through experience, creating structural barriers for younger firms even when technologically capable (Nieto and Rodríguez, 2022). The marginal effects in Table 10 show these age-effects are economically substantial.

6.2 Ownership and operational geography

Foreign ownership shows distinct patterns by investor origin. Firms with ASEAN majority shareholders demonstrate elevated overall collaboration but *reduced* international-only collaboration whilst strongly favouring domestic partnerships. This suggests ASEAN investors acquire UK firms primarily to *access domestic innovation networks* rather than facilitate international R&D. Conversely, Commonwealth ownership increases international-only collaboration, whilst North American and EU27 ownership support both domestic and international strategies.

Operational footprint creates powerful home-anchoring effects. UK subsidiaries substantially reduce international-only collaboration probability, reflecting coordination costs and embedded domestic relationships (Belderbos et al., 2013). EU27 subsidiaries show similar negative effects, suggesting firms use their European networks for regional rather than global R&D - a distinction potentially strengthened post-Brexit (Bloom et al., 2018). North American subsidiaries, however, increase international probability, serving as bridges to wider networks

6.3 High-innovation firms pursue mixed strategies

A counterintuitive pattern emerges from the multinomial logit analysis: firms with the largest patent stocks favour joint domestic-international collaboration over international-only strategies. Patents show a negative marginal effect on international-only collaboration but strongly positive effect on joint strategies (Table 10). The most inventive UK firms thus build broad portfolios spanning both domestic and international partners rather than focusing exclusively abroad, suggesting these modes serve complementary rather than competing functions (Kafouros & Forsan, 2012).

High-tech manufacturing and services firms show consistently elevated international engagement. Export status shows weak or small negative effects on international-only collaboration, suggesting trade and R&D internationalisation operate through different mechanisms.

6.4 Policy implications

These findings reveal systematic patterns with clear policy implications. First, demonstrated innovation outputs, particularly patents, drive international collaboration more than R&D spending, suggesting IP support should be prioritised for firms seeking to internationalise.

Second, younger firms face structural barriers independent of technological capability, indicating need for targeted network-building programmes before domestic commitments create path dependencies.

Third, foreign ownership effects vary substantially by investor origin. ASEAN investment appears oriented toward accessing UK networks rather than creating international linkages, whilst North American and Commonwealth ownership better facilitates global R&D integration (Driffield et al., 2023). This suggests more nuanced approaches to assessing spillover potential from different investment sources.

Fourth, the home-anchoring effects of domestic subsidiary networks and the regional-global distinction evident in EU27 patterns suggest Brexit may have created new barriers between European and global R&D (Pichler & Pisera, 2023). Policy must address how firms can maintain European access whilst developing genuinely global strategies.

Finally, the prevalence of mixed strategies among the most innovative firms indicates that domestic and international collaboration serve complementary functions. Policy should support both simultaneously rather than treating them as alternatives.

Table 9: Determinants of R&D collaboration type (Probit models)

Variable	Any collaboration (1)	International-only (2)	Domestic-only (3)
Firm capability			
R&D expenditure	0.0260*** (0.00206)	0.0046 (0.00285)	0.0247*** (0.00333)
Total patents	0.8459*** (0.03025)	0.1281*** (0.03065)	0.9199*** (0.04840)
Proportion of intangible assets	1.0901*** (0.15658)	0.1477 (0.23000)	0.7113** (0.25508)
Labour productivity	0.0310** (0.01061)	0.0319* (0.01574)	0.0152 (0.01847)

Variable	Any collaboration (1)	International-only (2)	Domestic-only (3)
Firm age	0.0713*** (0.01549)	0.1824*** (0.02375)	-0.0866*** (0.02460)
Firm size	0.0316*** (0.00838)	0.0353** (0.01308)	0.0312* (0.01446)
Exporter (dummy)	-0.0170 (0.02400)	-0.0649 (0.03658)	0.0068 (0.03878)
Geography of ownership			
Largest shareholder in ASEAN	0.9346** (0.29270)	-0.1781 (0.36899)	1.8233*** (0.43036)
Largest shareholder in EU27	0.4223*** (0.05482)	0.0951 (0.08925)	0.2406* (0.09974)
Largest shareholder in North America	0.2796*** (0.05677)	-0.3080*** (0.08003)	0.5129*** (0.09585)
Largest shareholder in Commonwealth	0.0782 (0.13380)	0.5262* (0.20578)	-0.7862** (0.24634)
Geography of operations			
Number of UK subsidiaries	-0.2971*** (0.04763)	-0.3387*** (0.07521)	-0.1177 (0.08594)
Number of North America subsidiaries	0.0821 (0.04544)	0.1710* (0.06837)	-0.1170 (0.09047)
Number of EU27 subsidiaries	-0.0129 (0.03706)	-0.1815** (0.05798)	0.0535 (0.06735)
Technology intensity (base: low-tech mfg)			
High-tech manufacturing	1.7949*** (0.23255)	—	—
Medium-tech manufacturing	0.5139*** (0.10462)	0.8621*** (0.15369)	-0.1386 (0.19750)
High-tech services	1.1679*** (0.09135)	1.6415*** (0.15264)	-0.1761 (0.16997)
Log-likelihood	-8893.8	-3811.2	-3426.7
Pseudo R^2	0.180	0.183	0.190

Note: Coefficients shown with standard errors in parentheses. All models include NUTS2 region, year, and 2-digit NACE sector fixed effects. Sample: UK firms, 2000–2021. N=16,252 (Column 1), 9,436 (Column 2), 7,631 (Column 3). *p<0.05, **p<0.01, ***p<0.001.

Table 10: Marginal effects on collaboration intensity (Ordered probit)

Variable	Pr(No collab.) (0)	Pr(Domestic) (1)	Pr(International) (2)
Firm capability			
R&D expenditure	-0.0082*** (0.00058)	-0.0002*** (0.00003)	0.0085*** (0.00060)
Total patents	-0.2289*** (0.00733)	-0.0064*** (0.00063)	0.2353*** (0.00736)
Proportion of intangible assets	-0.2685*** (0.04561)	-0.0075*** (0.00148)	0.2760*** (0.04688)
Firm age	-0.0377*** (0.00454)	-0.0011*** (0.00017)	0.0387*** (0.00467)
Geography of ownership			
Largest shareholder in ASEAN	-0.2243** (0.07740)	-0.0063** (0.00226)	0.2306** (0.07956)
Largest shareholder in EU27	-0.1003*** (0.01631)	-0.0028*** (0.00054)	0.1031*** (0.01677)
Largest shareholder in North America	-0.0339* (0.01657)	-0.0010* (0.00048)	0.0348* (0.01704)
Number of UK shareholders	-0.0288** (0.01093)	-0.0008* (0.00032)	0.0296** (0.01123)
Geography of operations			
Number of UK subsidiaries	0.0845*** (0.01384)	0.0024*** (0.00045)	-0.0869*** (0.01423)
Number of North America subsidiaries	-0.0297* (0.01289)	-0.0008* (0.00037)	0.0305* (0.01325)
Number of EU27 subsidiaries	0.0248* (0.01077)	0.0007* (0.00031)	-0.0255* (0.01107)
Technology intensity			
High-tech services	-0.1955*** (0.01311)	-0.0091*** (0.00118)	0.2046*** (0.01366)
Pseudo R^2		0.097	

Note: Marginal effects from ordered probit model. Dependent variable: 0=no collaboration, 1=domestic-only, 2=international or mixed. Shows change in probability for each outcome. Standard errors in parentheses. N=16,301. **p*<0.05, ***p*<0.01, ****p*<0.001.

7. Implications for UK Innovation Policy and Recommendations

The findings of this report have significant implications for the design and direction of UK innovation policy. They point to a national innovation system that combines world-class research institutions and strong international linkages, but is also marked by fragmentation, concentration, and under-engagement of a broad base of firms - especially domestic SMEs.

7.1 Bridging the firm-scale divide

A persistent divide between large, globally networked firms and smaller, domestically embedded innovators limits the diffusion of knowledge and capabilities across the UK economy. However, the barriers to international R&D collaboration extend beyond firm size alone. The econometric analysis in Section 6 reveals that firm *age* creates distinct structural barriers, independent of technological capability or scale. Younger firms, even when highly innovative, lack the networks, reputation, and cross-border experience needed to establish international R&D partnerships (Nieto and Rodríguez, 2022).

Moreover, the *timing* of internationalisation matters critically. Firms that build extensive domestic operations early face strong "home-anchoring" effects, i.e. each additional UK subsidiary substantially reduces the probability of international-only collaboration. Path dependencies emerge. Early internationalisation proves easier than later strategic pivots (Patel & Pavitt, 1991; Belderbos et al., 2013). This suggests that waiting for firms to "scale up" domestically before supporting international engagement may be counterproductive.

Evidence also indicates that *demonstrated innovation capacity* matters more than research investment levels. Patent portfolios - not R&D expenditure *per se* - predict international collaboration success (Section 6). This reflects the importance of absorptive capacity: firms need credible signals of technological competence to attract international partners (Castellani & Du, 2023; Tojeiro-Rivero & Moreno, 2019).

Policy implications include:

- Prioritise intellectual property support over simple R&D spending increases. Enhanced patent advisory services, support for international standardisation participation, and mechanisms to help firms signal technological capabilities should be central to internationalisation programmes.

- Target younger high-potential firms before domestic path dependencies form. Early-stage network-building programmes, international matchmaking platforms, and government-backed validation schemes can address reputation barriers that prevent capable young firms from accessing cross-border partnerships.
- Recognise that the most innovative firms pursue mixed domestic-international strategies (Kafouros & Forsan, 2012). These modes serve complementary functions - domestic partnerships provide depth and tacit knowledge, whilst international collaboration offers access to frontier research. Policy should support both simultaneously rather than treating them as competing alternatives.
- Expand tailored support for SME and scale-up internationalisation through accessible collaborative frameworks (e.g. Innovate UK Global Incubator Programme, EUREKA), whilst addressing the distinct challenges faced by younger versus smaller firms (Rodríguez and Nieto, 2016).

7.2 Enhancing participation in emerging technologies

The UK has a visible presence in strategic technology areas such as AI, green innovation, and semiconductors. However, activity is often dominated by a small number of firms and remains below global benchmarks in scale and diversity. Innovation policy should strengthen incentives for wider firm participation in emerging technology domains, especially through mission-oriented funding, applied R&D programmes, and place-based industrial strategies.

7.3 Rebuilding international collaboration

The UK's temporary withdrawal from Horizon and the broader Brexit context have disrupted established international research ties, particularly within Europe. Although new bilateral and global collaborations have emerged, they remain narrower in scope. To mitigate long-term fragmentation, UK policy should recommit to multilateral frameworks and reinvest in international R&D partnerships, particularly in domains where global cooperation is essential (e.g. climate, health, AI safety).

However, Brexit may have created barriers that extend beyond programme access. Firm-level evidence suggests a critical distinction between *regional* (European) and *global* R&D

strategies. Firms with EU27 subsidiaries appear to use their European networks for R&D collaboration rather than pursuing truly global partnerships (Section 6). Post-Brexit, this regional pathway has become less accessible (Pichler & Pisera, 2023), yet many firms have not pivoted to broader international strategies. The barrier is not only institutional (Horizon access) but also structural—embedded European networks that previously facilitated regional collaboration no longer function as seamlessly.

This creates a dual policy challenge: helping firms maintain *European* R&D access where valuable, whilst simultaneously supporting those ready to develop *genuinely global* strategies encompassing North America, Asia, and emerging innovation hubs. The analysis indicates that North American subsidiary networks serve as bridges to wider international collaboration, whilst European networks have historically been more regionally bounded.

Additionally, evidence shows that leading innovators pursue *mixed domestic-international strategies* rather than abandoning domestic partnerships in favour of international ones. Each mode serves distinct but complementary functions (Kafouros & Forsan, 2012; Narula, 2001). Domestic collaboration facilitates market expansion and maintains embeddedness in local knowledge ecosystems, whilst international partnerships provide access to frontier research and diverse technological perspectives. Policies promoting international collaboration should not inadvertently discourage domestic R&D networks, which remain valuable even for globally engaged firms.

Priorities include:

- Ensure sustained association with Horizon Europe and other multilateral frameworks whilst building complementary bilateral partnerships with the US, Canada, Australia, and emerging innovation economies.
- Develop explicit strategies to help firms navigate the regional-global distinction, recognising that European and global R&D networks may require different support mechanisms post-Brexit.
- Support both domestic and international collaboration simultaneously, avoiding policy designs that frame these as substitutes rather than complements.
- Monitor how Brexit reshapes collaboration networks, particularly for mid-sized firms previously reliant on European regional partnerships.

7.4 Leveraging multinational activity for spillovers

Multinational enterprises (MNEs) continue to play a central role in UK innovation (Alcácer et al., 2016), but their knowledge spillovers to the domestic economy are not automatic. Strengthening linkages between foreign R&D labs and local ecosystems—through innovation districts, supplier development programmes, and university-industry platforms—can help local firms absorb and adapt frontier knowledge.

However, not all foreign investment equally facilitates international R&D collaboration. Econometric evidence reveals systematic differences by investor origin. Firms acquired by ASEAN investors show elevated *domestic* collaboration but reduced *international* engagement. This pattern suggests knowledge-seeking FDI: ASEAN multinationals invest in the UK primarily to *access established domestic innovation networks* rather than to integrate UK subsidiaries into global R&D systems (Driffield et al., 2023).

Conversely, Commonwealth and North American ownership better support international collaboration. These investors appear more likely to integrate UK subsidiaries into broader cross-border R&D networks, facilitating knowledge flows beyond the UK market. EU27 ownership has historically supported both domestic and international collaboration, though post-Brexit patterns may be evolving.

This heterogeneity has important implications for FDI policy. The economic benefits of different investment sources may vary not just in capital or job creation, but in *how they integrate UK firms into global innovation networks*. ASEAN investment delivers value through providing access to UK capabilities for Asian firms, but may generate fewer spillovers to the broader UK innovation system than North American or Commonwealth investment that facilitates genuinely international R&D.

Policy responses could include:

- Develop more nuanced assessments of spillover potential by investor origin when evaluating FDI proposals, particularly for R&D-intensive acquisitions.
- Consider performance conditions or incentives for foreign investors to integrate UK subsidiaries into global R&D networks, not merely domestic operations.

- Monitor whether different ownership patterns deliver expected benefits, with particular attention to whether acquired firms maintain or expand international collaboration post-acquisition.
- Strengthen university-industry linkages and innovation districts to ensure domestic knowledge networks remain accessible to locally embedded firms, regardless of ownership structure.
- Recognise that knowledge-seeking FDI (accessing UK networks) and knowledge-augmenting FDI (integrating UK into global networks) serve different functions, both potentially valuable but requiring distinct policy approaches.

7.5 Investing in Data and Institutional Capacity

The complexity and fragmentation of the UK innovation system underscore the need for better evidence to inform policy. Continued investment in linked administrative data, longitudinal firm-patent datasets, and R&D metrics is essential for monitoring trends and evaluating interventions. Institutions such as UKRI and the ONS should also be resourced to coordinate these efforts and integrate them into strategic policy design.

These recommendations aim to move UK innovation policy beyond a narrow focus on excellence or sectoral performance, toward a broader, systemic approach that connects firms, technologies, and international partners. Doing so will enhance both the resilience and inclusivity of the UK's innovation system in an increasingly volatile global environment.

7.6 Summary Table of Policy Recommendations

The following table synthesises the key policy directions emerging from this study, aligning specific challenges with actionable priorities for government and innovation actors:

Table 11. Policy Challenges and Recommendations

Policy Priority	Recommendation	Evidence Base
Firm age creates barriers independent of capability	Target younger high-potential firms before domestic path dependencies form through early-stage network-building programmes and government-backed validation schemes	Older firms show substantially higher international collaboration; younger firms lack networks and reputation. Early internationalisation easier than later pivots (Section 6).
Demonstrated capacity matters more than R&D spending	Prioritise intellectual property support over R&D spending increases; enhance patent advisory services and mechanisms for firms to signal technological capabilities	Patent stock strongest predictor of international collaboration; R&D expenditure per se shows no significant effect once capability measures included (Section 6).
Path dependencies from domestic operations	Support early internationalisation rather than waiting for firms to scale up domestically; recognise home-anchoring effects of UK subsidiary networks	Each additional UK subsidiary substantially reduces international-only collaboration probability. Path dependencies make later pivots difficult (Section 6).
Most innovative firms pursue mixed strategies	Support both domestic and international collaboration simultaneously; avoid policy designs that frame these as competing alternatives	Firms with largest patent stocks favour joint domestic-international collaboration over international-only. Domestic and international serve complementary functions (Section 6).
Brexit created structural barriers beyond programme access	Navigate regional-global distinction explicitly; help firms maintain European access whilst developing genuinely global strategies	EU27 subsidiaries suggest firms used European networks for regional (not global) R&D. Post-Brexit, this pathway disrupted. North American subsidiaries serve as bridges to global collaboration (Section 6).
Narrowed international collaboration since 2014	Rebuild multilateral partnerships (Horizon Europe) whilst strengthening bilateral ties with US, Commonwealth, and emerging economies	International collaboration weakened particularly with EU partners. Deep US ties persist; UK-China links grew significantly (Sections 4-5).
Not all FDI equally facilitates	Develop nuanced FDI assessment by investor origin; distinguish knowledge-	ASEAN investors show elevated domestic collaboration but reduced international engagement (accessing UK networks).

Policy Priority	Recommendation	Evidence Base
international R&D	seeking from knowledge-augmenting investment	Commonwealth and North American ownership better supports international R&D (Section 6).
Foreign investment spillover heterogeneity	Consider performance conditions for integrating UK subsidiaries into global R&D networks; monitor post-acquisition collaboration patterns	Different ownership patterns have different effects on integrating UK firms into global innovation networks. ASEAN investment may generate fewer spillovers than North American investment (Section 6).
Concentration in emerging technologies	Broaden firm participation through mission-oriented funding, inclusive R&D programmes, and place-based industrial strategies in AI, green tech, semiconductors	Activity in emerging technologies dominated by small number of firms; remains below global benchmarks in scale and diversity (Section 7).
Limited firm-level evidence base	Invest in linked firm-patent datasets, patent linkage systems, and policy evaluation capacity	Novel linked data enabled longitudinal analysis. Continued investment essential for monitoring trends and evaluating interventions.

Together, these actions will help the UK move from innovation resilience to leadership. A more inclusive, outward-looking, and strategically coordinated R&D system is essential to securing long-term economic competitiveness and technological sovereignty.

8. Conclusion

This report has provided a comprehensive assessment of the UK's innovation system, with a focus on the internationalisation of research and development (R&D) at both the system and firm levels. Using novel linked data on patent activity, firm ownership, and collaboration patterns, the study offers new insights into how UK firms engage in cross-border innovation and how these patterns are evolving in response to economic and geopolitical change.

The UK's innovation system is marked by strong scientific foundations, high-quality research outputs, and deep global linkages - particularly with the United States and key European partners. Yet, this strength is unevenly distributed. A small number of large firms, many of them foreign owned, dominate patenting and international collaboration, while domestic SMEs remain underrepresented in global innovation networks. Technological activity is concentrated in a few sectors, with limited diffusion across the broader economy.

Firm-level analysis reveals nuanced barriers to international collaboration. Firm *age* creates obstacles independent of size - younger firms lack networks even when innovative. *Demonstrated capacity* (patents) matters more than R&D spending, and path dependencies emerge early as domestic operations create home-anchoring effects. Importantly, leading innovators pursue *mixed* domestic-international strategies, not exclusively international ones. Foreign investment effects also vary: ASEAN investors primarily access UK networks, whilst Commonwealth and North American ownership better facilitate international collaboration. Brexit has disrupted regional (European) R&D pathways without clear global alternatives emerging.

Despite steady R&D investment increases, the UK lags global leaders in intensity, scale, and emerging technology development. International engagement has narrowed since 2014, particularly with EU partners, whilst AI, semiconductors, and quantum activity remains concentrated among few firms.

Addressing these challenges requires evidence-based policy that targets *younger* firms before path dependencies form, prioritises IP support over R&D spending increases, distinguishes knowledge-seeking from knowledge-augmenting FDI, navigates post-Brexit regional-global distinctions, and supports both domestic *and* international collaboration as complementary activities. Broader participation in emerging technologies, rebuilt multilateral partnerships, and investment in firm-patent datasets remain essential.

These findings are intended to inform evidence-based decision-making across government, industry, and research communities. As the UK redefines its global position, understanding the firm-level determinants of collaboration, including age-based barriers, capacity signals, and ownership effects, will be critical. Future work could examine how these factors interact with technological specialisation and how policy can most effectively address the structural barriers identified.

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Appendices

Appendix A: Patent Classification Scheme and CPC Codes

Patent data were classified using the Cooperative Patent Classification (CPC) system and aggregated into five technology fields following the Schmoch (2008) taxonomy:

Technology Field	Example CPC Subclasses
Electrical Engineering	H01 (basic electric elements), G06 (computing)
Instruments	G01 (measuring), A61 (medical science)
Chemistry	C07 (organic chemistry), C08 (polymers)
Mechanical Engineering	F01 (machines), B60 (vehicles), B25 (tools)
Other Fields	Y02 (climate change), A47 (household tech)

Appendix B: Sectoral Definitions (NACE Rev.2)

Firm activities were categorised based on their primary industry using the two-digit NACE Rev.2 codes, further grouped as follows:

Sector Group	NACE Examples
Manufacturing	10–33 (e.g., pharmaceuticals, electronics)
Knowledge-Intensive Services	58–63 (e.g., software, R&D), 72
Other Services	45–47, 68–82 (e.g., retail, real estate)

Appendix C. Collaboration Type Definitions

We classified patent families based on applicant affiliations:

Collaboration Type	Definition
Solo Patent	Single UK-based applicant with no co-applicants or foreign applicants.
Domestic Collaboration	Multiple UK-based applicants or applicants.
International Collaboration	At least one foreign-based applicant in the same patent family.

Appendix D: Supplementary Figures and Tables

Table D1. International R&D by Manufacturing technology intensity

Manufacturing Technology Intensity	Parent Company location	# Patents	Overall %
High Tech Manufacturing	EU27	141	1.802%
Medium High Tech Manufacturing	EU27	171	2.186%
Medium Low Tech Manufacturing	EU27	33	0.422%
Low Tech Manufacturing	EU27	55	0.703%
High Tech Manufacturing	North America	300	3.834%
Medium High Tech Manufacturing	North America	159	2.032%
Medium Low Tech Manufacturing	North America	104	1.329%
Low Tech Manufacturing	North America	2	0.026%
High Tech Manufacturing	BRICS	12	0.153%
Medium High Tech Manufacturing	BRICS	0	0.000%
Low Tech Manufacturing	BRICS	0	0.000%
High Tech Manufacturing	ASEAN	6	0.077%
Medium High Tech Manufacturing	ASEAN	2	0.026%
Medium Low Tech Manufacturing	ASEAN	4	0.051%
Medium High Tech Manufacturing	Africa	46	0.588%
High Tech Manufacturing	UK MNE	670	8.563%
Medium High Tech Manufacturing	UK MNE	1154	14.749%
Medium Low Tech Manufacturing	UK MNE	570	7.285%
Low Tech Manufacturing	UK MNE	563	7.196%
High Tech Manufacturing	UK MNE	151	1.930%
Medium High Tech Manufacturing	UK Domestic	37	0.473%
Medium Low Tech Manufacturing	UK Domestic	70	0.895%
Low Tech Manufacturing	UK Domestic	28	0.358%

Source: Authors' Elaboration based on PATSTAT Autumn Edition 2023 and Orbis Financial. Number of patents filed with international applicants. Shares do not add up to 100 because firms that are pure domestic, have no assigned parent company. A company is considered an owner if it has at least 10% ownership share. Technology intensity classification is developed following Eurostat classification based on R&D expenditure/value added across NACE 2-digit industrial sectors. Shares are calculated over a sample of firms for which are able to retrieve precise ownership information over time. Also, they do not include collaborative patents between a domestic and a foreign owned company.

Table D2. International R&D by Service technology intensity

Service Technology Intensity	Parent Company location	# Patents	Overall %
High Tech Services	EU27	158	2.02%
Market Knowledge Intensive Services	EU27	113	1.44%
Other Knowledge Intensive Services	EU27	0	0.00%
Low Knowledge Intensive Services	EU27	43	0.55%
High Tech Services	North America	181	2.31%
Market Knowledge Intensive Services	North America	28	0.36%
Financial Knowledge Intensive Services	North America	59	0.75%
Other Knowledge Intensive Services	North America	2	0.03%
Low Knowledge Intensive Services	North America	31	0.40%
High Tech Services	BRICS	27	0.35%
Market Knowledge Intensive Services	BRICS	0	0.00%
Low Knowledge Intensive Services	ASEAN	0	0.00%
Market Knowledge Intensive Services	South America	0	0.00%
High Tech Services	UK MNE	1001	12.79%
Market Knowledge Intensive Services	UK MNE	624	7.98%
Financial Knowledge Intensive Services	UK MNE	38	0.49%
Other Knowledge Intensive Services	UK MNE	135	1.73%
Low Knowledge Intensive Services	UK MNE	637	8.14%
High Tech Services	UK Domestic	296	3.78%
Market Knowledge Intensive Services	UK Domestic	56	0.72%
Financial Knowledge Intensive Services	UK Domestic	21	0.27%
Other Knowledge Intensive Services	UK Domestic	18	0.23%
Low Knowledge Intensive Services	UK Domestic	78	1.00%

Source: Authors' Elaboration based on PATSTAT Autumn Edition 2023 and Orbis Financial. Number of patents filed with international applicants. Shares do not add up to 100 because firms that are pure domestic, have no assigned parent company. A company is considered an owner if it has at least 10% ownership share. Technology intensity classification is developed following Eurostat classification based on R&D expenditure/value added across NACE 2-digit industrial sectors. Shares are calculated over a sample of firms for which are able to retrieve precise ownership information over time. Also, they do not include collaborative patents between a domestic and a foreign owned company.

Appendix E: Methodological Notes and Data Cleaning Procedures

Data Harmonisation

- Name harmonisation was applied to patent applicants using standardised string matching and manual verification.
- Financial variables were cleaned using winsorisation at 1% and 99% percentiles.

Data Linkage

- ORBIS firm data were linked to PATSTAT patents via the publication number which is formed by publication country, publication number and publication authority and to Orbis Financial via applicant name, address, and unique identifiers where available.
- Cross-checks were performed using sector and ownership consistency to improve matching accuracy.

Missing Data and Treatment

- Missing financial data were imputed using firm-level medians within 2-digit NACE sectors when required for robustness checks.
- Sectoral misclassification was addressed by validating against secondary business registries where discrepancies were large.

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