IMPERIAL

Centre for Sectoral Economic Performance

Sectoral Systems of Innovation and the UK's Competitiveness:

The UK Biopharmaceutical Sector 2024

Professor James Barlow and Dr Mathias Hofer

Revised by Esther Havenaar

With Professor Nilay Shah, Professor Paola Criscuolo, Dr. Anne Ter Wal

Imperial College London

Executive Summary

The UK has a globally strong reputation in the life sciences and a large pharmaceutical and biotechnology industry. This report updates our 2023 research on the structure and recent performance of its biopharma sector, which we define here as companies involved in developing and manufacturing both traditional pharmaceuticals ('small molecule') and biotechnology-based pharmaceuticals ('large molecule').

We investigated trends in the economic performance of these companies and compared them to other leading countries, along with their research and development (R&D) capabilities and activity.

Biopharma R&D and manufacturing is one of the UK's leading industrial sectors, responsible for around 140,000 jobs. It contributes a gross value added (GVA) of around £20 billion annually to the UK economy.

Over the last 15 years the sector has experienced some significant challenges to its economic performance.

Biopharma GVA (constant prices) peaked in 2008 and then declined for the next 10 years. Although it has picked up in in recent years, it remains below the peak and the UK has fallen behind other competitor countries in international rankings.

The UK has seen a consistent downward trend in biopharma labour productivity and has been overtaken by other European countries.

Exports of pharmaceutical products were in continuous decline from 2017 to 2021, leading to a negative trade balance, although they have since picked up and the UK had a small trade surplus in 2023.

Medicines manufacturing volume has fallen by 29% and 7,000 jobs have been lost since 2009, partly as manufacturing of lower value generic drugs and active pharmaceutical ingredients has transferred to lower cost locations.

Despite the challenging business environment, we identified important strengths in biopharma R&D. The UK ranks fourth in total biopharma R&D spending and third for R&D activity when measured by the location of inventors of patentable innovations. The UK's two leading pharma companies (GSK and AstraZeneca) spend around £15 billion (not all in the UK). There is also high inward investment by companies conducting R&D in the UK. Public funding for life science and health sciences R&D is around £5 billion.

There is also a large number of small UK biopharma companies that are R&D active and raise private investment (around $5 billion in 2021). The R&D output of small biopharma companies tends to be at an early stage and they often find it hard to obtain investment to move innovations through the development pipeline. There is concern that too many companies are bought by non-UK players before they grow in size.

The decline in clinical trials over recent years, hampering R&D and rapid access to innovative medicines for UK patients, has been much discussed. Measures put in place recently to address the decline have had some success in reducing MHRA approval times. Funding has also been made available to strengthen the clinical trials infrastructure and support patient recruitment.

We believe there are opportunities to improve R&D productivity by leveraging the rich clinical and other life science data available in the UK, support the emerging data science sector that is targeting drug development, and foster small and young companies to help them grow.

There are also opportunities to gain a competitive advantage in manufacturing high-value medicinal products by fostering innovation in manufacturing technologies, and supporting the re-shoring of manufacturing capacity.

Government and industry are making efforts to address some of the current challenges faced by UK biopharma, especially around the clinical trials infrastructure and decline in manufacturing. However, while there is talk about the importance of an integrated national life sciences R&D ecosystem, we believe that much remains to be achieved in connecting the UK's capabilities in drug discovery and early clinical development with an easier adoption environment that takes advantage of the scale of the NHS.

Our recommendations include stimulating R&D productivity, ensuring there is targeted support for early- and scale-up stage biopharma companies (including data science specialists), continued improvement in clinical trials capacity through enhancements to the data infrastructure, ensuring the NHS integrated care systems work to promote and adopt innovations, and strengthening the biopharma manufacturing base.

Table of Contents

Part 1: Sector background

The UK has a very strong and longstanding reputation for the life sciences. It has world-leading universities, with researchers generating the largest number of papers after the USA and China, resulting in a very high weighted volume of citations. It has been ranked second globally in attracting foreign investment in life sciences.[1] The pharmaceutical industry is one of the UK's leading industrial sectors, contributing around £15 billion in gross value added (GVA) to the economy each year and responsible for around 70,000 jobs. Biopharma research accounts for a further £4 billion GVA per annum. The UK is home to two of the world's largest pharmaceutical companies – GSK and AstraZeneca – and numerous smaller companies active in R&D. Around these is a wider ecosystem of companies and organisations that provide services and inputs, including R&D and drug trials. These account for another 75,000 jobs.

We focus in this report on drugs based on chemistry (small molecule) and biotechnology (large molecule) production processes, and its industrial sector. For convenience, we describe the sector as 'biopharma'. We do not discuss advanced cell and gene therapeutics here.

The UK aspires to be a world leader for the development, commercialisation and adoption of new and innovative biopharma products, and in the science of drug discover it is. Yet there are concerns about the ability to sustain UK biopharma's global competitiveness over the longer-term. The sector is experiencing pressures across its full range of activities, from the R&D phases in drug development to commercialisation and adoption.

Some of these pressures are global. Biopharma companies around the world are experiencing pressures associated with the scientific challenges of drug discovery targeting more complex diseases in an increasingly ageing population. Other challenges relate to the lack of economic incentives to develop drugs for rare diseases, antibiotic resistance or new vaccines.

BOX 1. DEFINING 'DRUGS'.
Pharmaceuticals are substances used as medicinal drugs to prevent, treat, or alleviate symptoms of diseases or medical conditions. They usually comprise small molecules designed to have specific pharmacological effects and are typically synthesized through chemical reactions or extracted from non-living natural sources. They are commonly available in various forms, including tablets, injectables, creams and liquids.

Biopharmaceuticals, or 'biologics', are therapeutic agents derived from living systems, such as microorganisms, plant cells, or animal cells. They are manufactured using biotechnology processes, including use of fermentation and cell culture in bioreactors to generate the desired proteins and further purification steps to ensure quality and safety. Biopharmaceuticals offer targeted and personalised treatments due to their high specificity and effectiveness.

Companies are also facing increased environmental and safety regulation, and stricter controls by governments and purchasers on prices paid for drugs.

But other challenges are more homegrown. A fall in the number of clinical trials conducted in the NHS has prompted concerns about the attractiveness of the UK for launching new drugs. The slow adoption of proven products and barriers that hinder the timely spread of new healthcare technologies have long been highlighted in the UK, which lags behind some other European countries in speedy access to newly-approved medicines (see section 3). And despite the strong research base, the sector is dominated by small and medium-sized enterprises (SMEs) that rely on successive fundraising rounds to maintain cash flow and are frequently acquired by companies from the USA or elsewhere before they can grow into large UK companies.[2] There are also concerns about the UK's challenges in competing with other countries in drug manufacturing stages – manufacturing capacity has been lost to other countries, both through outsourcing and the rise in generic drugs manufacturing elsewhere, impacting on imports, self-sufficiency and jobs.[3,4]

The nature of biopharma as an industrial sector is also slowly evolving, driven by innovation in the technologies underpinning drug development and creating niches for the entry of new players. The nature of drug discovery and development is beginning to change through the application of data science, including artificial intelligence (AI), the availability of comprehensive drug and chemical databases, and advances in computational life sciences and engineering biology (the application of engineering principles to the design of biological systems). These technologies offer the prospect of faster drug development and better targeted products, for example by enabling rapid screening of data to generate potential leads or cheaper drug trials.

This evolution in drug development technologies has been accompanied by emerging ecosystems which bring together new specialist players and the 'traditional' large pharmaceutical companies. These include a drug repurposing ecosystem and an innovation ecosystem based around engineering biology.[5] The former comprises specialists providing data science and database technologies and platforms, university or other research centres, small start-ups developing repurposed drugs using open-source data or working with larger biopharma companies, and non-profit funders and patient-led groups focused on cures for rare diseases. The engineering biology ecosystem links specialists in data science, biology, genetic manipulation, fermentation, chemistry and robotics.

These emerging ecosystems are dynamic, involving a variety of interdependent organisations, playing different roles in the innovation process; they begin to raise questions about how to define the 'drug industry' or a 'drug company'. The processes and organisations involved in developing drugs are increasingly varied, involving a wide range of routes and players. New companies are emerging which provide competences not possessed by traditional large drug companies, but they may also disrupt the traditional pharmaceutical companies. Although the level of 'appropriability' of financial returns in biopharma is high because protection of intellectual property is strong, the underpinning technologies and knowledge and skill sets involved in drug discovery are relatively generic, making incumbent firms potentially vulnerable to innovative new players.[6]

The importance of bringing the new players and communities together and building understanding between them has not gone unnoticed.[5,7,8] The strength of these biopharma ecosystems are pre-requisites for a globally productive UK pharmaceutical sector. Ensuring the sector is able to raise its 'innovation productivity' – the ability to discover, develop and commercialise new products faster and more affordably – will be essential if the UK biopharma sector is to remain globally competitive and meet the demand for affordable drugs.

The UK has a strong life science base with good public funding and the NHS provides a large single anchor customer for its products. This context offers good opportunities to build on the existing strengths of UK biopharma. Over the last decade, there have been numerous reports from government and industry bodies which identify areas and prescriptions for improvement. But the problem is not diagnosis or lack of ideas – the problem is an 'execution gap' in momentum and support for key initiatives, according to Emma Walmsley, head of GSK.[9]

This study presents findings from a review of the key technology, business and policy trends which will influence the future productivity and competitiveness of the UK's biopharma sector. We draw lessons for policymakers seeking to maximise the UK's potential in this field.

The next section describes the broad context within which the UK biopharma sector is operating, including global and national trends. We then discuss the findings from our analysis of key indicators of the health of the sector. In the final section we outline our conclusions and recommendations for policymakers and business.

BOX 2. RESEARCH METHODOLOGY
The appendix provides details of data sources and methods to analyse it. To characterise the UK's biopharma sector, we created a firm-level database by combining two datasets, from the 2019 'Biopharma core' dataset provided by the Office for Life Sciences and the GMDP database by the Medicines and Healthcare Products Regulatory Agency (MHRA).

We extracted firm-level financial and economic variables from data provided by Bureau van Dijk and used Pitchbook to extract data on international private capital investments in biotechnology and pharmaceuticals.

Other sources of data include the NIHR Innovation Observatory Scan Medicine database and the EU R&D Investment Scoreboard.

Part 2: UK Performance and International Comparison

This section describes the background context for the UK's biopharma sector – the forces shaping the activities of the sector and its component parts. Some of these forces result from technological innovation, others from social or economic trends, or policy decisions.

The global context

The R&D 'productivity crisis' in drug development

The challenges faced by the pharmaceutical industry in developing new drugs are long-standing and well-known. This is not a uniquely UK problem – drug companies around the world are facing similar pressures from a decline in R&D productivity. This has been highlighted by industry leaders, observers and researchers, and policy makers since the late 1990s. Some recent investigations[10] have shown a slight upward trend in terms of number of new drugs per billion US dollars of R&D spending but others suggest that the decline in R&D efficiency has merely stablised at a significantly lower level than the past (see box 3).

The reasons for this have been widely investigated and there is disagreement about the relative impact of different factors. These include increased attrition (failure) rates across all drug development phases, investment in therapeutic areas associated with high risk of failure,[16] and tighter regulations.

It is important to note that the measures commonly used in discussions on R&D productivity have limitations. In particular, simply focusing on the number of new drugs does not measure or adjust for their value for scientific progress, patients, and society. Some commentators suggest that the real innovation crisis lies in the decrease in the number of drugs that offer true therapeutic advances.[16,17]

As well as the long-term fall in R&D productivity, drug companies have had to confront a series of other challenges which have impacted on the profitability of drug development:

BOX 3. THE LONG-TERM DECLINE IN R&D PRODUCTIVITY

Measured by new drugs authorised by the FDA each year, there was steady growth from the mid-1960s to the mid-1990s. Since then, the number has consistently declined. At the same time, the total cost of R&D steadily rose, resulting in a significant decline in R&D efficiency.[11-14] The number of new approved drugs per billion US dollars, adjusted for inflation, fell from around 50 per year in the 1950s to under one drug per year by the 2010s, with the first wave of biotechnology-derived therapies in the 1990s having no effect on the decline in productivity.[15]

Some recent investigations into R&D productivity / efficacy have shown a slight upward trend in the number of new drugs per unit of R&D expenditure. This seems to be associated with a decrease in attrition rates at all drug development stages. While research has found that significant R&D investment into highly specialised therapeutic areas (e.g. rare diseases) is associated with higher risk of failure, validation of drug targets has been improving through the application of data science technologies (e.g. genome-wide association studies)[19,20], and the time to terminate failing R&D projects has decreased. However, other research suggests that while the long-term decline in pharmaceutical R&D efficiency has slowed and stabilised, questions remain whether this is will be sustained[14] and the gradually diminishing rates of return on investment from drug discovery and development will continue.[10] This is the result of the inability of large pharmaceutical companies to adopt new business and innovation models that are capable of tackling the changing scientific, market and regulatory challenges of drug development.[10]

- Regulatory costs have increased due to the need to generate more demanding and higher-quality clinical data.
- There is downward pressure on prices, with much greater focus by regulatory bodies and payers (e.g. insurance companies) on the societal benefits and economical costs of drugs.
- The use of lower-cost generics and biosimilars has grown; European and US drug companies face more competition from generic manufacturers based in India and elsewhere, and there is more rapid 'genericisation' after a branded drug's patent expiration.[20,21]

Changing drug development technologies and ecosystems

Over the last two decades, the rising cost of developing new drugs, coupled with increasingly stringent value for money expectations of governments and regulators, led pharmaceutical companies to restructure and seek new R&D and business models. An initial strategy for companies facing expiring patents and a lack of new drugs in their pipeline was to embark on mergers and acquisitions (M&A).[23,24] The effectiveness on R&D productivity remains inconclusive.[21] Pharmaceutical companies also reformed their internal innovation processes to terminate failing research projects faster; most also outsourced or out-licensed some projects to specialist drug R&D companies. In time, a consensus emerged that drug discovery and development is often better accomplished through models of collaborative R&D (such as 'open innovation'), alliances between biotech and pharmaceutical companies around specific therapeutic areas, and collaborations with specialist firms providing data science tools and platforms.

The relationship between the biotechnology and pharmaceutical parts of biophama has evolved over time. Partnerships provide funding and access to new product opportunities for both parts. Advances in biotechnology, including recombinant technology and genetics, have introduced a more systematic approach to drug development overall (see box 4).

Drug development therefore takes place in an increasingly complex and segmented way. Several different R&D models have been adopted. Some companies focus on developing new drugs in-house or through licensing. Others pursue a similar strategy but also engage in generics. Large diversified companies invest across multiple areas. Some generic drug companies have diversifed from generics into drug development. Some pharmaceutical service companies are expanding their own innovative activities.

Data availability and data technology, especially AI, are now playing a role in transforming the early-stage drug development process by identifying and validating new drugs and their targets faster and more efficiently.[27] A new ecosystem is beginning to emerge, driven by a proliferation of startups with occupying specific niches in biopharma R&D and creating new niches (see box 5). As yet, there is no consensus on the overall impact of these strategies on R&D productivity, but the adoption of AI technology and the availability of comprehensive drug and chemical databases, coupled with rapid advances in the experimental and computational life sciences, may help to remove some of the serendipity from drug development.[28,29]

BOX 4. THE CHANGING DRUG DISCOVERY LANDSCAPE

The drug discovery landscape has undergone considerable change over the past decade, driven by the integration of new technologies into drug development processes.[26] Traditional pharmaceutical companies have increasingly outsourced the early stages of scientific research to organisations and companies with specialist expertise, such as in genomics and proteomics, and are increasingly collaborating with data science companies. A more diverse range of players is now actively engaged in collaborative arrangements to identify new drug candidates, conduct preclinical research on cell-based and animal models, and design and manage human clinical trials. Collaborations with contract research organisations (CROs), specialist technology platforms and academic institutions have enabled traditional pharmaceutical companies to expand their drug discovery capabilities and gain access new areas expertise and technologies. Outsourcing operations to CROs and contract development and manufacturing organizations (CDMOs) helps pharmaceutical companies reduce costs and improve efficiency by providing flexible capacity to accommodate changes in demand for the production of drugs.

BOX 5. THE NEW DRUG DEVELOPMENT ECOSYSTEM

There were around 900 AI-driven companies involved in biopharma in mid-2024, including 81 based in the UK.[30] The overall global market for drug discovery technologies has recently been estimated at USD 55bn per annum and is expected to grow to USD 157bn by 2030.[31]

One challenge for the sector is the global shortage of data science expertise, with AI specialists being recruited by large tech corporations rather than pharmaceutical companies. Another challenge is the acquisition of accessible high quality data for deep learning technologies due to privacy, ethical, legal, data ownership, and regulatory issues.

A specialist subsector, with its own emerging ecosystem is drug repurposing (identifying potential new uses for existing drugs). At least 65 companies and other types of organisation such as rare disease NGOs, offer drug repurposing services to the pharmaceutical industry (unpublished internal research). This is projected to to be worth over USD 1.2 billion by 2030.[32]

Technological innovation alone will not address the slow decline in R&D productivity. Large pharmaceutical companies need to be as efficient as possible in how they allocate resources to exploratory and R&D projects; this will require closer collaboration with the entrepreneurial and start-up community, and academia. Large pharmaceutical companies have often struggled to take advantage of new collaborative models, but R&D productivity could be improved in some areas of drug development (rare diseases, vaccines and antibiotics) by greater use of public-private partnerships and the development of R&D ecosystems that encourage shared risk and reward.[10]

Digital transformation in the pharmaceutical industry

Apart from tackling R&D productivity, pharmaceutical companies are also trying to improve the efficiency of their overall business processes and findings ways to add value to their existing products and services. This is partly being achieved through digital transformation across all their activities. Digital transformation is generally viewed in terms of re-imagined business models that are facilitated by integrating multiple digital technologies. It represents large-scale organisational change rather than localised improvement. In biopharma, digital transformation aims to move companies from product-centric operations to more patient-centric and service-oriented business models. As well as exploring ways to improve business processes by using of AI and other digital technology innovations, companies are hoping that by leveraging powerful data analytics, large-scale data sets, comprehensive personal health records and real-world evidence they will improve the precision and effectiveness of their products. Achieving this vision requires overcoming significant technical, data and regulatory challenges, but elements of digital transformation are taking place across the biopharma industry and some commentators have argued that the pace of change was accelerated by the Covid-19 pandemic.[33]

The integration of AI, robotics, and the 'internet of things' to optimise the production of drugs, to drive cost savings and reduce errors and wastage is one important area for digital transformation[34–36]. It is also beginning to have a tangible impact in the design and conduct of drug trials and in moves towards greater engagement with patients. Decentralised clinical trials (DCTs) aim to improve trial efficiency and participant enrolment by incorporating features like direct delivery of drugs to participants and remote data collection. The number of DCTs conducted globally has increased since 2021[37] and many trials now use at least some decentralised elements. While DCTs are seen as effective for lower-risk trials and dispersed populations, they face regulatory and technical challenges, including data privacy, technology integration, and ensuring compatibility with existing data systems and electronic patient records. The second area where digital transformation is having an impact on pharmaceutical companies – and one which supports moves towards DCTs – is the use of remote care or telemedicine. This provides pharmaceutical companies with opportunities for real-time data collection, potentially enhancing their role in patient care and the introduction of more personalised treatment options.

It has long been argued that pharmaceutical companies need to move 'beyond the pill' and find ways to marry existing business models with new value-adding revenue streams, either directly evolving from their existing products or focused on adjacent services and complementary products, or brand new healthcare related services.[38,39] Digital therapeutics is seen as a potential source of revenue by adding value to existing and new drug products, for example by incorporating patient advice or support delivered through telemedicine, or medication reminders. Potential benefits of digital therapeutics include enhanced patient adherence with drug regimens, drug effectiveness monitoring, improved management of long-term conditions, the ability to feed patient data back to clinicians, and the use of anonymised data for wider effectiveness and population studies. Although pharmaceutical companies are forming partnerships with digital platform providers to develop digital therapeutic solutions, integrating these into traditional drug development-led industry cultures has proved hard. Successful implementation involves addressing data ownership, integration, and privacy challenges to ensure compliance and trust, as well as identifying reimbursement models that account for the added value of digital therapeutics and align the interests of drug companies, healthcare providers and payers.

In time, digital transformation may blur the boundaries between the pharmaceutical and medical device sectors, with digital medicine innovations such as drug-device combinations. An example is the digital pill, which combines traditional medication with an ingestible monitoring sensor.[38] This raises questions about how to define a 'drug'. And the proliferation of different types of organisation involved in drug development – data science, analytics, digital platforms, academic and other research, rare disease advocacy – are beginning to make the definition of a 'drug company' harder as new ecosystems of players emerge.

The UK context

Commercial environment – drug pricing

The UK has considerable strength in pharmaceutical R&D but drug companies are also concerned about the commercial environment they operate in.[39] Drug pricing policies and the UK's generally declining share of the global pharmaceutical market, are said to reduce the attractiveness for R&D investment.

The head of International Federation of Pharmaceutical Manufacturers and Associations (IFPMA) recently stated that the industry's warnings should not be dismissed as 'pure rhetoric' and pointed out that 'Not only are there great scientists in the US … but you also get a return on investment in a tough environment'.[39]

Since 1957, the Department of Health and the pharmaceutical industry have negotiated voluntary agreements covering pricing of branded medicines, designed to keep NHS drug costs under control while also encouraging investment in new drugs (the Voluntary Pricing and Access Scheme or VPAS). In 2019 the agreement involved companies paying back 5 to 10% of UK sales if the NHS drugs bill rose by more than 2% annually. In 2022 the rebate rate increased to 15% and then 26.5% in 2023.[40] Other European counties and the USA also employ methods to control drug spending, but UK's clawback rate became significantly higher than other European countries, where 10% or lower is common.

Following industry protests – the Association of the British Pharmaceutical Industry (ABPI) argued that the high tariff could lead to a loss of £5.7 billion in R&D investment over the following five years[41,42] – a new scheme was agreed (the Voluntary Scheme for Branded Medicines Pricing, Access, and Growth, VPAG).[43] This came into effect in January 2024 and is scheduled to continue until 2028. The main objective of VPAG is to balance the costs of branded medicines sold to the NHS and financial returns for the pharmaceutical industry, without damaging R&D or the UK's global competitiveness in life sciences. The VPAG also sets out plans for NHS England to work with companies to create a new patient database to encourage local NHS services to collaborate with pharmaceutical companies and encourage the wider use of new approaches to patient support post treatment.[44]

Under VPAG, the cap on NHS expenditure on branded medicines will increase from 2% to 4% per annum by 2028. The rebate rate paid by companies depends on whether the drug is 'newer' or 'older', or exempt in some cases. The rate for older drugs is now 10%, with an additional variable top-up ranging from 1% to 25%; this depends on the degree to which the price of the drug has been eroded over time. Newer drugs – generally those under 12 years after the grant of initial marketing authorisation – are required to pay a 15.1% rebate.

An outcome of VPAG is that pharmaceutical companies will pay differential rebates, depending on their product mix. Some companies may be more adversely affected than others and therefore less willing to engage in the scheme.[45] Those with UK drug portfolios largely comprising older, off-patent drugs that have not seen significant price reductions will be harder hit than innovative companies which have been successful in commercialising new drugs.

The VPAG scheme is still seen by biopharma as out of line with other countries with rebate systems. For example, recent amendments to Germany's Medical Research Act allows companies to keep their sales price for a drug confidential, in return for a 9% discount on the agreed price and providing a proportion of clinical trial patients are enrolled in Germany.[46] The ABPI argues that payment percentage rates for newer medicines and the underlying financial mechanism do not bring the UK rebate back to a position of international competitiveness and represent an increase in annual payment rates.[47]

The increase in the rebate rate has resulted in a backlash from pharmaceutical companies. Under the previous scheme there was concern that generic drug manufacturers would be adversely affected because their prices are 70 to 90% lower than the original drugs.[41] The tiered approach under VPAG takes into account the contribution made by off-patent medicines to NHS savings, although the British Generic Manufacturers Association is concerned that the growth rate in the expenditure cap is too low to ensure stability in the supply of drugs.[48]

R&D tax credits and funding for research

Tax credits can reduce the cost of innovation for UK companies and help meet government aspirations to raise investment in R&D. Research has shown that tax credits can stimulate R&D spending and patent registrations, particularly among younger firms, but there are concerns about their cost and value for money. The last Government's decision to cut R&D tax credits for SMEs and boost the rate for larger companies was criticised.[49] Changes in April 2024, with the merger of two separate tax credit schemes, provoked concern that that there are now multiple tax and tax credit rates depending on the profitability of a company, making the system more complex to understand. The implications for R&D-intensive SMEs will only become clearer once the new scheme beds down. Labour is planning to evaluate the R&D tax credit scheme sector-by-sector, starting with life sciences.[50]

More broadly, the Labour manifesto announced the intention to address problems associated with short-term funding cycles that hinder longer-term partnerships between research bodies and industry. This would be achieved by introducing a similar approach to the successful model of the Aerospace Technology Institute, where there is a ten-year funding settlement.

Clinical trial capabilities

Clinical trials are central to a successful drug development pipeline. While decentralised clinical trials (DCTs) have made it easier to perform trials across wide geographic areas, trials deliver significant financial benefits to a country. The O'Shaughnessy report[51] found that in the UK most of the gross value added (GVA) arising from research supported by the National Institute for Health and Care Research (NIHR) clinical research networks (£1.8 billion) resulted from clinical trials funded by the life sciences industry. The return on investment includes direct health benefits, profits to UK firms involved in research, and spill-over effects on the wider economy.

Comparing different countries' performance on conducting clinical trials is hard because of inconsistencies in the way data are compiled.[52] Our previous report outlined concerns that in recent years there were weaknesses in the UK's performance in attracting clinical trials, particularly in phase 3 trials which generate the highest revenue for the NHS and provide the largest number of patients with cutting edge medication.[53] Other countries have also seen a fall in trials, but the UK, Germany and Japan have experienced a sharper decline (figure 1).

For commercial trials, the share of patients recruited by the UK and other European comparators tends to fluctuate, while the USA continuously accounts for a substantially higher share. For commercial clinical trials of novel drugs, the UK's share of patients grew to 2.6% in 2022 (an increase from 2.2% in 2021) and the UK's ranking amongst comparator countries rose from fifth to fourth. The most recent ABPI study acknowledges that the decline in the number of industry-led clinical trials initiated in the UK shows signs of recovery, although performance in phase three trials remains poor, with the UK ranked tenth.[54]

Other data is available from the NIHR Clinical Research Network (CRN). This covers a range of commercial interventional trials in the UK but does not include early phase trials and no internationally comparable data is available. The data shows an increase in patient recruitment into trials. Pre-Covid around 200,000 patients were recruited annually. This dropped to 167,000 patients in 2020/21, before rising to 342,390 in 2022/23 and 349,019 in 2023/24. In total, the number of participants recruited to studies supported by the CRN in England grew from 952,789 (2022/23) to 1,045,282 (2023/24).[55]

One problem identified in the O'Shaughnessy report and by the ABPI was the perception that the pharmaceutical companies seeking to conduct trials in the UK experience inconsistencies in the approval process and delays in site-level approvals. The median time taken from regulatory approval to administration of the first dose to participants across countries depends on the type of trial conducted but the UK has tended to lag behind comparators (figure 2). Median times were impacted by the Covid-19 pandemic and by 2022 all comparator countries were taking longer to approve and set-up clinical trials. Median times in the UK grew from 222 to 271 days between 2018 and 2022 and 273 days in 2023. While the UK has lagged behind other countries (between seventh and ninth since 2018), there is little difference in the median number of days between European countries with significant pharmaceutical industries (e.g. Germany, France). Switzerland is currently performing significantly worse, seeing a rise of 200 days between 2018 and 2022 to 372 days. In contrast, median times were only 172 days in the USA, a rise of 25 days since 2018.

The last Government responded to concerns about the UK performance in clinical trials by committing £121 million to reduce approval times, provide real-time data on clinical activity, establish a common approach to patient contact, and create clinical trial acceleration networks (CTANs).[56,57] This appears to have had some success in reducing MHRA approval times to within 60 days, but does not tackle the subsequent time for local approvals and administration of first dose in patients. In August 2024, the new Government announced investment of 'up to £400 million' to support clinical trials (and improve drugs manufacturing, see below) in the UK.[58] This includes plans for 18 new clinical trials hubs across UK to build on the existing commercial clinical trials infrastructure, support patient recruitment, improve access to technology to enable innovative trials, and develop and introduce new health technology assessment (HTA) approaches.

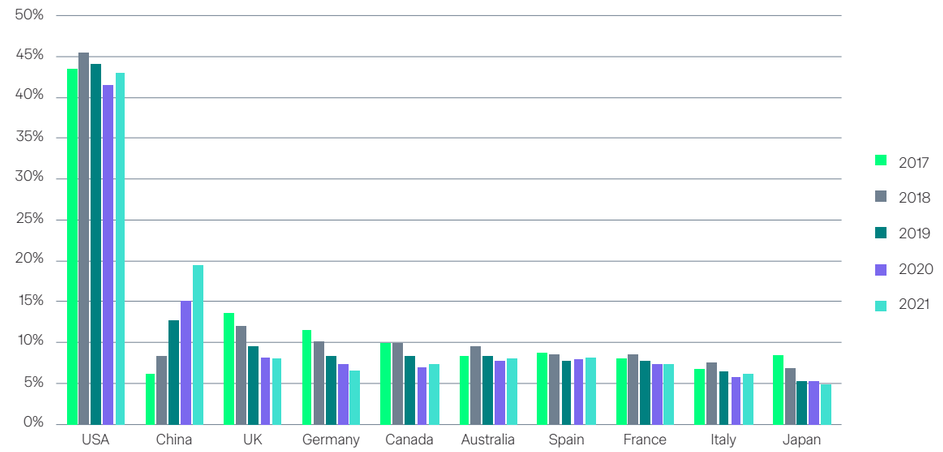


Figure 1: Proportion of initiated and completed clinical trials between 2017 and 2021 by trial site location.
Source: NIHR Innovation Observatory Scan Medicine

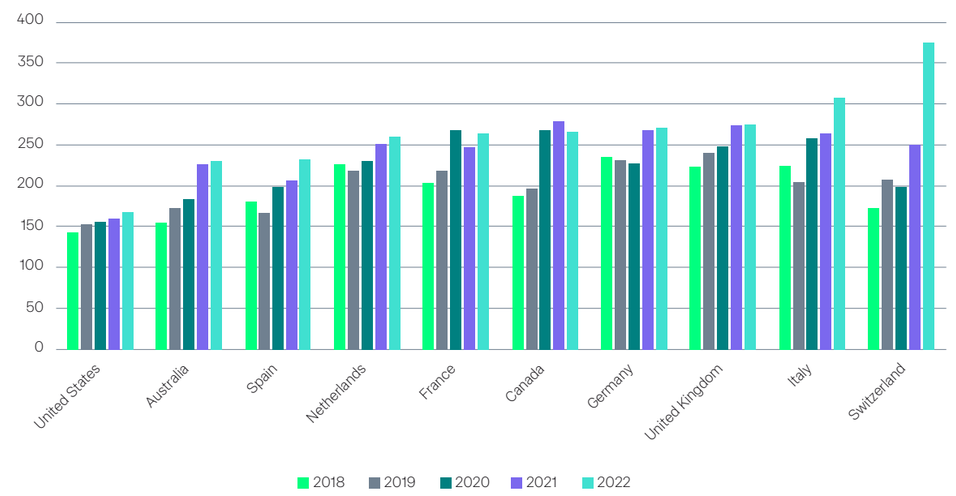


Figure 2: Median number of days from clinical trial application to first patient receiving a first dose (subset of commercial trials).
Source: Life Science Competitiveness Indicators 2024: Data Tables https://www.gov.uk/government/publications/life-sciences-sector-data-2024

Access to innovative drugs

Between 2019 and 2022 167 new drugs received authorisation from the European Medicines Agency (EMA). Slightly more than half (56% in England and 54% in Scotland) were made available to patients, with a continuous decline from 72% since the 2016 to 2019 period. European countries vary considerably in the proportion of medicines made available, ranging from 88% in Germany compared to 28% in Ireland. England ranked seventh out of 13 comparator countries (fifth in 2016 to 2019) and Scotland ranked ninth. Most other comparators have seen similar declines, apart from Spain.[59]

The time to taken for new drugs to become available for patients varies substantially across Europe (figure 3)[60] The EU median was 474 days in 2022. England and Scotland perform reasonably well, ranking seventh and eight in time taken for drugs to become available after market authorisation by the EMA (median times of 299 and 313 days respectively for the period 2019 to 2022). Germany (47 days) and Spain (613 days) were outliers amongst large European countries. The range reflects differences in how health technology assessments and drug approval processes are conducted.

Over the long term, there has been a small (but not statistically significant) upward trend in the number of new drugs added to the British National Formulary that were not generics or new formulations (with periods of higher and lower activity).[61] The number of highly innovative drugs launched annually remained relatively stable.[62]

While the speed of new drug launches in the UK remains a concern for industry commentators, some have suggested that a bigger threat may be pharmaceutical companies withdrawing certain drugs from the UK and wider European market due to pricing concerns.[39] These reflect the increased scrutiny by regulators and health authorities over the value of drugs. Debate over the value of novel drugs and the mechanisms to cover their cost is likely to grow as the pharmaceutical industry focuses increasingly on expensive personalised and targeted therapies for rare diseases and specific mutations in oncology. Various alternative payment models, such as pay-for-performance or flat fees based on therapeutic requirements, are being explored and the department of health has signed agreements to ensure they are accessible to the NHS.

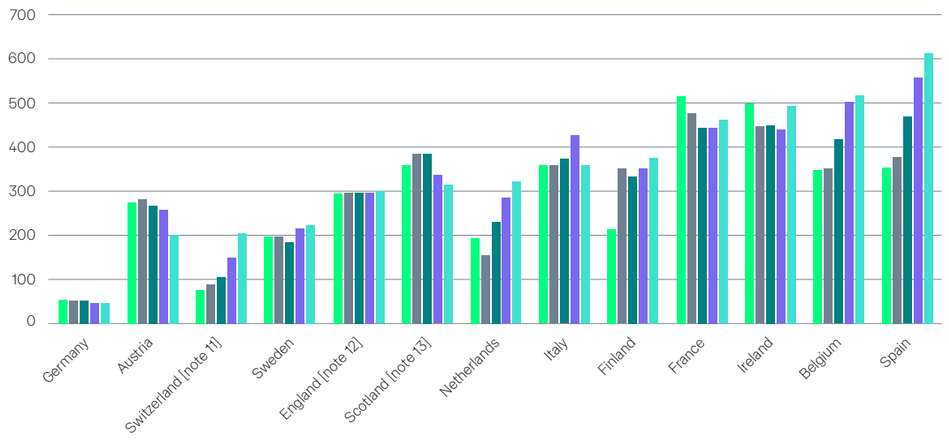


Figure 3: Median time to availability (number of days) for drugs Source: Life Science Competitiveness Indicators 2024: Data Tables. https://www.gov.uk/government/publications/life-sciences-sector-data-2024

Medicines authorisation

After Brexit in 2021, the Medicines and Healthcare products Regulatory Agency (MHRA) replaced the European Medicines Agency (EMA) as the regulatory agency for drug authorisations. This raised concerns that a separate application process would lead to additional costs for drug developers and delays in timely access to new drugs for UK patients, compounded by the UK's small share of the global pharmaceutical market.[63,64] The first study of the MHRA's regulatory activity post-Brexit studied approvals in 2021, its first year of independence, compared to other international regulatory bodies. The MHRA has lagged behind the USA and EU in novel drug approvals and remained reliant on EU regulatory decision-making for approximately 70% of novel medicines approvals. There were significant regulatory delays for a small number of novel medicines in the UK. However, the MHRA has introduced initiatives which show early promise for faster authorisation of innovative medicines for cancer and other areas of unmet need.[65] Partnerships with regulators in Australia, Canada, Singapore and Switzerland have also been introduced (the Access Consortium and Project ORBIS), and from 1 January 2024 the International Recognition Procedure allows the MHRA to take into account the expertise and decision-making of trusted regulatory partners to save time and resources in authorising new drugs.[67]

Manufacturing

Manufacturing of drugs is important both to ensure resilience in the supply chains for key drugs and to support economic growth by creating high-value jobs in life sciences. Although the UK saw growth in pharmaceutical manufacturing employment between 2016 and 2019,[68] there remain concerns about the long-term loss of manufacturing activity to other countries, especially in generic drugs.

Historically, the location of pharmaceutical R&D – where the UK has strengths – and commercial manufacture has tended to be closely linked.[4] However, since the early 2000s the manufacturing sector in the UK has been shaped by economic pressures and merger and acquisition activity. Falling sales margins, coupled with the cost of regulatory certification in older plants, have undermined their financial viability and led companies to close or mothball of unprofitable manufacturing plants. As a result, there has been a rise in contract development and manufacturing operations (CDMOs), which has replaced direct manufacturing by larger pharmaceutical companies. Manufacturing volume in the UK has fallen by 29% and 7,000 jobs have been lost since 2009 (see box 7).

Workforce

The biopharma industry is reliant on specialised skills, and there have been periodic reports of skill shortages in the UK. The most recent ABPI survey of its member (2023) highlights continuing skills shortages in some areas, notably around core scientific, mathematical and digital skills, although progress has been made in easing shortages in specialist areas such as formulation science and in manufacturing engineering. The report also highlighted that the impact of immigration policies have been detrimental to the ability of companies – particularly those with operations across multiple countries – to move existing staff into UK-based roles and recruit people from overseas.[71,72]

BOX 7. TRENDS IN THE LOCATION OF BIOPHARMA MANUFACTURING

Only about 25% of the total number of generic drugs prescribed annually in the UK – which account for 81% of all prescribed drugs – are manufactured within the UK. Apart from the large growth in generic drug manufacturing in India, drug manufacturers have relocated production to the Republic of Ireland, supported by a combination of capital grants, low tax rates, and planning policies.[70]

The production of biologics has concentrated in the USA, Japan, Singapore, Switzerland and Ireland.[3]

The manufacturing base for active pharmaceutical ingredients (API) has transferred to lower cost locations, especially China and India, and questions have been raised about the possible detrimential impact on the resilience of supply chains.[4]

Sectoral trends and international comparison

Contribution to the economy

The ONS reports annually on gross value added (GVA) for economic sectors, including the 'manufacture of basic pharmaceutical products and pharmaceutical preparations' (Standard Industrial Classification code 21). The data show that GVA for pharmaceutical manufacturing in the UK (in 2019 prices) peaked in 2008 at about £19 billion, then fell for the following decade, before stabilising at around £15-16 billion in the period 2020-22 (data after 2022 are not yet available). However, the ONS data underplays the true scale of the biopharma sector as it excludes other industries within the wider ecosystem, notably companies that support the sector, perform R&D activities and biotechnology-based drug research. A PwC study published estimated the UK life sciences sector as a contributes £43.3 billion in GVA in 2022. Life sciences research (which includes part of the wider picture) accounted for approximately £4.1 billion GVA in 2021.[73]

Comparison of pharmaceutical GVA for different countries is not straightforward (figure 4).[68,74] The UK has fallen behind France and Italy over the last 15 years and is also an outlier, with Japan, in its downward trend in GVA. In contrast, the growing strength of the USA, and the rising importance of Ireland and India, stand out.

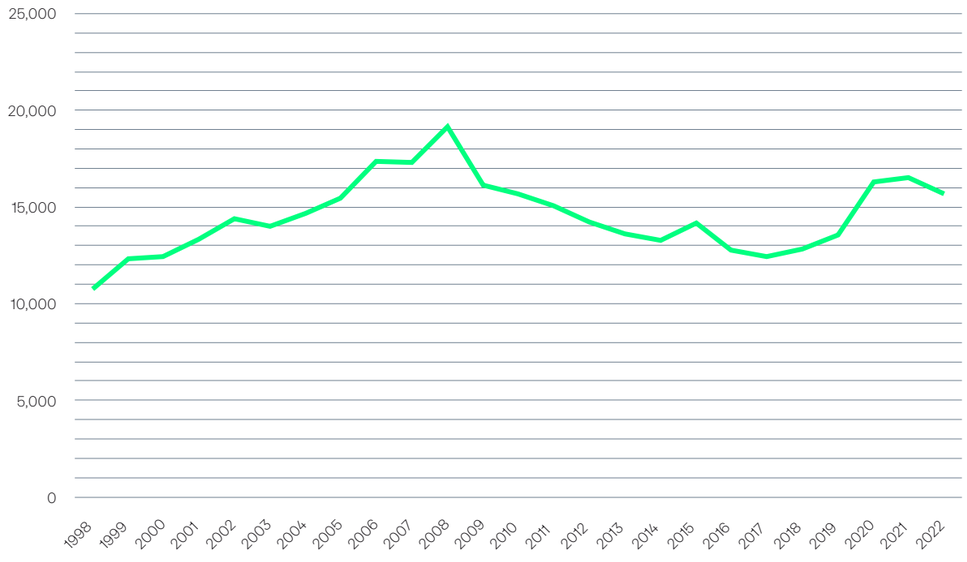


Figure 4: Manufacturing of pharmaceutical products (SIC21) (chained volume measures, £ million, 2019 prices).
Source: Office for National Statistics.

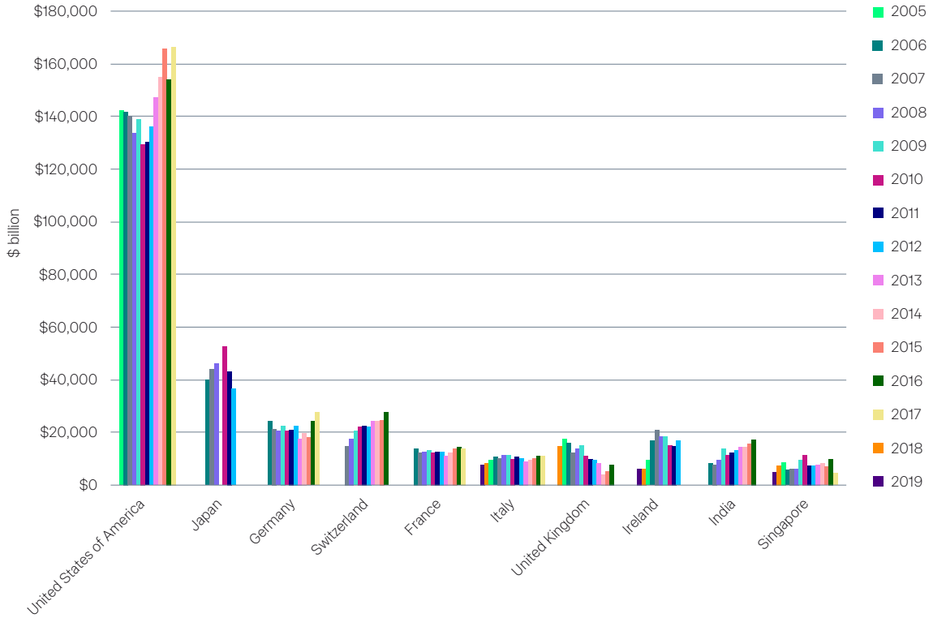


Figure 5: International comparison of GVA figures for pharmaceutical manufacturing. Displayed are the top 10 countries with the highest GVA figures over the observed time frame. Note: some data points are missing across countries and years.
Source: Calculation by study authors by data from UNIDO INDSTAT 4 2022, ISIC Revision 4

Labour productivity

In the UK, financial and insurance activities (£145.1k), information and communication (£83.1k), manufacturing (£74.4k), and construction (£55.3k) had among the highest levels of labour productivity in 2019.[74] According to United Nations Industrial Development Organization (UNIDO) figures, GVA per employee for pharmaceutical manufacturing in the UK has continuously decreased since 2007 to £117.9k in 2018 (figure 6). This is, however, still higher than the labour productivity of the UK manufacturing sector as a whole.

Singapore, Ireland, USA and Switzerland show the highest pharmaceutical industry labour productivity levels, characterised by periods of growth and stability since 2005. The UK has seen a consistent downward trend in labour productivity, and now ranks eleventh having been overtaken by other European countries (Belgium, Finland, Denmark) (figure 7). These findings are in line with other reports showing falls in UK labour productivity of -9.5% between 2007 and 2017 [75] and -2% between 2015 and 2019.[8]

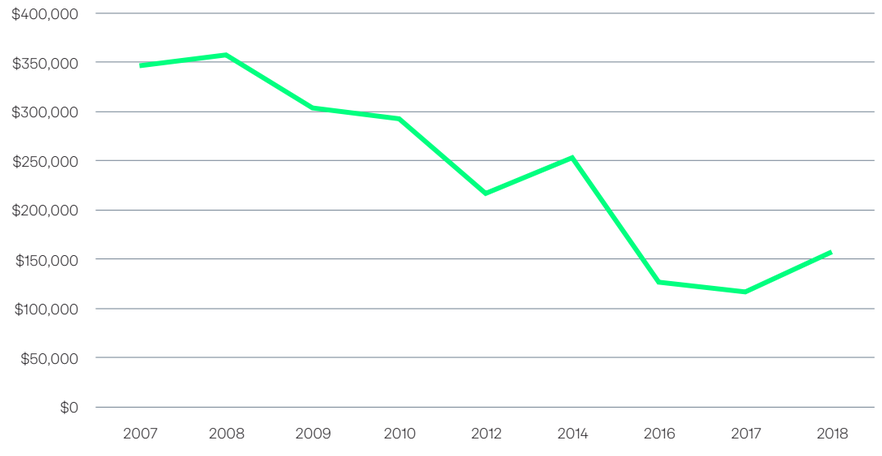


Figure 6: GVA per employee for manufacturing of pharmaceuticals in the UK. Source: Calculation by study authors by data from UNIDO INDSTAT 4 2022, ISIC Revision 4

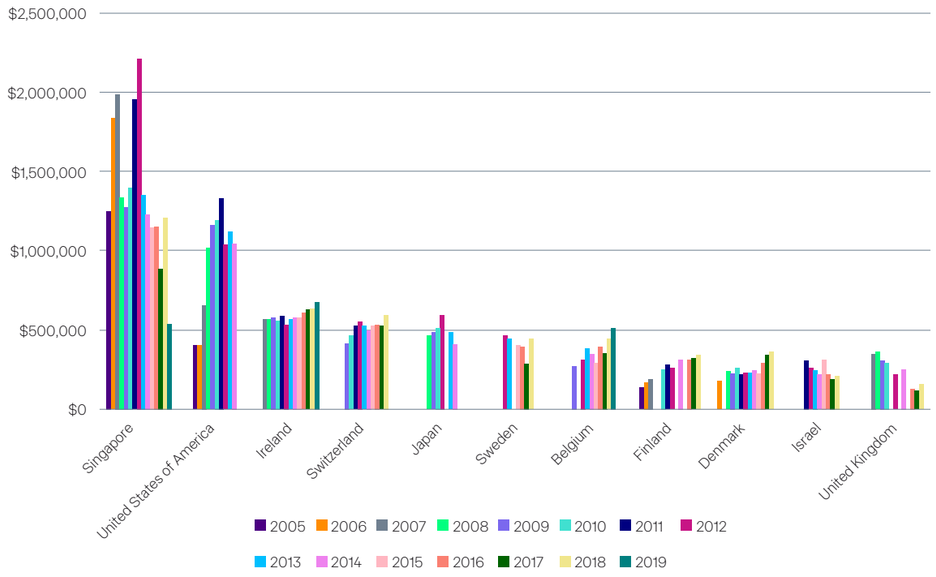


Figure 7: International comparison of GVA/employee figures for pharmaceutical manufacturing. Source: Calculation by study authors by data from UNIDO INDSTAT 4 2022, ISIC Revision 4

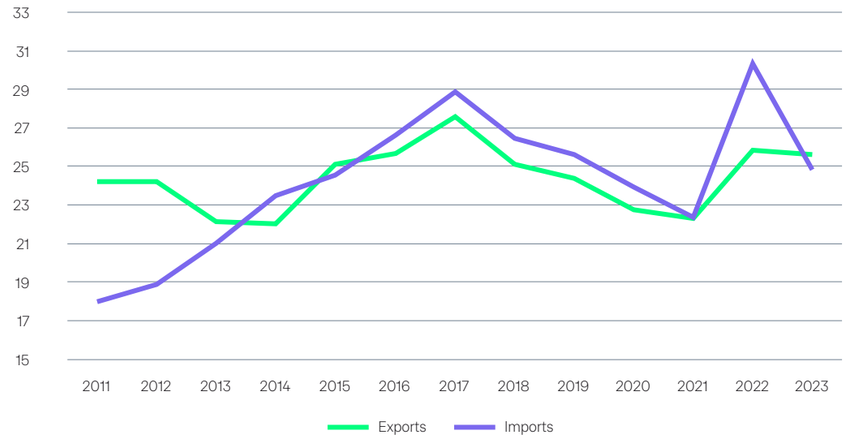


Figure 8: Export and import for pharmaceutical products for the UK (£bn). Source: Calculation by study authors by data from Life Science Sector Data 2024 [52]

Trade balance

Exports of pharmaceutical products declined from 2017 to 2021, before picking up slightly in 2023, to generate a small trade surplus of £700 million (figure 8).[76] However, since 2013 the trade balance has remained consistently negative and internationally the UK's ranking has dropped 94 places since 2010, from fourth (with a positive trade balance of over £6 billion) to ninety-eighth in 2020. The most consistent countries according to trade balance are Switzerland, Ireland, Germany, France, India and Israel (Table 1).

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

Table 1: International comparison of the trade balance for pharmaceutical products Source: UK Innovation Report 2022 [77]

R&D investment and environment

There are several ways of looking at R&D investment in the UK. Overall gross domestic expenditure on R&D (GERD) as a share of GDP was around 2.9% to 3% in 2023, above the OECD average of 2.67%.[74] In 2020 the UK spent the fourth highest share of GDP among the G7 countries, behind the USA (3.47%), Japan (3.27%) and Germany (3.13%).[78] However, Israel (5.4%) and South Korea (4.8%) are high spending outliers amongst all OECD nations.[79]

Total UK business expenditure on R&D (BERD) was £46.9 billion in 2021, with most of the funding (£37.2 billion) coming from the business sector itself (other sources include the public and private non-profit sectors). Pharmaceuticals was the largest ONS industrial sector, with R&D an expenditure of £9.0 billion in 2022. Two thirds of this comprised experimental development, followed by applied research (24%) and basic research (10%).[80] About 79% of the expenditure came from businesses' own funds, and only 10% from government.

Between 2015 and 2021, R&D performed by the government and the private non-profit sectors represented a generally constant share of GDP. In 2021 public institutions performed £160 million of medical and health sciences R&D, a smaller proportion of GDP than comparator countries. The private non-profit sector performed £973 million.[80] Another estimate of public funding for life science and health sciences R&D is reported by the UK Health Research Analysis. This analyses health and biomedical research awards from various organisations and reported £5 billion expenditure within the UK in 2022.[81]

The EU R&D Investment Scoreboard is published annually and provides an annual list of the top 2,500 companies with the highest enterprise R&D spending worldwide and top 1,000 companies in the EU. Across all industrial sectors in 2022 and taking the world's 2,500 top R&D-investing companies alone, 94 of have their headquarters in the UK, which ranks fifth behind the USA, China, Japan, and Germany.[74] For pharmaceutical companies alone, the UK ranks fourth, after the USA, China and Japan, ahead of leading comparator countries including Switzerland, Germany and France (Table 2).

Country	Number of companies	Highest ranked pharma company amongst all 2,500 companies
USA	273	10
China	85	154
Japan	24	48
UK	17	9
India	10	707
Denmark	10	65
Switzerland	10	14
South Korea	9	1089
Canada	8	412
Germany	8	31
France	7	29
Ireland	7	385
Netherlands	7	404

Table 2: Pharma companies in relation to top 2,500 R&D spending companies globally. Source: EU scoreboard 2022

We also combined the top 2,500 worldwide and top 1,000 EU datasets, removing double entries for a wider picture of the biopharma sector. Between 2014 and 2020, the timeframe with methodologically comparative data is available, the UK consistently had the second highest number of companies amongst companies with the highest enterprise R&D spending worldwide, but China is closing the gap (figure 9). The UK scores fourth in total global R&D spending, behind USA, Switzerland, and Japan (figure 10). However, when considering the average R&D spend by company, UK drops to ninth position behind countries including Switzerland, Germany, Israel, Japan, USA, France, and Ireland (data not shown). Most R&D by all pharmaceutical companies in the ranking is performed in the US and Germany, when measuring the location of patent inventors of patentable innovation. The UK is in third position for R&D activity overall (Figure 11) and has one of the top ten companies with the largest R&D budgets, AstraZeneca (GSK is just outside the top 10) (see table 3).

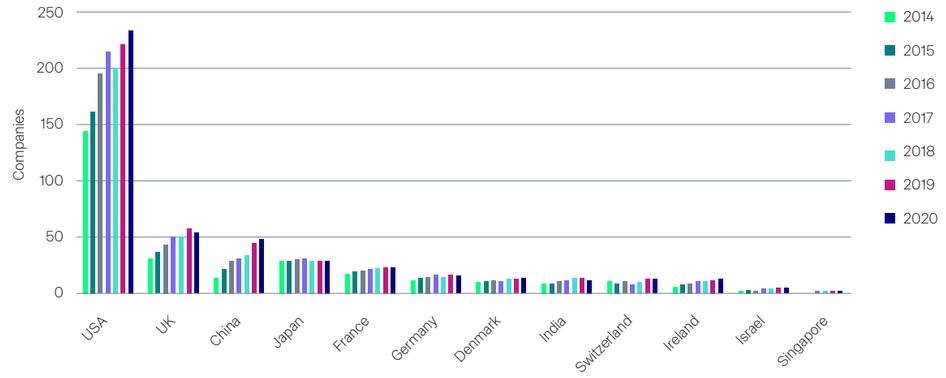


Figure 9: Number of companies by location of HQ amongst the companies with the highest enterprise R&D spending worldwide between 2014 and 2020. Source: Calculation by study authors by data from EU industrial R&D investment scoreboard 2014-2020

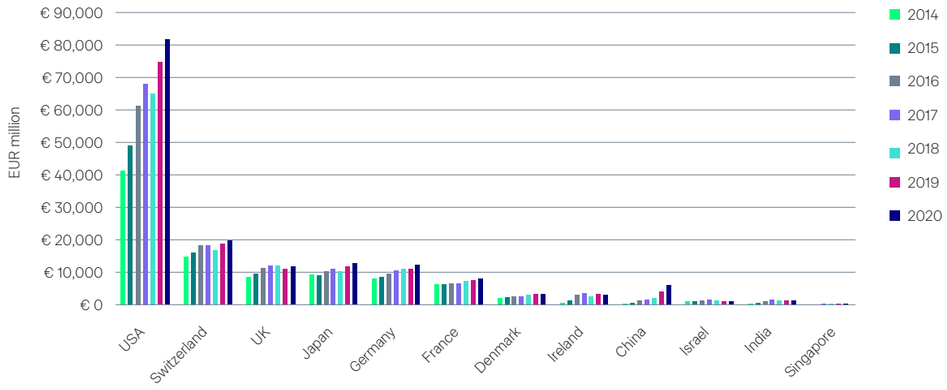


Figure 10: Total R&D expenditure by company HQ between 2014 and 2020. Source: Calculation by study authors by data from EU industrial R&D investment scoreboard 2014-2020

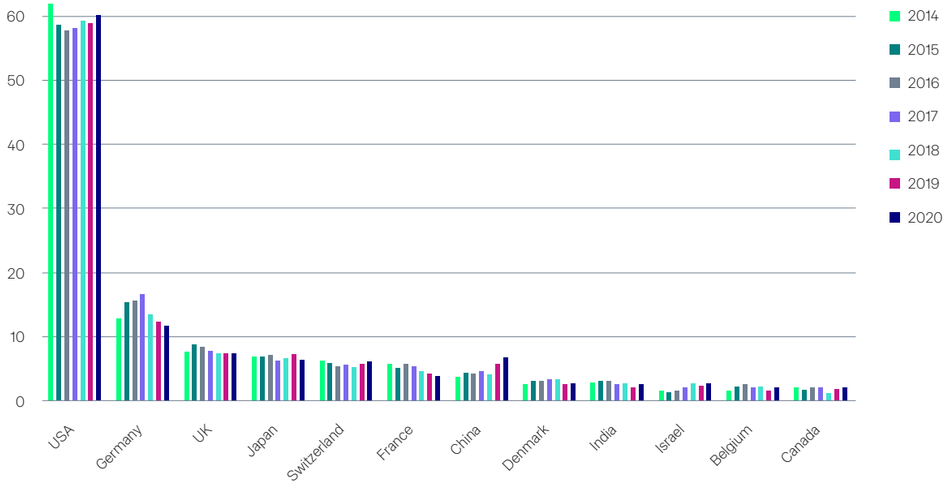


Figure 11: R&D location/ Patent inventor location for BioPharma firms with highest R&D investments worldwide. Source: Calculation by study authors by data from EU industrial R&D investment scoreboard 2014-2020 and patent data from ORBIS Intellectual Property (Bureau van Dijk)

R&D budget	USD billion
Johnson & Johnson (USA)	15.10
Merck* (USA)	13.60
Roche (Switzerland)	15.97
Novartis (France)	11.37
AstraZeneca (UK)	10.94
Pfizer (USA)	10.67
Eli Lilly (USA)	9.31
Bristol Myers Squibb (USA)	9.29
AbbVie (USA)	7.68
Sanofi (France)	7.32

Table 3. Companies with the largest pharma R&D budgets (2023). Source:

*Merck reported USD 30.5 billion in R&D costs for 2023 compared to USD 13.5 billion for 2022. However, USD 5.5 billion of the total stems from a collaborative project with Daiichi Sankyo and USD 11.4 billion relates to acquisitions (Prometheus and Imago Biosciences).

Private capital market financing

We used Pitchbook for national benchmarking of the pharmaceutical and biotechnology sectors, with data spanning the period 2000-2021. For these analyses, the proprietary Pitchbook industry categorisations were used to define sectors to ensure comparability over time. It is important to note that the biotech category includes both medical and non-medical biotech companies. Up to 44% of the medical biotech companies are listed as performing 'drug discovery', i.e. researching and developing of new drug products, including identification, screening, and efficacy testing of drug candidates. Other companies are involved in health-related activities such as genetic engineering and artificial tissue growth, or the development of platform technologies (see methodology for Pitchbook definitions).

Measured by deal count and investment size, both sectors have shown steady growth, with steeper growth associated with the biotech sector (figure 12a and b). The growth in venture capital and IPO investments since 2000 is similar between biotech and pharma (data not shown). Growth in VC investments have been driven by early and late-stage investments (figure 13). Most company exits involve merger and acquisition, followed by IPO. There are low levels of bankruptcy and buyout (figure 14).

When looking at Pitchbook pharmaceutical and biotechnology industry data across 20 countries (2000-2021), the UK pharmaceutical sector ranks seventh in total capital invested through private equity, VC, public offering, and M&A, behind the USA, China, Switzerland, Germany and France (figure 15a and b). The UK biotechnology sector ranks fifth, with an upward trend in 2021. The UK pharmaceutical industry ranks eight in IPO funding (data not shown). The USA and China dominate the ranking for VC funding, with consistent increases over recent years. The UK biotechnology and pharmaceutical sectors rank third, with a recent upward trend (figure 16 and 17).

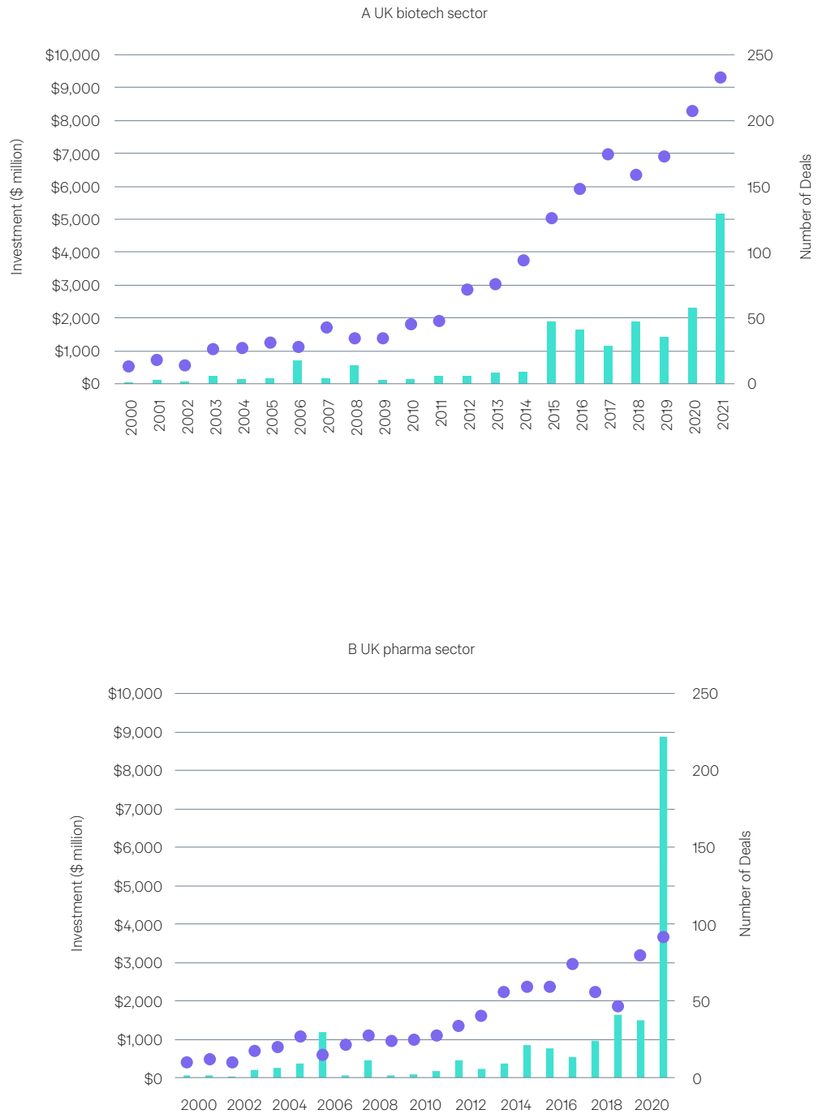


Figure 12a and 12b: Number of companies (bar chart) and median private capital market investment size (line chart, $ million) between 2000 and 2021. Source: Calculation by study authors by data from Pitchbook

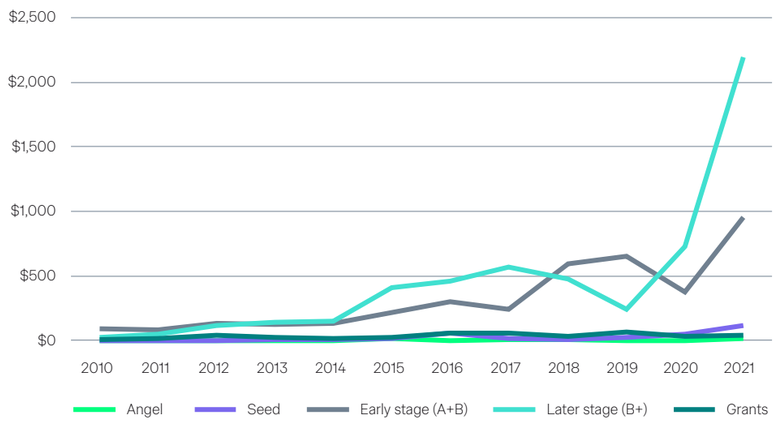


Figure 13: Sum of VC funding between 2000 and 2021 according to VC capital round/stage: comparison between UK biotech and UK pharma sectors ($ million). Source: Calculation by study authors by data from Pitchbook

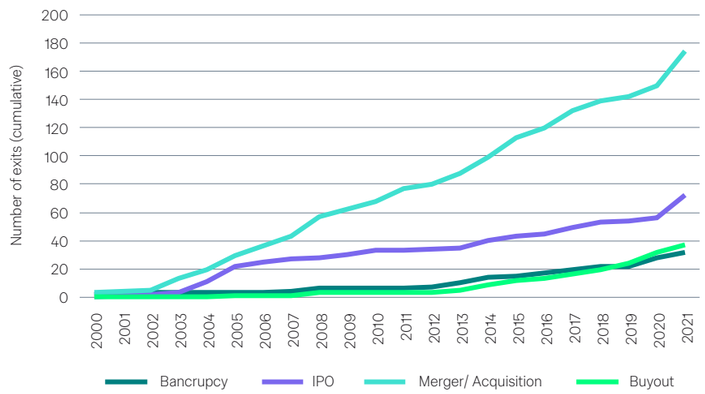
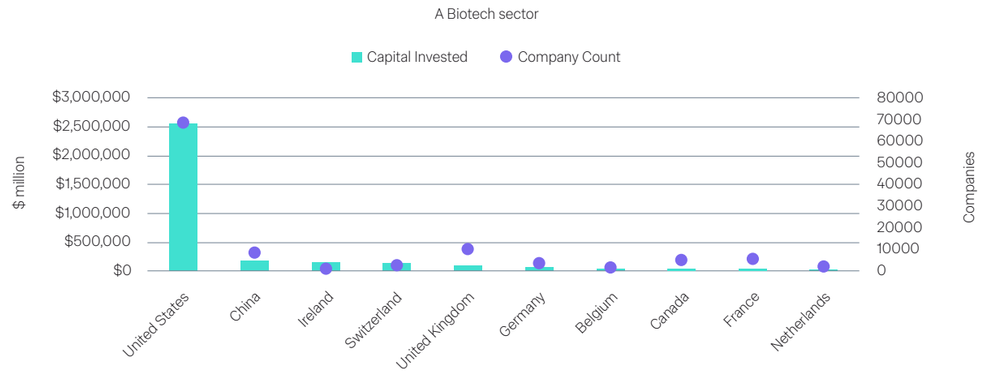


Figure 14: Cumulative number of company exit types between 2000 and 2021. Source: Calculation by study authors by data from Pitchbook



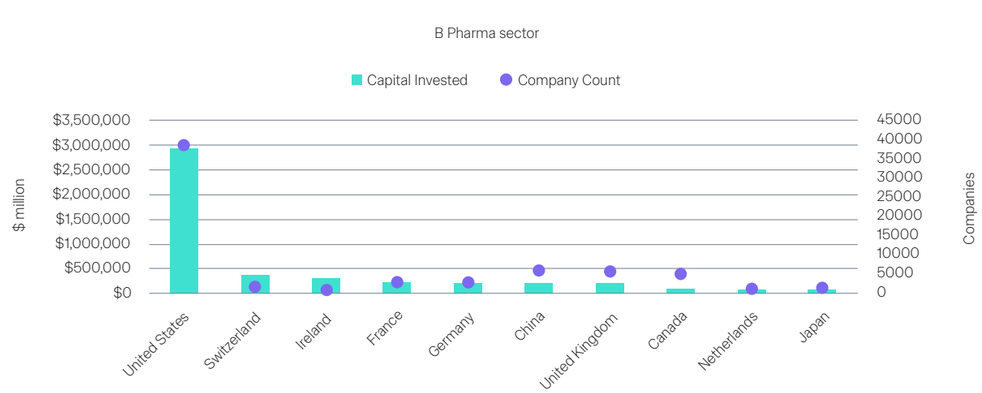


Figure 15a and b: Total private capital market investment (bar chart, $ million) and number of companies (line chart). Source: Calculation by study authors by data from Pitchbook

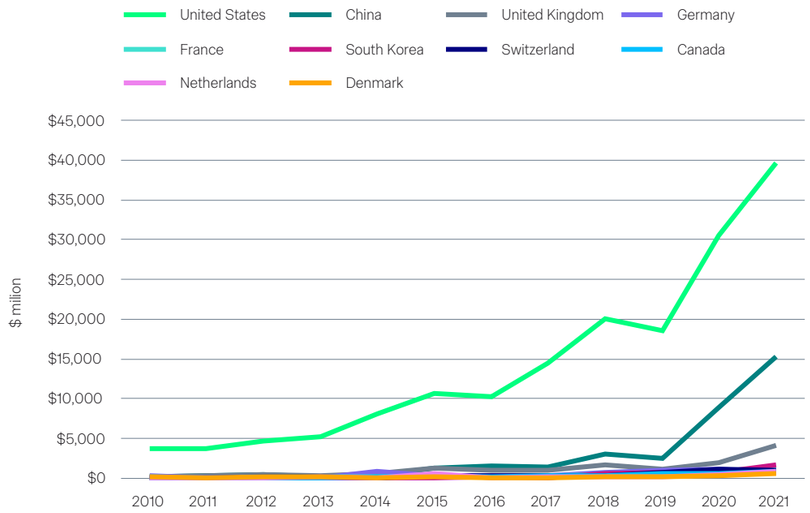


Figure 16: VC funding for biotech sector by country between 2010 and 2021 ($ million). Source: Calculation by study authors by data from Pitchbook

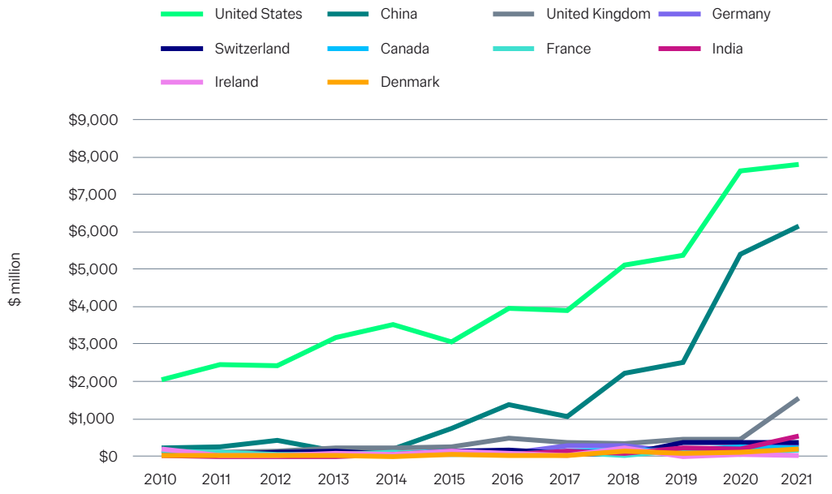
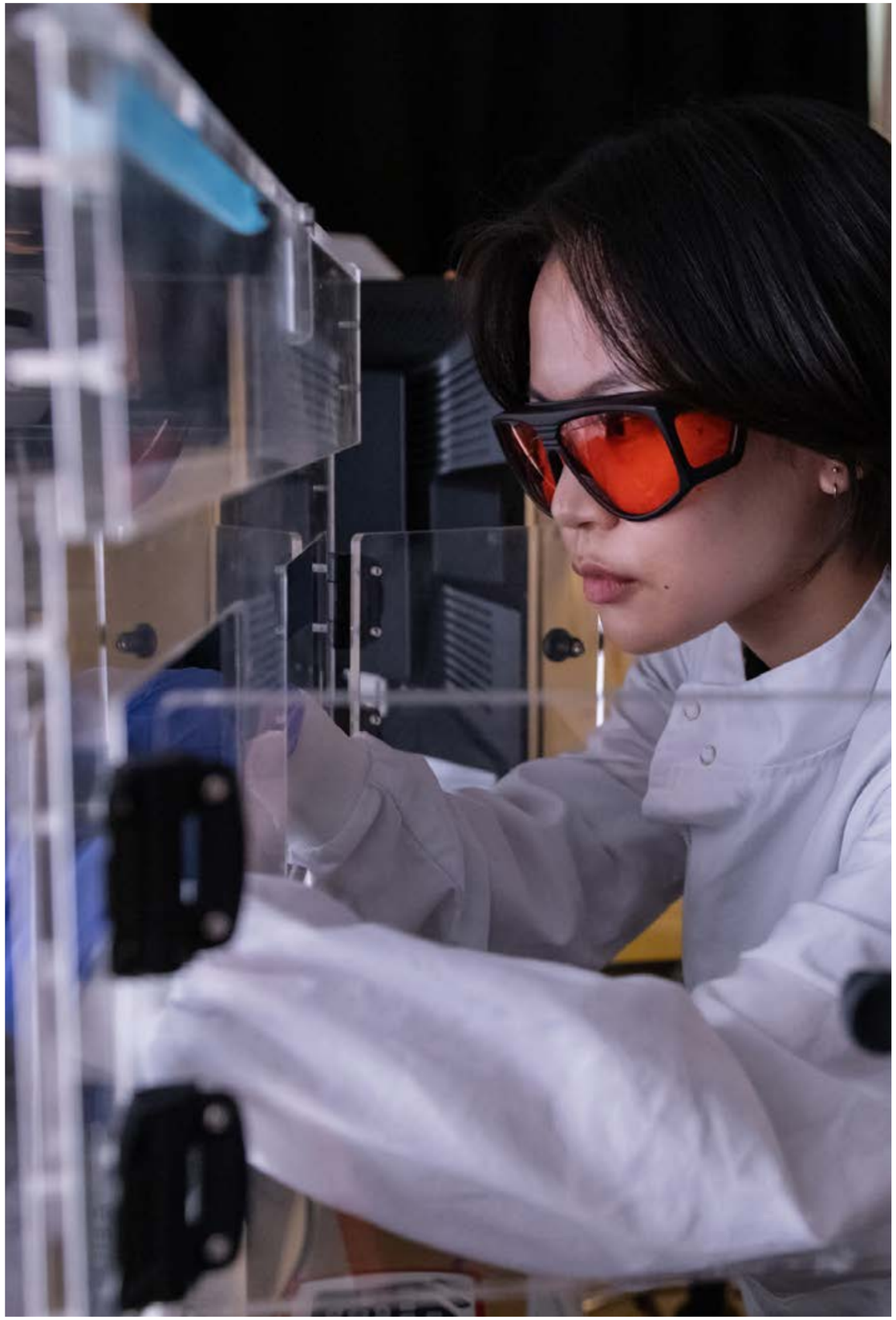


Figure 17: VC funding for pharma sector by country between 2010 and 2021 ($ million). Source: Calculation by study authors by data from Pitchbook



Part 3: Opportunities and capabilities

In part 3 we take a deeper look at the current structure of the UK biopharma industry and its R&D activities and capabilities. We then discuss its opportunities and threats. This is based on our own database of companies involved in the wider biopharma ecosystem (see appendix for details), including all national and international companies that are involved or supporting the development, manufacture or supply of medicines in the UK (both pharmaceuticals and biopharmaceuticals). However, this excludes the emerging data science sector supporting biopharma R&D.

Data came from the 'Biopharma core' dataset provided by the Office for Life Sciences (OLS) and the MHRA GMDP database. This captures a wider range of companies than the ONS industry classification for the "manufacture of pharmaceutical products" (SIC 21). Financial and economic variables were extracted at a firm level from Bureau van Dijk (a publisher of business information) and this was used to calculate direct GVA.

The estimated GVA was consistently higher than the ONS reported figures, which could be explained by the different pool of companies that were considered in this database including biopharma companies and manufacturing companies.

Industry structure

The UK's biopharma sector consists of around 977 firms, of which around 80% are SMEs and 60% are headquartered in the UK. The sector has many international ties, with headquarters in countries including USA (140 companies), India (34), Germany (34), Japan (30), Switzerland (25), France (22) and Ireland (21).

In 2021, the sector employed 393,627 people and had a turnover of £149.8 billion. There has been steady growth across all indicators, including employment, turnover, and R&D investment, with positive five-year compound annual growth rates between 2016 and 2021. However, GVA for the whole sector peaked in 2020 at £62.6 billion, then decreased to £50 billion in 2021. Similarly, GVA per employee peaked in 2020 at £157,000 and subsequently declined in 2021 (see table 4).

GSK and AstraZeneca, the two leading pharmaceutical companies headquartered in the UK, contribute over 40% to all sector economic and performance indicators (figure 18). This report compiled economic information on GlaxoSmithKline plc before the demerger and split into GSK plc (pharmaceutical business) and Haleon plc (consumer health business) announced at the beginning of 2022.

Although biopharma companies are located across all UK regions, clusters stand out in Northwest and Southeast England. There is a clustering of company and manufacturing locations around financial and scientific centres: (1) the London, Cambridge, Oxford and Southeast England more widely, and (2) Liverpool and Manchester. Other clusters include Newcastle and Northeast England, and the Edinburgh – Glasgow belt (figure 19). The highest GVA contribution of pharmaceutical industry can be found in clusters around London (11.9%), East of England (12.3%), South-West England (9.6%), and North-West England (38%).[69]

	Employment	Turnover (£m)	GVA (£m)	GVA/employee (£m)	R&D investment (£m)
2016	359,317	£109,586	£41,159	£0.115	£11,201
2017	370,946	£117,470	£42,821	£0.115	£11,099
2018	379,633	£124,789	£47,906	£0.126	£11,444
2019	390,191	£127,574	£50,923	£0.131	£12,223
2020	399,896	£136,316	£62,596	£0.157	£12,168
2021	393,627	£149,808	£49,979	£0.127	£14,833
CAGR rate	+ 1.84%	+ 6.45%	+ 3.96%	+ 2.08%	+ 5.78%

Table 4: BioPharma ecosystem and economic indicators from 2016 to 2021.

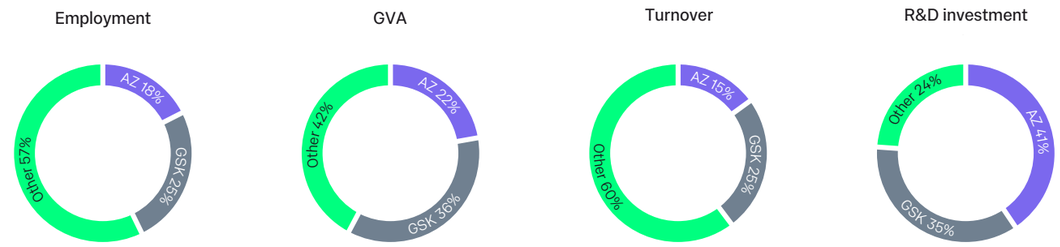


Figure 18: Contribution of GlaxoSmithKline (GSK) and AstraZeneca (AZ) to 5-year employment, GVA, turnover, and R&D investment (2016-2021)

Figure 19: Heat maps of the geographical distribution of UK biopharma sector companies. Panel A: locations of company headquarters. Panel B: locations of manufacturing sites. Panel C: locations of supply sites. Source: Project database with data from MHRA and Bureau van Dijk

The Oxford, Cambridge and London 'golden triangle' includes globally leading R&D clusters such as the Oxford Biotech Network, with over 250 businesses, and the area around Cambridge, where both AstraZeneca and GSK have significant R&D facilities. Located between these two clusters are the UK's first open innovation biopharma campus, Stevenage Bioscience Catalyst, and a major Roche R&D hub in Welwyn Garden City. A 2020 report for Enterprise Ireland estimated that 38% of the output and 43% of the UK pharmaceutical turnover is generated here. The Northwest England region contains biopharma R&D facilities such as Alderley Park, near Macclesfield, the UK's largest single site life science campus.[69]

The biopharma industry can be divided into five subsectors according to whether they are involved in researching and developing pharmaceutical products, manufacturing them, importing and supplying them, or any combination of these (see box 8). Its key features are:

- The largest sector by number of companies is the biopharma sector, i.e. businesses involved in developing and/or producing pharmaceutical products. This predominantly comprises micro- (337, 57%) and small-sized companies (122, 21%). In contrast, the biopharma and manufacturing sector, and biopharma and supply sector, comprise a relatively small number of companies, of which approximately half are large companies (table 5).
- Overall, companies in the biopharma sector are relatively young, with approximately 70% incorporated in the last 20 years (data not shown). This might explain why it is comprised largely of micro- and small-sized companies. Understanding the factors that may lead to at least some of these companies growing to become significant global players is therefore important.
- The biopharma and manufacturing sector is responsible for the highest level of employment (approximately 60%).
- The two subsectors that concern drug manufacturing are responsible for the highest economic contribution in terms of GVA (Figure 18). The biopharma and manufacturing sector has the highest GVA, with £37.4 billion and a 3.36% compound annual growth rate (CAGR) since 2016. This is followed by the manufacturing and biopharma sectors with GVAs of £6.7 billion and £3 billion respectively. The supply sector shows the highest growth since 2016 with a CAGR of approximately 15%.
- The biopharma and supply sector has the highest GVA/employee, closely followed by the biopharma and manufacturing sector. Both sectors have seen growth since 2016 of approximately 8% and 1.3% CAGR since 2016. The other sectors are characterised with relatively low productivity.

BOX 8. CATEGORISING THE UK BIOPHARMA INDUSTRY

1. Biopharma: 591 businesses involved in developing and/or producing pharmaceutical products. Prominent examples include drug developers Hikma (UK), Galen (UK), Amryt (UK), Vertex (USA), Astellas (Japan), Eli Lilly (USA), and drug development service firm Abcam (UK).
2. Manufacturing: 141 businesses with import and manufacturing license for medicines in the UK with registered activity in medicines manufacturing. Examples include Croda (drug delivery platforms and solutions, UK), Almac (USA), Pantheon (UK, part of Thermo Fisher, USA), Sigma Aldrich (part of Merck KG Germany), TriRx (USA), Catalent (USA), Recipharm (Sweden), Piramal Pharma Solutions (India), and Fareva (France).
3. Supply: 105 businesses with import and manufacturing license for medicines in the UK with registered activity of import, quality control and packaging. Examples include Lexon (UK), Bap Pharma (UK), Ivor Shaw (UK), Beachcourse Limited (part of AmerisourceBergen USA), Alcura UK (AmerisourceBergen USA)
4. Biopharma and manufacturing: 82 businesses involved in developing and/or producing their own pharmaceutical products and with registered activity of medicines manufacturing. Prominent examples include the major drug development and manufacturing companies such as GSK, AstraZeneca, Novartis (Switzerland), Baxter (USA), Pfizer (USA), Eisai (Japan), Teva (Israel). Other companies which manufacture drugs in the UK includeReckitt Benckiser (UK), Napp Pharmaceuticals (UK), Seqirus (Australia), Accord (India).
5. Biopharma and supply: 58 businesses involved in developing and/or producing their own pharmaceutical products and with registered activity of import, quality control and packaging. Examples include Clinigen (drug development support, UK), Mawdsley-Brooks (wholesaler, UK), Atnahs Pharma/ Pharmanovia (drug developer, UK), Mundipharma (drug developer, UK), Roche (drug developer, Switzerland), 3M (drug development support, USA), Janssen-Cilag (drug developer, Johnson & Johnson USA), Bristol-Myers Sqibb (drug developer, USA), Chiesi (drug developer, Italy), Gilead (drug developer, USA), Abbvie (drug development, USA), Sandoz (drug development, Novartis Switzerland).

Characteristics	Total	Biopharma	Manufacturing	Supply	Biopharma & Manufacturing	Biopharma & Supply
Company number	977	591	141	105	82	58
Number of SMEs (%)	800 (82%)	540 (91%)	105 (75%)	89 (85%)	36 (44%)	30 (52%)
UK HQ (%)	562 (58%)	376 (64%)	72 (51%)	65 (62%)	30 (37%)	19 (33%)
Employment 2021 (5-year CAGR rate)	393,627 (1.84%)	34,808 (3.04%)	90,201 (1.83%)	11,486 (7.74%)	247,091 (1.59%)	10,041 (-1.29%)
Turnover 2021 (£m) (5-year CAGR rate)	£149,808 (6.45%)	£23,574 (7.57%)	£13,724 (5.19%)	£4,245 (13.92%)	£101,025 (6.38%)	£7,239 (3.17%)
GVA 2021 (£m) (5-year CAGR rate)	£49,979 (3.96%)	£2,973 (4.79%)	£6,722 (5.08%)	£1,020 (14.96%)	£37,430 (3.36%)	£1,833 (6.68%)
GVA/employee 2021 (£m) (5-year CAGR rate)	£0.127 (2.08%)	£0.085 (1.7%)	£0.075 (3.19%)	£0.089 (6.7%)	£0.151 (1.74%)	£0.183 (8.08%)
R&D investment 2021 (£m) (5-year CAGR rate)	£14,833 (5.78%)	£1,169 (0.31%)	£288 (2.18%)	£10 (13.5%)	£12,855 (6.57%)	£511 (6.57%)

Table 5: Overview of characteristics of five biopharma sectors. Source: Project database with data from Bureau van Dijk

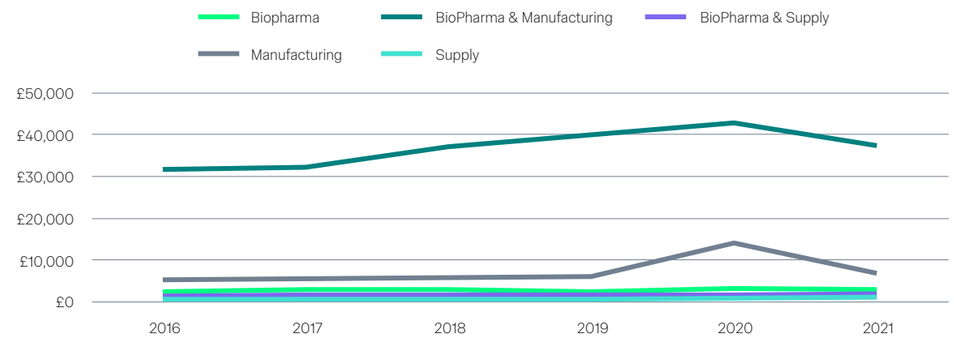


Figure 20: Time series of the estimated GVA for the different sub-sectors
Source: Project database with data from Bureau van Dijk

Research and development

R&D activity

Most companies are research active and only 23% have no published measurable R&D output yet. However, only a relatively small proportion of UK biopharma sector companies have managed to go through the full development cycle leading to medicinal product approval (12%). The largest proportion of all companies was found to be patenting stage (34%), while 25% of all companies had entered clinical trials (figure 21).

Unsurprisingly, there seems to an association between company size and stage of R&D output on the development pathway. While micro-sized companies are lagging and mainly operate at early R&D stage, e.g. patent stage, large-sized companies are associated with late-stage clinical activity and drug approval to a higher degree (figure 22).

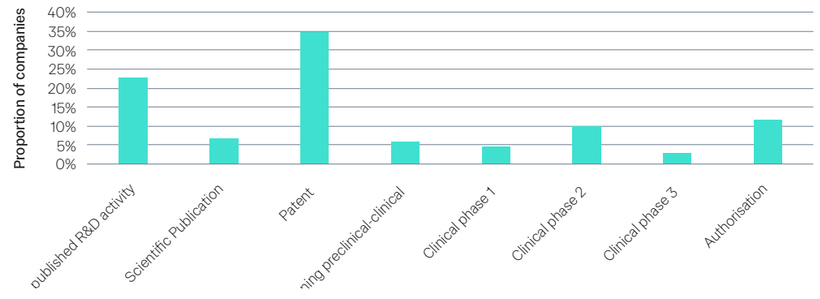


Figure 21: Percentage of all companies in different phases of R&D pipeline. Data sources: Project database with data from Clarivate Web of Science, Elsevier Scopus, Clinicaltrials.gov, EudraCT, ISRCTN registry

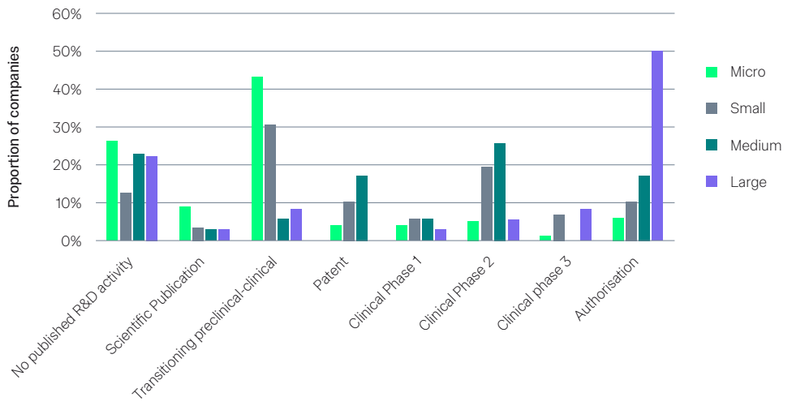


Figure 22: Percentage of companies in different phases of R&D pipeline - comparing company subsets based on company size. Data sources: Project database with data from Clarivate Web of Science, Elsevier Scopus, Clinicaltrials.gov, EudraCT, ISRCTN registry

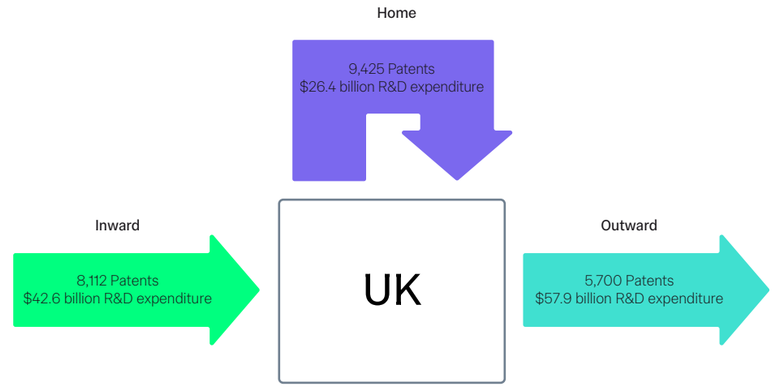


Figure 23: Patenting activity of UK biopharma companies between 2016 and 2021 according to R&D location, i.e. the location of the patent inventor. The patenting activity of UK Biopharma project database was analysed on headquarter level, which included companies with UK and overseas headquarters. Patents (live, priority date 2016-2021, family size ≥2) associated with the companies were pooled and analysed for patent inventor location. R&D expenditure for the estimation of R&D investment flow was available for 227 of 652 companies in the database (35%). Source: Project database with data from Bureau van Dijk

R&D location

In line with previous studies and the methodology in the EU Industrial R&D Investment Scoreboard, we used patenting data to understand the location of biopharma R&D activity.[82] In other economic sectors, the use of patent data to measure innovation is debated but the patenting system in the pharmaceutical sector plays a vital role in protecting intellectual property to recoup R&D investment costs and the location of patent filing provides at least a proxy for R&D activity.[83, 84]

Patenting activity was analysed for the following categories (Figure 23):

- **Home activity:** Home activity: UK headquartered companies filed 9,425 patents with patent inventors in the UK. This is estimated to equate to an R&D expenditure of USD 26.4 billion. Around USD 20 billion of this expenditure can be attributed to AstraZeneca and GSK (data not shown).
- **Outward activity:** UK headquartered companies filed 5,700 patents with patent inventors outside the UK. This is estimated to equate to an R&D expenditure of USD 57.9 billion. Most of this activity and expenditure is directed to the USA, followed by the EU, notably Sweden, Belgium, and Italy (figure 24). AstraZeneca and GSK perform more than half their R&D activity in the USA measured this way, equivalent to approximately USD 30 billion (data not shown).
- **Inward activity:** Biopharma companies with headquarters overseas filed 8,112 patents with patent inventors in the UK. This equates to an R&D expenditure of USD 42.6 billion. Large global pharma companies are amongst the companies with the highest R&D activity in the UK. These include Roche, Bayer, Johnson & Johnson, Sanofi, Merck, Pfizer, and Novartis. While in absolute terms these companies contribute high levels of R&D in the UK, relative to their total R&D activity, they only spend a small proportion of their total R&D activity in the UK (approximately 10%).

A previous study that found that between 2001 and 2005, 46.8% of pharmaceuticals patenting activity by UK firms was associated with inventors in the UK, lower than other European nations, including France (64.2%) and Germany (65.5%).[85] According to the findings outlined above, UK headquartered firms conduct 62% of their patentable R&D activity in the UK.

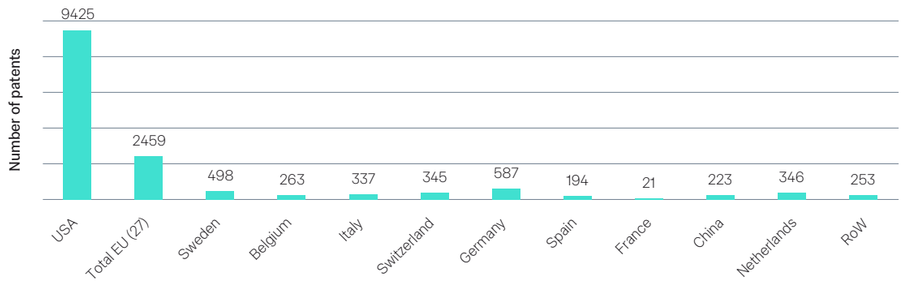


Figure 24: Outward activity in number of patents. Source: Project database with data from Bureau van Dijk

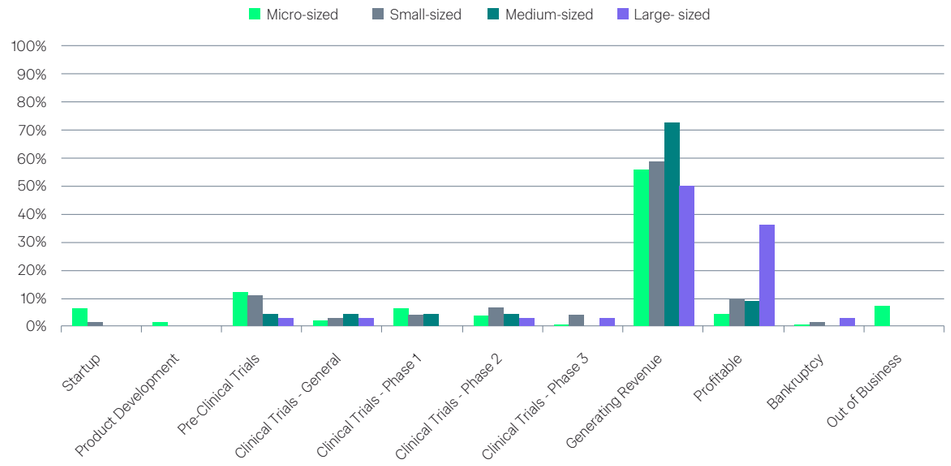


Figure 25: Proportion of private capital market funding deals according to company size and business stage/product development stage. Source: Project database with data from Pitchbook

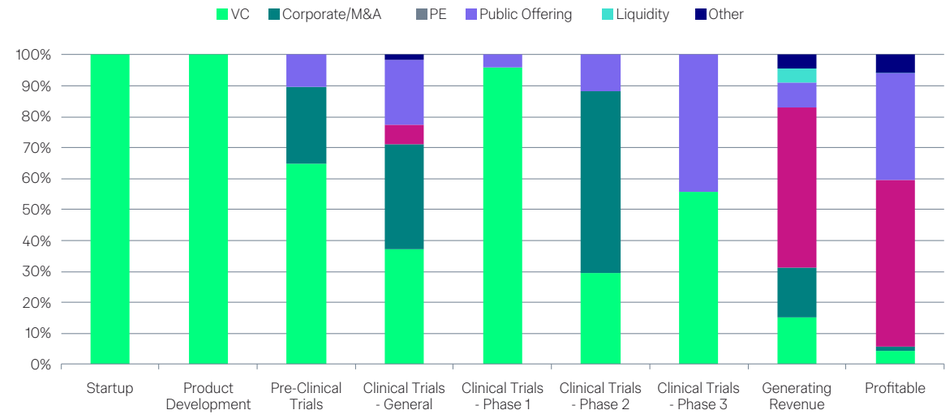


Figure 26: Proportion of private capital market funding according to type of funding and business stage/ product development stage. Source: Project database with data from Pitchbook

Investment

We used Pitchbook data to examine private capital market investments and funding sources for biopharma companies (including manufacturing and supply) in our project database (Pitchbook coverage was 63%). We did not investigate public funding for biopharma R&D projects in this study.

A total of 1,498 investment deals of any kind were identified, amounting to USD 47.6 billion investment and a median deal size of USD 3.56 billion. Companies raised the highest investment through private equity deals (USD 27.9 billion), public offerings (USD 10.9 billion), venture capital (USD 9.9 billion), and corporate investment (USD 8.5 billion).

The highest proportion of deals were secured when companies start generating revenue, but there were fewer investment deals at the start-up, product development, pre-clinical testing, and early clinical testing phases (figure 25). For small- and micro-sized companies, funding of early pre-clinical and clinical testing is more important, shown by slightly higher funding in early phases (data not shown). Proportionally, early pre-clinical, and clinical testing is mainly reliant on VC funding.

Later phases of clinical development see funding via corporate investments (e.g. M&A) and public offerings like initial public offerings (IPO). Private equity deals mainly occur during late-stage clinical development and when revenue is generated (figure 26).

Manufacturing

Producing drugs involves two key phases – manufacturing the drug substance and manufacturing the final product. The former involves making the 'active pharmaceutical ingredient' (API) in bulk, while the latter involves processing the API into the final product for consumption by patients. Some drug developers (i.e. conducting the R&D to create an API and shepherding it through the trials process) outsource final product manufacturing and others keep manufacturing in-house. From a business perspective there are advantages and disadvantages to each approach in terms of profit margins, tax benefits and operational efficiency. Drug product manufacturers typically process the API at a 'form, fill, finish' site, where ingredients are added to the bulk API chemicals and turned into pills or other forms, and then packaged.

Identifying the size of the drug manufacturing sector in the UK is not straightforward because it is hard to disaggregate company data to distinguish between companies which are involved in different phases of the overall production process for drugs. Some companies are focused predominantly on R&D to create new or repurpose existing drugs and manufacture of the APIs. Some are manufacturers of the final product and some supply other inputs into the manufacturing process, such as other chemicals and gases or equipment. The UK pharmaceutical manufacturing sector therefore comprises an ecosystem of companies that transform APIs and inputs from other sectors into the final product for consumption.

We attempted to categorise the sector by using manufacturing approval data (2022/23) from the MHRA, the regulator responsible for authorising drug manufacturing sites in the UK (see box 8). We identified around 141 companies with registered manufacturing activity in the UK and a further 82 companies which both develop new drugs and have a manufacturing presence. Several leading pharmaceutical companies manufacturer the APIs for manufacturing their drugs in the UK, including AstraZeneca, GSK, Viatris, and Teva. Others – Piramal and BASF – solely manufacture APIs.

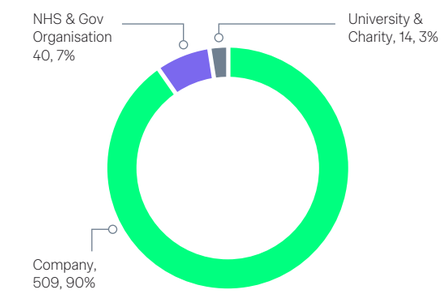


Figure 27: Number of manufacturing sites according to ownership (top panel), and the manufacturing capability per product group and ownership (bottom panel). Source: Project database with data from MHRA database

The UK pharmaceutical sector relies heavily on contract development and manufacturing organisations (CDMOs) and contract manufacturing organisations (CMOs) to provide a range of services across different stages of drug production, including drug formulation and manufacturing.[86] Leading companies with manufacturing facilities in the UK include Lonza, Patheon (Thermo Fisher), Catalent, TriRx, Almac Group, and Recipharm. One estimate put the UK's CDMO market at USD 6.0 billion (2023), with expected growth to USD 7.1 billion by 2028. The API market is expected to grow at a CAGR of 6.3% between 2024 and 2029.[87,88]

There is a growing demand for manufacturing biologics as the pharmaceuticals sector moves from small to large molecule drugs. There have been several important investments in new biomanufacturing facilities, including RoslinCT, a cell and gene therapy CDMO that manufactures the therapy exa-cel for Vertex Pharmaceuticals, and Touchlight, manufacturing DNA for mRNA therapies, gene therapies and other new biologics modalities.[89] Other important biologics CDMOs that have recently expanded manufacturing operations in the UK include FUJIFILM Diosynth, Pharmaron, and Autolus Therapeutics. We have not investigated the sub-sectors supporting biologics manufacturing and the UK's capabilities in this area. Stability and quality in the production process are particularly important in biotechnology-based production as the inherent unpredictability of a 'live' manufacturing process and the implications for the stability of the end product mean that manufacturers need real-time, in-line analytical tools to save time and effort with sampling.

We mapped the location and structure of the manufacturing sector using manufacturing approval data (2022/23) from the MHRA.

The analysis identified 563 licensed manufacturing sites. Private pharmaceutical companies have a total of 509 unique manufacturing sites across the UK. Other licensed manufacturers include 40 NHS hospital and government organisations and 14 university facilities or charity organisations. These are largely in manufacturing using biological ingredients and gene and cell therapies (figure 27).

Commercial medicines manufacturing by is spread across 509 sites, both manufacturing sites (298) and supply-only sites engaged in import and distribution, packaging, and quality testing (211). These are mainly located in Northwest England, London, Northeast England, the Midlands and Scotland. These manufacturing sites mainly produce medicines with chemical ingredients (147) and active ingredients (63). Less than 10% of sites produce biological products and more advanced therapies (figure 28). The majority of supply-only sites are concerned with import and distribution (161) and packaging (67) (figure 29).

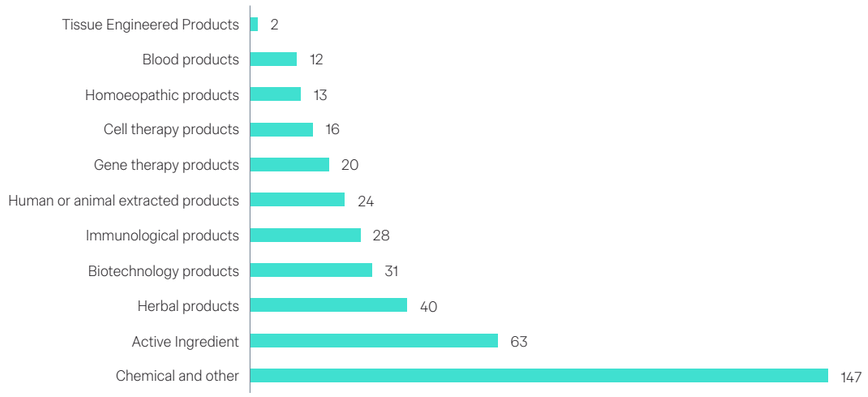


Figure 28: Manufacturing capabilities of pharmaceutical industry in UK. Total number of manufacturing sites = 298. Individual sites can have two or more capabilities. Source: Project database with data from MHRA database

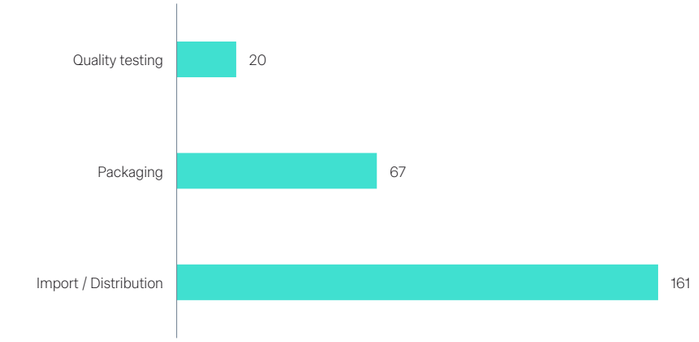


Figure 29: Supply capabilities of pharmaceutical industry in UK. Total number of supply sites = 211. Individual sites can have two or more capabilities. Source: Project database with data from MHRA database

Key trends and forces impacting on the manufacturing sector

We highlight two forces impacting on the pharmaceutical manufacturing sector – vulnerability in the supply of essential ingredients and tightening environmental regulations.

First, global pharmaceutical companies have increasingly relied on China and India for the production of APIs due to cost advantages such as lower labour and operational costs, relaxed patent laws, and access to raw materials.[90,91] Although high-quality data regarding API manufacturers is lacking, a report by Access to Medicine estimated that in 2018, around 40% of the global API supply chain came from China.[91] This heavy dependence has raised concerns about the vulnerability of the global supply chain, particularly acute during the COVID-19 pandemic.[92] The generics market, which accounts for 90% of global drug consumption, is especially at risk.[93,94] There are therefore calls to diversify supply chains, improve quality control, and establish local manufacturing capacity for critical drugs to mitigate these risks and enhance supply chain resilience.[91,95] Recent reports suggest that the UK pharmaceutical industry is increasingly reshoring its activities to strengthen supply chain resilience.[96]

Second, the pharmaceutical sector is facing pressures to address sustainability and environmental challenges, both in terms of carbon and other emissions, and the waste generated during drug manufacture and use. Improper disposal of APIs and other chemicals during drug manufacturing can be seriously detrimental to human health and the environment. While the highest levels of pollution are found in low- to middle-income countries in Sub-Saharan Africa and Southeast Asia, a 2022 global review found API pollution was widespread across all continents.[97] Managing pharmaceutical industry waste is challenging because the diversity of products makes it hard to establish uniform disposal protocols and there is a lack of transparency over waste management monitoring in many countries. For companies with global manufacturing operations, improving supply chain visibility is essential both for improving resilience as well as ensuring the environmental safety of its business.[98,99]

The pharmaceutical industry is increasingly turning to sustainable practices by investing in green chemistry principles to change manufacturing practices, minimise waste, and transition to renewable energy to reduce the total environmental impact of its processes. Around 80% of the industry's largest companies have set net-zero or carbon-neutral targets. The ABPI has argued that the UK has an opportunity to lead in environmentally sustainable pharmaceutical practices by creating global standards for greenhouse gas emissions, developing innovation roadmaps for sustainable manufacturing, and investing in infrastructure to achieve net-zero production. Doing so could help to attract environmentally conscious businesses and open new market opportunities.

Around 20% of the £400 million investment announced by the new Government in August 2024 will be directed at sustainable pharmaceutical manufacturing innovation, to support efficiency and reduce waste and emissions.[100]

Manufacturing innovation

Innovation trends in drug manufacturing include continuous manufacturing, modular manufacturing and modular factory design, and the integration of AI, robotics, digital twins, and the internet of things into production processes.[101,102,103] The Medicines Manufacturing Innovation Programme (MMIP) is a collaboration between academia, industry, and government that aims to position the UK as a leader in advanced pharmaceutical processes. The Medicines Manufacturing Innovation Centre (MMIC) in Scotland plays a key role in developing and maturing innovations, focusing especially on sustainable manufacturing processes for oral solid dosage medicines to creating new methods for manufacturing oligonucleotides. The overall aim is to strengthen UK's position as global pioneer in innovative advanced medicines manufacturers.[104]

A small amount of public funding is available to drive innovation in sustainable manufacturing, green chemistry, circularity, and productivity and resource efficiency through Innovate UK's Sustainable Medicines Manufacturing Innovation programme (part of the wider VPAG Investment Programme – see above). The OLS has also allocated some funding to support companies with skills development and training requirements (the Medicines Manufacturing Skills Investment Programme). The total funding for both these initiatives is only around £21 million and the industry has called for more robust interventions to expand the Advanced Therapy Apprenticeship Programme and the Skills and Training Network to enhance biomanufacturing skills, along with five-year digital innovation in medicines manufacturing technology roadmap, including a world-class UK Medicines Manufacturing

Opportunities and threats

The science and R&D environment for the UK's biopharma sector has strengths and opportunities to sustain and improve on its performance in the future. The university sector is highly ranked globally, most UK biopharma companies are R&D active, and there is still relatively high inward investment to conduct R&D in the UK. There are important opportunities to foster the newer companies providing data science, AI, diagnostics, digital health, and other innovative technologies supporting drug development.

There are also weaknesses and threats. The R&D output of companies tends to be at early stage and smaller companies continue to face problems securing investment to move it forwards through the development pipeline. There are other countries with stronger growth in R&D investment and better translation into commercialised products. The decline in the clinical trial infrastructure since 2017 has also inhibited companies from conducting drug development activity in the UK, although this may now be turning a corner.

The business environment for biopharma also presents strengths and opportunities – the presence of two global pharmaceutical companies, funding for translational research, the potential for economic impact by small and young companies with high R&D activity. But there are also risks associated with dominance of micro- and small-sized companies in the biopharma sector, where there is a tendency to sell to non-UK companies as soon as revenue generation begins.

For biopharma manufacturing and trade, the weaknesses and threats arguably outweigh the strengths. There was a small trade surplus of £700 million in pharmaceutical products in 2023.The shift in certain areas of manufacturing away from the UK has been a clear trend over many years and despite signs of moves towards re-shoring some manufacturing, this is unlikely to be the case for lower value products. To counter this decline, the UK needs to gain and maintain competitive advantage in manufacturing high value products. **Opportunities exist here, as well as in developing the future technologies for advanced manufacturing processes.**

There are concerns about the UK's regulatory and policy environment. There is a strong desire to grow the UK's biopharma and life sciences capabilities. Although certain policy initiatives have been put in place to help support this, such as measures to improve the attractiveness of the UK for conducting drug trials and the Horizon Europe agreement on 1 January 2024, there remain concerns over divergence from European regulatory frameworks, leading to potentially increased costs for biopharma companies and potentially slowing access to new medicines for the UK's population.leading to potentially increased costs for biopharma companies and potentially slowing access to new medicines for the UK's population.

[1] Implemented through the Medicines Manufacturing Skills Centre of Excellence RESILIENCE project, the Industry Skills Accelerator, the ATAC (Advanced Therapy Apprenticeship Programme) and ATSTN (Advanced Therapies Skills Training Network).

	Business Environment	Science and R&D	Manufacturing and Trade	Regulatory and Policy
Strengths	▪ Two global top biopharma companies AstraZeneca and GSK are headquartered in the UK ▪ Sector's total employment and turnover remain relatively stable over the last 10 years ▪ Clusters of scientific and economic excellence allow for networking ▪ VC funding is available to fund translational research, especially for biotech companies	▪ Highly ranked university sector ▪ Most UK biopharma companies are R&D active ▪ High inward investment to conduct R&D in the UK	▪ Historically strong sector in medicines manufacturing ▪ Manufacturing capabilities are situated around the same geographic clusters ▪ Support for R&D and adoption of manufacturing innovation	▪ UK government has set out a policy agenda for life sciences and biopharma manufacturing ▪ Strong industry bodies ▪ High reputation for regulatory bodies MHRA and NICE ▪ National health system for single procurement (with local fragmentation)
Weaknesses	▪ Biopharma sector is characterised by micro-sized and small-sized companies ▪ Without AZ and GSK, the economic value added is relatively low	▪ R&D output by UK biopharma companies is at early stage and it is unclear if the current R&D investment will ever create new therapies or economic benefit ▪ Clinical trial infrastructure has declined since 2017, although this may now be improving ▪ Supply of appropriate life-sciences R&D and manufacturing built infrastructure	▪ Long-terms shift of manufacturing from UK to India, China, Ireland etc. ▪ Reported and perceived skill shortage in some fields, e.g. data science	▪ Regulatory divergence after Brexit ▪ No participation in European unitary patent system ▪ Potential changes to data protection framework that protects authorised medicines beyond patent expiry
Opportunities	▪ Potential for high economic impact by small and young companies with high R&D activity in the future	▪ Fostering active R&D and supporting the growth of companies involved in new drug development technologies, e.g. data science, AI, diagnostics, digital health	▪ Gain and maintain competitive advantage in manufacturing of high value products, e.g. advanced therapeutics ▪ Championing innovation in manufacturing process, e.g. Continuous Manufacturing	▪ Foster new international cooperation after Brexit ▪ Create a fully integrated approach for developing, regulating, and fostering pharmaceutical innovation (NIHR, NHS, MHRA, NICE, DHSC) ▪ Championing innovative regulation and integration of new technical advances regarding data science, AI, diagnostics, digital health, real world evidence
Threats	▪ High economic risk associated with micro- and small sized companies in the biopharma sector	▪ Competitor countries with stronger growth in R&D investment and better translation	▪ Highly competitive countries for lower value medicine manufacturing, e.g. China, India	▪ Without a formal reliance on other regulatory systems, UK might fall behind in terms of authorisation, which could affect patient access ▪ UK IP system might lose international relevance

Table 6: Strengths, weaknesses, opportunities and threats for UK biopharma

Part 4: Conclusions and recommendations

Overall, the biopharma goal for government, industry and the NHS should be an integrated national life sciences R&D ecosystem which supports drug discovery, early clinical development, and uptake into healthcare, reduces transaction times and costs, and ultimately produces more attractive investment opportunities.

Investing in and adopting innovative drugs and other healthcare technologies creates a virtuous circle, as pointed out by ABPI in its 2022 review of the state of the UK life sciences sector.[8] Such a virtuous cycle should also consider a return on investment for public investment not only in terms of economic benefits and job opportunities, but also in terms of sustainability of the national healthcare system and improvement of population health.

The UK still offers many advantages for life science businesses: opportunities for collaboration with the NHS in R&D, globally leading science from academic institutions, access to talent in science and technology, well-developed sources of early-stage research support, a growing investor base, a respected regulator in the MHRA, and several geographical biopharma clusters attracting international talent and innovation.[105]

But to enhance this ecosystem, it needs to be as efficient and effective as possible, integrating both the public – NHS and academia – and private sectors, and able to coordinate its activities from early-stage science to adoption into healthcare practice. Not only does this require the right policy environment to be created, there also needs to be continuity in policy making and in public funding and support to instil greater confidence in research organisations, companies and private investors.[2]

Several reviews over the last few years have highlighted that support should also be targeted on high value products and services in areas where the UK has particular strengths:[2,26]

- The discovery of novel chemical compounds through biological screening and structural biology.
- Enabling technologies for drug discovery, such as large-scale human omics, cellular assay methods and precise genome editing.

BOX 9. CREATING A VIRTUOUS CIRCLE.
A thriving commercial environment that values technological innovation in the life sciences reinforce a country's position as a priority market for global pharmaceutical companies. This in turn attracts investment from venture capital, private equity, government funding, philanthropy, and other sources. Increased funding sustains research to support the next wave of innovation. Clinical trials to evaluate the impact of life science innovation contribute to the economy and raise the likelihood that patients will receive early access to beneficial new treatments. Progression from clinical trials to approval and launch stimulates manufacturing, generating economic benefits and job opportunities.

Source: PWC and ABPI (2022) Life Sciences Superpower.

- Data-driven life sciences, with a thriving ecosystem of start-ups and small companies. However, there is some concern that the ecosystem could be better integrated, with government agencies and NHS bodies presenting a more unified approach to access projects, contracts and data.[105]
- The UK has a rich data legacy of disease cohorts, which are valuable sources of well-validated drug targets that can be further profiled using advanced biomarker technologies.
- Some experts see potential in commercial repurposing, where existing compounds are developed for new therapeutic purposes.[106]

The opportunities vary across different stages of the biopharma development process.[8] In the early research phase, the UK has emerging companies but they need help to grow into medium-sized companies before they become targets for foreign acquisitions. During the pre-clinical and clinical development phase, the UK has the potential to excel in clinical trials by reducing setup times, leveraging existing data capabilities, and integrating clinical research into routine care. The drug manufacturing sector needs to be revitalized, focusing on higher value products and advanced therapy medicinal products (ATMPs), where there are UK strengths. While the UK faces challenges in access to and adoption of new drugs and biopharma products, various levers are available to increase access, and the scale of the NHS as a customer should be leveraged as an attractive market.

In the previous section we concluded that while the UK performs well on basic science, attention is needed to grasp the opportunities and translate potential innovations into commercialised products and services.

Section 4 sets out our recommendations, drawing on our own empirical research on the biopharma sector and stakeholder interviews. We also reviewed previous policy and other recommendations for the sector found in reports and submissions on the state of the UK's life sciences. We identified around 200 policy recommendations in over 30 reports and submissions published between 2015 and early 2024. Figure 30 provides an overview of the main areas where life science stakeholders have suggested policy intervention is needed to support the sector.[1]

Several initiatives were announced by the last Government after our first biopharma report went to press. These include investment zones focusing on key industries, including life sciences (Merseyside and West Yorkshire), the Advanced Manufacturing Plan (which includes £520m to support health and life sciences from 2025 via the Life Sciences Innovative Manufacturing Fund), the Life Sci for Growth Package (with £650m to support a broad range of measures including the national biobank, a Biomanufacturing Fund, and the Transforming Medicines Manufacturing Programme), and the British Manufacturing Package (joint investment with industry to enhance manufacturing and R&D capabilities in life sciences, automotive and aerospace). These policies have remained in place since the election of the Labour Government on 4 July 2024, but it is unclear what the implications of the October 2024 budget will be for them. The Labour Party manifesto signalled that life sciences are one of the priority industries, with plans including reorganising responsibilities for life sciences and innovation, modernising the regulatory regime, improving access to finance (e.g. though greater consolidation across pension schemes and strengthening the British Business Bank), and maintaining the current system of R&D tax credits and evaluating the impact of the R&D tax credit scheme.[107]

Our own recommendations are summarised in table 7. They are largely unchanged since our 2023 report, but we note where the new Labour Government has signalled that it accepts the need for intervention in a particular area.

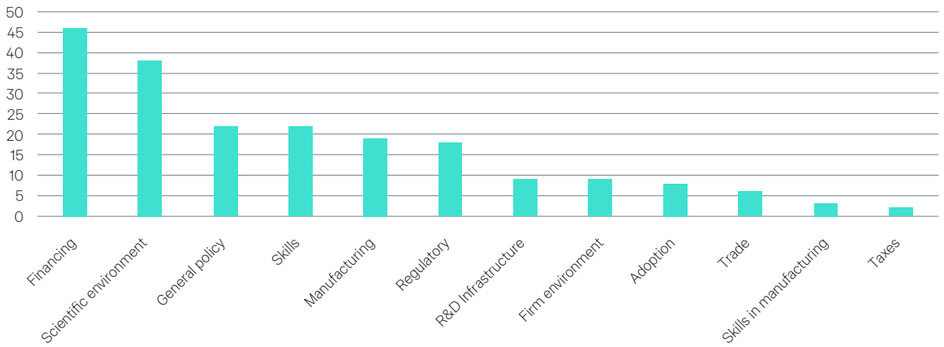


Figure 30: Number of policy recommendations per category that were identified in 30 policy reports that were published between 2015 and 2023. Policy recommendations were categorised

Business environment	Science and R&D	Manufacturing and skills	Regulatory
1. Transparency and reporting of R&D investment, including monitoring pipeline of new drugs produced by UK companies 2. Easily accessible mechanisms for smaller companies, including grants, to support evidence generation in the earlier stages of the R&D 3. Support for small companies to improve business case and business model development 4. Procurement practices and buying power of NHS	5. Data availability – access, interoperability, linkage 6. Understanding and navigating the data environment 7. Integrated care systems performance in promoting and adopting innovations 8. Review mechanisms for supporting innovation adoption and implementation	9. Targeted support for UK biopharma manufacturing 10. Up / re-skilling personnel, especially around data science 11. Review UK capabilities to supply biologic manufacturing and related technologies	12. Regularly review approaches to pricing and access to innovative drugs 13. Monitoring the impact of regulatory alignment and divergence on UK performance

Table 7: Recommendation areas - summary

Business environment

In section 3 we described how the UK biopharma sector's GVA is primarily driven by AstraZeneca and GSK. These companies are responsible for the bulk of R&D activity but conduct most of their spending outside the UK, primarily in the USA. Attracting inward investment from foreign biopharma companies, encouraging the relocation of outsourced R&D activities from AstraZeneca and GSK, and promoting the growth of existing UK biopharma firms would all increase the sector's GVA.

The UK has a large number of micro- and small-sized biopharma companies which are R&D active – at the time of our research around three-quarters have measurable R&D output. Micro-sized companies primarily operate at early R&D stages, while large-sized companies are more involved in late-stage clinical activities and drug approval. In 2023 about a quarter of these companies had entered clinical trials for their products but only around 12% had successfully completed the full development cycle leading to product approval.

Recommendation 1: The lack of systematic data on SME enterprise R&D investment limits analysis that can be done, so industry and government should explore ways of improving transparency and comprehensive reporting.

It would also be useful to monitor the pipelines of smaller companies to identify whether they progress in their drug development cycles and if not, what factors underlying this are.

There has long been concern about the failure to turn promising UK technology start-ups into global players. The UK's biopharma sector has been described as a feeder for the US market. It is essential that sufficient growth finance is available to small UK companies, otherwise their early technologies and IP may be sold prematurely to foreign companies. Our research highlighted the heavy reliance of micro- and small-sized companies on grants, seed funding and angel investors, which provide limited financial support during the initial R&D stages, and venture capital for early pre-clinical and clinical testing. Once companies begin to generate revenue, private equity deals, corporate investments and public offerings are more likely to be available. Although long-term funders have emerged and the number of venture funds available to small biopharma companies has grown, there is still concern over the availability of finance to pull new products through the system. Two areas of particular concern that have been identified are (1) the ability of smaller companies to engage in concept testing and (2) scale-up challenges faced by the data-driven life sciences companies in securing investment.[26, 105] Smaller companies face difficulties in accessing financial support to carry out concept testing to industry standards, despite the relatively low costs. Small data science focused life sciences companies face specific challenges when it comes to securing investment. Biotech investors may feel uncomfortable with the rapidly evolving nature of data technology. Technology investors may be wary of the regulatory complexities related to human health, and their conventional metrics for assessing investment opportunities may not be applicable to slower-moving life sciences companies.

In our 2023 report we recommended that improving financial support to help scale-up of promising small companies should be a policy priority. Since then, the previous Conservative government and the new Labour Government have begun to strengthen measures to address the industry's concerns. Labour's Financial Services Review and its election manifesto outlined aims to increase access to finance for investment and innovation by enabling greater consolidation across pension and retirement saving schemes, giving the British Business Bank a more ambitious remit, and fiscal measures relating to R&D.[108] One potentially interesting scheme to direct investment to UK growth companies would be a UK version of France's 'Tibi' scheme. This would enable some types of pension funds to invest a proportion of their assets in UK growth companies, split between venture capital, smallcap growth equity and infrastructure investment.[109]

It will be important to monitor how these measures unfold over the next 12 months. Even if they help improve the flow of finance to small and early-stage companies, we believe these will require additional focused support in two areas: evidence generation and the development of investment cases and business models.

Recommendation 2: Easily accessible mechanisms for smaller companies to support evidence generation in the earlier stages of the R&D process are essential for improving the flow of potential biopharma through the innovation pipeline. The sums involved are likely to be relatively small and might take the form of grants.

Recommendation 3: Support – perhaps in the form of mentorship and small grants to help develop business models or investment cases – would be useful to help companies articulate their value proposition, develop a clear and concise business model, and demonstrate to investors how they will generate revenue.

More could be done to use the buying power of the NHS and other public bodies involved in healthcare to support smaller companies and market entrants. Procurement practices often act as a brake on innovation by generally favouring incumbent suppliers with tried and tested technologies. A risk averse approach to procurement

[2] Maintaining the current structure and current rates of R&D tax credits, but also evaluating its impact, maintaining the patent box regime, and protecting the Enterprise Investment Scheme and Venture Capital Trusts.

therefore risks embedding inefficient suppliers into the healthcare market by freezing-out market disruptors. Decisions on awarding contracts remain heavily skewed towards price and competition, rather than wider value considerations. While there are now moves to develop more sophisticated approaches to health technology assessment and value-based healthcare models are at least part of the discussion about the future of the NHS, small and early-stage companies are generally excluded from procurement decisions. This is a greater problem for medical device and digital health innovators than the biopharma sector, where there is a strictly controlled process for testing, regulating and procuring drugs. However, as boundaries between drug companies and the former blur and more hybrid innovations – for example, combining medication and telecare – a there is a danger that innovative digitally-enabled therapies may fail to be adopted.

Recommendation 4: Explore the impact of current procurement practices on smaller companies and new market entrants with promising innovations, in particular whether reform is needed to make it easier for them to win government and NHS contracts.

Science and R&D

Data infrastructure

The UK needs to increasingly approach biopharma R&D as data science; access to accurate and comprehensive data, and the advanced tools to analyse it, are essential for improving the productivity of R&D efforts. The abundant data generated by the NHS, real-world data sources, and new life science discovery technologies form the basis for the twenty-first century biopharma sector. The UK Biobank, a repository for genetic data of half a million people is becoming a key hub to facilitate multidisciplinary research collaborations between industry and academia.

Making use of real-world data is still an emerging field, with many unresolved technical, ownership, ethical and privacy challenges. The NHS possesses rich health data, but there have long been difficulties for researchers and life sciences companies in accessing, curating, and sharing this data amongst research partners effectively.

We welcome current initiatives to address these challenges of interoperability and accessibility across and within vertical and horizontal data silos sources in the NHS: the investment to establish secure data environments as the default route for accessing research-ready NHS data, the plans for a federated data platform to maintain data connectivity, the Data Saves Lives strategy to streamline access and enhance security and transparency.

The Labour Government has restated the importance of harnessing data to support biopharma R&D and improve patient care. Measures include leveraging the opportunities offered by the NHS data platform, providing a single access point for researchers to use data, continued delivery of Secure Data Environments, and ensuring interoperability between digital systems in the NHS and in social care. To help achieve this, an accountable senior official within the Department of Health and Social Care Department will be appointed. We support these measures, but bolder, longer-term goals should also be considered.

Recommendation 5a: Industry, regulators and the NHS should speed-up current efforts to harness data and also create a longer-term roadmap to ensure there is linkage across multiple types of data, e.g. clinical trial data and patient-reported outcome measures, and genomics and phenotypic outcomes.

Recommendation 5b: Funding should be made available for a feasibility study to investigate the possibility of a centralised information resource on molecular and other biopharma assets, ownership and patent status, and potential collaborating organisations.

Both these require a commitment – supported by funding and regulatory reform – by the NHS, government and biopharma to make the UK a leader in the breadth and depth of data available for life sciences research and innovation purposes. Achieving this goal will require the collective support and collaboration of policymakers, healthcare providers, professionals, data custodians, the pharmaceutical and life sciences industry, as well as the public and patients.

Start-ups and smaller companies and drug researchers and developers often lack skills in understanding health data access processes and constraints, and sources and availability of research data.

Recommendation 6: Current initiatives to provide support for navigating and analysing health and other data through the Medicines Discovery Catapult should be encouraged and strengthened.

The Government has accepted key recommendations by the O'Shaughnessy review, including the need to decrease the approval time for commercial clinical trials and rebuild capacity for approving trials, led by the Medicines and Healthcare Products Regulatory Agency (MHRA) and the Health Research Authority (HRA). It also commits to improving the transparency and availability of data regarding commercial clinical trials and has allocated £81 million over three years from the National Institute for Health and Care Research for this purpose. A further £20 million over two years has been pledged to establish clinical trial acceleration networks, focusing initially on infectious disease vaccines, cancer, and dementia. We support these measures, but monitoring their effectiveness on the number of trials started and completed will be important.

The NHS as a context for research and adoption

Significant opportunities for efficient, high-quality research and translation into mainstream healthcare practice exist because of the NHS's cradle to grave health records on the entire UK population and its status as a single payer. However, there are widespread concerns about its current capacity for engaging in research. Operational pressures and funding constraints mean there is little time for implementation of innovations, especially where healthcare processes need to be adapted and new learning is needed to ensure the innovation is correctly implemented.

The NHS remains a complex and fragmented environment for adopting healthcare innovations. The NHS needs to be far more efficient at adopting, implementing and diffusing new treatments and technologies. This is well recognised by NHS organisations, leaders and staff on the ground. The pressures on the NHS will not be alleviated in the short term and any further phase of significant organisational change will distract attention from the capacity to engage in collaborative research with the biopharma sector.

Structurally, however, the NHS has taken steps forward in recent years through the introduction of Integrated Care Systems (ICS) in 2022 and continued evolution of the Academic Health Science Networks (AHSNs, now Health Innovation Networks, HINs). The Hewitt review of ICS 66, reporting in April 2023, reiterated the role of AHSNs in helping to stimulate and support the spread of innovations across local healthcare systems.[110]

We support the review's emphasis on the need for careful alignment of AHSNs with local ICS priorities to spread and adopt innovation and best practice efficiently. As the ICS begin to mature, the challenges in implementing and embedding innovations which result from silo thinking – both organisational and financial – should begin to diminish. The Hewitt review noted the possibility for an enhanced role for the Care Quality Commission (CQC) in capturing the innovation efforts of ICSs as a tool for development and improvement.

Recommendation 7: Ensure Integrated Care Systems develop consistent and coherent approaches to the adoption of biopharma innovations and share their practice and experience – successful and unsuccessful. This will require them to develop metrics for assessing their maturity and performance in relation to the promotion and introduction of appropriate innovations.

The availability of data is an essential component of this process, and ICSs will need to ensure data collection systems are timely, high-quality and transparent.

Fifteen years ago, the Policy Exchange estimated that around twelve times more public funding is spent by the UK on the creation of health technology innovations than on supporting their adoption and implementation.[111] There are no recent estimates of the value of the public investment in this direction, but despite significant improvements in the infrastructure for encouraging adoption and spread such as the AHSNs, the balance of support still favours the early stages of innovation development.

Recommendation 8: Government should commission an up-to-date comprehensive review of all the mechanisms for supporting adoption and implementation to ensure that they are as effective as possible, complementary, and are still relevant to research and industry needs.

Manufacturing and skills

The re-shoring of manufacturing activity in the UK's healthcare sector is welcome but it should be driven by strategic considerations rather than solely focusing on increasing domestic production. The British Generic Manufacturers Association (BGMA) emphasizes the need to enhance the overall resilience of the generic and biosimilar medicines supply chain while maximising the industry's economic contribution to the UK.[112] This would partly be based on a categorisation of critical drugs, but according to the BGMA, the supply of active pharmaceutical ingredients (API) and raw materials is a more significant threat to supply chain resilience than the location of drug manufacturing sites.

The BGMA has put forward various incentives to improve UK manufacturing capacity, such as capital grants for flexible advanced manufacturing facilities. Establishing common international quality standards for manufacturing is also seen as a way of ensuring fair competition between countries. The previous Government introduced small amounts of funding to support innovative manufacturing via the Medicines and Diagnostics Manufacturing Transformation Fund (MDMTF) pilot programme, launched in April 2021 (now closed), and via the Life Sciences Innovative Manufacturing Fund (LSIMF).[113] The Life Sciences Innovative Manufacturing Fund was later incorporated into the Advanced Manufacturing Plan (including a Biomanufacturing Fund and the Transforming Medicines Manufacturing Programme). The British Manufacturing Package also included joint funding with industry to enhance R&D capabilities in life sciences. It is not yet clear what the implications of the October 2024 budget will be for them.

Recommendation 9: Targeted support for developing and implementing innovative manufacturing techniques should be increased. While support to ensure that manufacturing critical medicines and some APIs may be needed for UK security purposed, there needs to be better evidence on where such support should be targeted and the likely impact of different measures.

While there was initial uncertainty about the impact of the UK's exit from the EU on talent recruitment, this concern seems to have decreased. There has been progress in addressing skill shortages, but there are still certain disciplines where shortages persist, notably – given the increasing role of data science in the biopharma sector – these tend to be related to data and digital skills.[71] Maintaining a focus on STEM skills within the education system and ensuring there is access to training to develop the data science skills required within biopharma remains essential.

Recommendation 10: Industry has an important role to play in re- and upskilling its workforce in this regard, and in promoting the diverse and viable career pathways within the sector. This includes improving the leadership and entrepreneurial skills needed to build and scale biopharma businesses.[2]

As well as manufacturing capacity for biologics, the UK needs to ensure that there are capabilities and suppliers of analytics for monitoring product quality.

Recommendation 11: A review of the UK's capabilities to supply biologic manufacturing technologies and related monitoring, analytical and quality control technologies should be carried out to identify any opportunities for home-grown business to be supported.

Regulatory

Labour has described plans to modernise the regulatory regime to help to increase the number of industries sponsored clinical trials being conducted in the UK. The aim is to bring together the Regulation Executive and the Regulatory Horizons Council into a Regulatory Innovation Office (RIO). This will set and monitor targets for regulatory approval timelines and help to identify activities regulators should be prioritising.

Both the pharmaceutical and medtech industries have expressed concerns the health technology methodologies used by the National Institute for Health and Care Excellence (NICE) about appraising new drugs and treatments.[114] NICE is a leader in the evaluation of new health technologies and as such it helps to signal to global investors and biopharma companies the UK's commitment to innovation.

There is now more flexibility and pragmatism in NICE's approach in some contexts. These include acceptance of higher uncertainty in evidence generation in rare diseases and complex therapies, support for the use of more comprehensive evidence, including real-world evidence and patient experience of care, and greater consideration of the broader healthcare system costs. However, there are still industry concerns about how these changes will be implemented and the process for refining the methodologies.[115] The biopharma and medtech industries also argue that NICE's decision not to change the discount rate it uses in appraisals has a detrimental impact on the valuation of new drugs and innovation more generally. Others have argued that further research is needed on the appropriate theoretical and empirical basis for discounting practice.[116]

Recommendation 12: It is essential that NICE's approach to appraisal is regularly and independently reviewed against the changing context of public expectations, the availability of government expenditure for healthcare, and the evolution of technological innovation and breakthroughs in science.

Our 2023 report recommended that all parties establish a sustained vision for pricing and market access, shared between government, NHS, NICE, the biopharma industry and other key stakeholders. We argued that this should acknowledge the importance of balancing access and affordability, with support to ensure the competitiveness and sustainability of the UK's biopharma sector.

There remain concerns by the British Generic Manufacturers Association (BGMA) about biosimilar drugs and branded generics, but the VPAG has been cautiously welcomed. Concerns remain about the degree of alignment between the VPAS and VPAG schemes, and the need for transparency on use of revenue from the rebate, which is designed to be reinvested into the healthcare system to support innovation and improve access to medicines. Another concern is the possible increased operational burden of VPAG on smaller companies, with calls for tailored support and guidance to help them navigate the scheme. Finally, there remains a large extensive backlog of drug licenses waiting for MHRA approval, which the new VPAG/VPAS model is not designed to address.

Following Brexit, the Medicines and Healthcare products Regulatory Agency (MHRA) became an independent regulatory agency. Our research on its first year of independent operation in 2021 suggested there had been some delays in authorising certain novel medicines, although the reasons were unclear.[65] These initial findings were confirmed more recently in a report by the Nuffield Trust that compared medicinal product authorisations between EMA and MHRA in the year 2023.[117] Furthermore, the available data suggested the at least 70% of new drugs were authorised through a temporarily introduced EU reliance mechanism. In this context, the government announced that from 2024 onwards the MHRA would be able to follow other trusted regulators, including the EMA, FDA and its Japanese counterpart, to free up time and resources and enable it to focus on more innovative products. Since the first medicine was only approved under this procedure in March 2024, it is still too early to fully understand its impact. Future analysis will be crucial to determine its full impact.[118]

Recommendation 13a: Monitor the performance of the UK in authorising innovative new drugs. Comparison with the only other independent European regulatory body Swissmedic might be useful to understand the functioning and efficacy of their regulatory system and the lessons for UK as an independent European country.

One area where the UK should ensure it remains competitive is in the regulation of data and data driven life science companies and products, including use of real-world data and responsible data use, assessment of more complex drug/device combination products, and IP protection of data-driven life science products.

In April 2023 the European Commission published its proposed revisions to the basic pharmaceutical legislation as a part of its overall of European biopharma strategy. The European Parliament adopted its position on the proposal in April 2024, but the consensus is that the legislation is unlikely to be adopted before 2026. The revisions include new incentives, which aims to promote wider access to medicines across EU countries, address unmet medical needs, facilitate early availability of generics and biosimilars, and simplify market authorisations. The plans also aim to create a favourable regulatory environment for new and repurposed drugs by moving from a 'one-size-fits-all' to a more flexible framework for regulatory protection and intellectual property rights with a lower baseline protection.[119] European pharmaceutical industry groups have expressed concerns that the changes to incentives will undermine innovation without guaranteeing better access for patients. There are particular concerns about the shorter baseline data and market protections. The proposal also includes a reduction in market exclusivity for orphan drugs.[120,121,122]

Recommendation 13b: Government and the biopharma industry would benefit from monitoring progress towards more flexible EU regulatory pathways on their impact for the UK's attractiveness for biopharma R&D, drug trials and product launches.

One area where the UK should ensure it remains competitive is in the regulation of data and data driven life science companies and products, including use of real-world data and responsible data use, assessment of more complex drug/device combination products, and IP protection of data-driven life science products.

References

1. Department for Business, Energy & Industrial Strategy. Life Sciences Vision. 63 (2021).

2. UK BioIndustry Association. BIA submission to Sir Paul Nurse's review of the UK RDI landscape. https://www.bioindustry.org/resource-listing/bia-submission-to-nurse-review-on-rdi.html (2022).

3. Medicines Manufacturing Industry Partnership. Manufacturing Vision for UK Pharma: Future Proofing the UK Through An Aligned Technology and Innovation Road Map. (2017).

4. Quelch, R. Building the UK's domestic pharma manufacturing capability. European Pharmaceutical Review (2021).

5. Royal Academy of Engineering. Engineering biology: A priority for growth. (2019).

6. Casper, S. & Soskice, D. Sectoral systems of innovation and varieties of capitalism: explaining the development of high-technology entrepreneurship in Europe. In Malerba, F. (ed.) Sectoral Systems of Innovation. Cambridge University Press, 2004. doi:10.1017/CBO9780511493270.011.

7. Department for Business, Energy & Industrial Strategy. Bioeconomy strategy: 2018 to 2030 [Withdrawn]. https://www.gov.uk/government/publications/bioeconomy-strategy-2018-to-2030 (2018).

8. ABPI and PwC. ABPI Life Sciences Superpower Report. (2022).

9. Thomas, H. Ailing UK life sciences sector will need further treatment | Financial Times. Financial Times (2023).

10. Fernald, K. et al. The pharmaceutical productivity gap – incremental decline in R&D efficiency despite transient improvements. Drug Discovery Today, 104160 (2024).

11. Paul, S. M. et al. How to improve R&D productivity: the pharmaceutical industry's grand challenge. Nat Rev Drug Discov 9, 203–214 (2010).

12. Laermann-Nguyen, U. & Backfisch, M. Innovation crisis in the pharmaceutical industry? A survey. SN Bus Econ 1, 164 (2021).

13. Munos, B. Lessons from 60 years of pharmaceutical innovation. Nat Rev Drug Discov 8, 959–968 (2009).

14. Pammolli, F., Magazzini, L. & Riccaboni, M. The productivity crisis in pharmaceutical R&D. Nat Rev Drug Discov 10, 428–438 (2011).

15. Scannell, J. W., Blanckley, A., Boldon, H. & Warrington, B. Diagnosing the decline in pharmaceutical R&D efficiency. Nat Rev Drug Discov 11, 191–200 (2012).

16. Shih, H.-P., Zhang, X. & Aronov, A. M. Drug discovery effectiveness from the standpoint of therapeutic mechanisms and indications. Nat Rev Drug Discov 17, 19–33 (2018).

17. Cockburn, I. M. Is the Pharmaceutical Industry in a Productivity Crisis? Innovation Policy and the Economy 7, 1–32 (2006).

18. Light, D. W. & Lexchin, J. R. Pharmaceutical research and development: what do we get for all that money? BMJ 345, e4348 (2012).

19. Ringel, M. S., Scannell, J. W., Baedeker, M. & Schulze, U. Breaking Eroom's Law. Nat Rev Drug Discov 19, 833–834 (2020).

20. Pammolli, F. et al. The endless frontier? The recent increase of R&D productivity in pharmaceuticals. J Transl Med 18, 162 (2020).

21. Burns, L. R., Nicholson, S. & Wolkowski, J. P. Pharmaceutical strategy and the evolving role of merger and acquisition. in The Business of Healthcare Innovation (ed. Burns, L. R.) 116–193 (Cambridge University Press, 2012). doi:10.1017/CBO9781139176620.003.

22. Grabowski, H., Long, G. & Mortimer, R. Recent trends in brand-name and generic drug competition. Journal of Medical Economics 17, 207–214 (2014).

23. Euh, Y. & Lee, D. How Do Pharmaceutical Companies Overcome a Corporate Productivity Crisis? Business Diversification into Medical Devices for Growth Potential. Int J Environ Res Public Health 18, 1045 (2021).

24. Buvailo, A. Pharma R&D Outsourcing Is On The Rise. https://www.biopharmatrend.com/post/30-pharma-rd-outsourcing-is-on-the-rise/ (2020).

25. Cunningham, C., Ederer, F. & Ma, S. Killer Acquisitions. SSRN Scholarly Paper at https://doi.org/10.2139/ssrn.3241707 (2020).

26. BioIndustry Association & Medicines Discovery Catapult. State of the Discovery Nation 2018. https://md.catapult.org.uk/resources/report-state-of-the-discovery-nation-2018/ (2018).

27. Paul, D. et al. Artificial intelligence in drug discovery and development. Drug Discov Today 26, 80–93 (2021).

28. Naylor, S. & Schonfeld, J. M. Therapeutic Drug Repurposing, Repositioning and Rescue Part I: Overview. Drug Discovery World (DDW) https://www.ddw-online.com/therapeutic-drug-repurposing-repositioning-and-rescue-part-i-overview-1463-201412/ (2015).

29. Barker, S. et al. COVID-19: Finding the Right Fit. (2020).

30. Deep Pharma Intelligence. Artificial Intelligence for Drug Discovery Landscape Overview Q1 2022. (2022). Updated from Deep Pharma Intelligence AI in Drug Discover database: https://www.deep-pharma.tech/ai-in-dd-database

31. 360iResearch LLP. Drug Discovery Market Research Report by Drug Type (Biologic Drugs and Small Molecule Drugs), Technology, End User, Region - Cumulative Impact of COVID-19, Russia Ukraine Conflict, High Inflation - Global Forecast 2023-2030. (2023).

32. Roots Analysis Private Ltd. Drug Repurposing Service Providers Market, 2020-2030. https://www.reportlinker.com/p05955648/Drug-Repurposing-Service-Providers-Market.html?utm_source=PRN (2020).

33. Koetsier, J. 97% Of Executives Say Covid-19 Sped Up Digital Transformation. Forbes https://www.forbes.com/sites/johnkoetsier/2020/09/10/97-of-executives-say-covid-19-sped-up-digital-transformation/ (2020).

34. Lesmeister, F. & Ghosh, P. Digital Manufacturing Is (Finally) Coming to Pharma. https://www.bain.com/insights/digital-manufacturing-is-finally-coming-to-pharma/ (2020).

35. Nawrat, A. Turning pharma green: an eco-wish list for the industry - Pharmaceutical Technology. Pharmaceutical Technology https://www.pharmaceutical-technology.com/analysis/eco-wish-list-pharma/ (2020).

36. Trivedi, M. et al. Additive manufacturing of pharmaceuticals for precision medicine applications: A review of the promises and perils in implementation. Additive Manufacturing 23, 319–328 (2018).

37. Parkins, K. & Hillman, H. Forecast: decentralised trials to reach new heights with 28% jump. Clinical Trials Arena. https://www.clinicaltrialsarena.com/features/2022-forecast-decentralised-trials-to-reach-new-heights-with-28-jump/ (2022).

38. Martani, A., Geneviève, L. D., Poppe, C., Casonato, C. & Wangmo, T. Digital pills: a scoping review of the empirical literature and analysis of the ethical aspects. BMC Med Ethics 21, 3 (2020).

39. Champagne, D., Hung, A. & Leclerc, O. The road to digital success in pharma | McKinsey. McKinsey https://www.mckinsey.com/industries/life-sciences/our-insights/the-road-to-digital-success-in-pharma (2015).

40. Philpott, J. Out with the old, in with the new: Decoding biosimilar access with VPAG. Pharmaceutical Technology (2024).

41. Kuchler, H. Drugmakers demand big cut in Britain's medicines levy. Financial Times (2023).

42. Kuchler, H. Drugs tax risks inflating NHS medicines' bill, warns industry body. Financial Times 14 April 2023.

43. Department of Health and Social Care. Voluntary Scheme for Branded Medicines Pricing, Access and Growth. https://assets.publishing.service.gov.uk/media/657b2977095987001295e139/2024-voluntary-scheme-for-branded-medicines-pricing-access-and-growth.pdf (2024).

44. Lovell, T. Medicine pricing agreement will double annual growth in cost of branded drugs sold to the NHS. The Pharmaceutical Journal. https://pharmaceutical-journal.com/article/news/medicine-pricing-agreement-will-double-annual-cost-of-branded-drugs-sold-to-the-nhs (2023).

45. Lin, S. & Vouga, M. Navigating the Impact of VPAG: Opportunities, Challenges, and Strategic Considerations for Pharmaceuticals. Windrose Consulting Group. https://windrosecg.com/posts/navigating-the-impact-of-vpag (2024).

46. Koyuncu, A. & Maximilian, A. Germany amends drug pricing and reimbursement laws with 'Medical Research Act'. Drug pricing becomes intertwined with local clinical research expectations. Inside EU Life Sciences. www.insideeulifesciences.com/2024/07/12/germany-amends-drug-pricing-and-reimbursement-laws-with-medical-research-act-drug-pricing-becomes-intertwined-with-local-clinical-research-expectations/ (2024).

47. ABPI Statutory Scheme consultation response 2024. Executive summary. https://www.abpi.org.uk/media/h3pkffrz/statutory-scheme-consultation-executive-summary-april-2024.pdf

48. Voluntary Scheme for Branded Medicines, Pricing, Access and Growth (VPAG). BGMA. www.britishgenerics.co.uk/view-news/voluntary-scheme-for-branded-medicines-pricing-access-and-growth-vpag.html (2024).

49. Thomas, H. Endless innovating when it comes to R&D policy can only be unhelpful. Financial Times (2023).

50. Hannaway, A. The Labour government's plans for R&D, innovation and funding. EmpowerRD. https://www.empowerrd.com/labour-governments-plan-for-rd/ 2024.

51. Lord O'Shaughnessy. Commercial clinical trials in the UK. https://www.gov.uk/government/publications/commercial-clinical-trials-in-the-uk-the-lord-oshaughnessy-review/commercial-clinical-trials-in-the-uk-the-lord-oshaughnessy-review-final-report (2023).

52. Office for Life Sciences & Department for Science, Innovation & Technology & Department of Health & Social Care. Life sciences competitiveness indicators 2024: summary. https://www.gov.uk/government/publications/life-sciences-sector-data-2024/life-sciences-competitiveness-indicators-2024-summary (2024).

53. The Association of the British Pharmaceutical Industry. Rescuing patient access to industry clinical trials in the UK. https://www.abpi.org.uk/publications/rescuing-the-uk-industry-clinical-trials/ (2022).

54. UK industry clinical trial performance shows signs of improvement, says ABPI report. ABPI. https://www.abpi.org.uk/media/news/2023/november/uk-industry-clinical-trial-performance-shows-signs-of-improvement-says-abpi-report/ (2023).

55. NIHR Annual Statistics. https://www.nihr.ac.uk/about-us/who-we-are/our-research-performance/annual-statistics.htm

56. UK Government. Government response to the Lord O'Shaughnessy review into commercial clinical trials in the UK. GOV.UK https://www.gov.uk/government/publications/commercial-clinical-trials-in-the-uk-the-lord-oshaughnessy-review/government-response-to-the-lord-oshaughnessy-review-into-commercial-clinical-trials-in-the-uk (2023).

57. Department of Health and Social Care. What we're doing to speed up clinical trials in the UK. https://healthmedia.blog.gov.uk/2023/11/22/what-were-doing-to-speed-up-clinical-trials-in-the-uk/ (2023).

58. UK secures £400 million investment to boost clinical trials. https://www.gov.uk/government/news/uk-secures-400-million-investment-to-boost-clinical-trials (2024).

59. Life sciences competitiveness indicators. https://www.gov.uk/government/publications/life-sciences-sector-data-2024/life-sciences-competitiveness-indicators-2024-summary#section-2-domestic-market (2024).

60. EFPIA Patients W.A.I.T. Indicator 2023 Survey. https://www.efpia.eu/media/vtapbere/efpia-patient-wait-indicator-2024.pdf (2024).

61. Ward, D. J., Martino, O. I., Simpson, S. & Stevens, A. J. Decline in new drug launches: myth or reality? Retrospective observational study using 30 years of data from the UK. BMJ Open 3, e002088 (2013).

62. Ward, D. J., Slade, A., Genus, T., Martino, O. I. & Stevens, A. J. How innovative are new drugs launched in the UK? A retrospective study of new drugs listed in the British National Formulary (BNF) 2001–2012. BMJ Open 4, e006235 (2014).

63. Britain without the EMA. BMJ 357, j2168 (2017).

64. The Association of the British Pharmaceutical Industry. ABPI Vision Paper: UK medicines regulatory policy and global influence in a post-pandemic world. https://www.abpi.org.uk/publications/abpi-vision-paper-uk-medicines-regulatory-policy-and-global-influence-in-a-post-pandemic-world/ (2021).

65. Hofer, M. P., Criscuolo, P., Shah, N., Wal, A. L. J. ter & Barlow, J. Regulatory policy and pharmaceutical innovation in the United Kingdom after Brexit: Initial insights. Front. Med. 9, 1011082 (2022).

67. MHRA announces new recognition routes to facilitate safe access to new medicines with seven international partners. GOV.UK https://www.gov.uk/government/news/mhra-announces-new-recognition-routes-to-facilitate-safe-access-to-new-medicines-with-seven-international-partners (2023).

68. UK Government. Life science competitiveness indicators 2022. https://www.gov.uk/government/publications/life-science-sector-data-2022/life-science-competitiveness-indicators-2022 (2022).

69. Enterprise Ireland. The UK Pharmaceutical Sector. An Overview. (2020).

70. British Generic Manufacturers Association. Generic industry supply chain resilience post Covid-19. (2020).

71. The Association of the British Pharmaceutical Industry. Bridging the skills gap in the biopharmaceutical industry (2022).

72. Budabuss, K. How the Life Sciences Innovative Manufacturing Fund can boost funding for pharma. Pharmaphorum. https://pharmaphorum.com/rd/how-life-sciences-innovative-manufacturing-fund-can-boost-funding-pharma (2024).

73. PwC Life Science Future50. https://www.pwc.co.uk/press-room/press-releases/uk-life-sciences-sector-contributes-43-3-billion-in-gva.html (2023).

74. IfMEngage. Institute for Manufacturing, University of Cambridge. The UK Innovation Report 2023. https://www.ciip-group.org/uk-innovation-report-2023/ (2023).

75. IfMEngage. Institute for Manufacturing, University of Cambridge. The UK Innovation Report 2021. https://www.ciip.group.cam.ac.uk/uk-innovation-report-2021/ (2021).

76. ABPI Creating trade policy for a life sciences superpower. https://www.abpi.org.uk/international-trade-and-ip/international-trade/ (2024).

77. IfMEngage. Institute for Manufacturing, University of Cambridge. UK Innovation Report 2022. https://www.ciip.group.cam.ac.uk/uk-innovation-report-2022/ (2022).

78. Panjwani, A. Research & Development spending. House of Commons Library. https://researchbriefings.files.parliament.uk/documents/SN04223/SN04223.pdf (2023).

79. OECD Main Science and Technology Indicators. https://www.oecd-ilibrary.org/science-and-technology/gross-domestic-expenditure-on-r-d-gerd-per-capita-at-current-prices-and-ppp_0d45286b-en (2022).

80. Life Science Competitiveness Indicators 2024: Data Tables. https://www.gov.uk/government/publications/life-sciences-sector-data-2024

81. UK Clinical Research Collaboration. UK Health Research Analysis 2018. HRCS Online https://hrcsonline.net/reports/analysis-reports/uk-health-research-analysis-2018/ (2020).

82. Friedman, Y. Location of pharmaceutical innovation: 2000–2009. Nature Reviews Drug Discovery 9, 835–836 (2010).

83. Reeb, D. M. & Zhao, W. Patents Do Not Measure Innovation Success. SSRN Scholarly Paper at https://papers.ssrn.com/abstract=3940229 (2020).

84. Grabowski, H. G., DiMasi, J. A. & Long, G. The Roles Of Patents And Research And Development Incentives In Biopharmaceutical Innovation. Health Affairs 34, 302–310 (2015).

85. Abramovsky, L. Global engagement in R&D: a portrait of biopharmaceutical patenting firms. https://www.ifs.org.uk/uploads/publications/wps/WP201518.pdf (2015) doi:10.1920/wp.ifs.2015.1518

86. Heiberv, I. How CDMOs are leading innovation for pharmaceutical partners. EY (2022).

87. CDMO Market. Size, Share, Industry Growth & Report. Mordor Intelligence. https://www.mordorintelligence.com/industry-reports/pharmaceutical-contract-development-and-manufacturing-organization-cdmo-market (2024).

88. United Kingdom Active Pharmaceutical Ingredients (API) Market Size & Share Analysis - Growth Trends & Forecasts (2024 - 2029). Mordor Intelligence. https://www.mordorintelligence.com/industry-reports/united-kingdom-active-pharmaceutical-ingredients-market (2023).

89. Pearson, S. UK Boosts Presence at the Biologics Manufacturing Table. GEN. https://www.genengnews.com/topics/bioprocessing/uk-boosts-presence-at-the-biologics-manufacturing-table/ (2024).

90. Veleva, V. et al. Benchmarking green chemistry adoption by the Indian pharmaceutical supply chain. Green Chemistry Letters & Reviews 11: 439-456. https://doi.org/10.1080/17518253.2018.1530802 (2018).

91. Wilkinson, E. India and China spark concerns for UK drug supplies. The Pharmaceutical Journal. https://pharmaceutical-journal.com/article/feature/india-and-china-spark-concerns-for-uk-drug-supplies (2019).

92. Horner, R. The world needs pharmaceuticals from China and India to beat coronavirus. The Conversation. https://theconversation.com/the-world-needs-pharmaceuticals-from-china-and-india-to-beat-coronavirus-138388 (2020).

93. Adak, S. Current Risk in the Supply Chain for the Active Pharmaceutical Ingredients Business. Universal Journal of Pharmacy & Pharmacology 3: 1-5. https://doi.org/10.31586/ujpp.2024.906 (2024).

94. Qelch, R. Building the UK's domestic pharma manufacturing capability. European Pharmaceutical Review,. https://www.europeanpharmaceuticalreview.com/article/152339/building-the-uks-domestic-pharma-manufacturing-capability/ (2021).

95. ABPI Manifesto for Investment, Health and Growth. https://www.abpi.org.uk/about-the-abpi/abpi-manifesto-for-investment-health-and-growth/ (2024).

96. UK Pharmaceutical Sector Embraces Reshoring for Enhanced Supply Chain Resilience. International Centre for Trade Transparency. https://icttm.org/uk-pharmaceutical-sector/ (2024).

97. Pharmaceuticals may help us but they are harming our rivers. This is what needs to change. World Economic Forum. https://www.weforum.org/agenda/2022/02/pharmaceutical-pollution-health-drugs-rivers/ (2022).

98. Okeke, E.S. et al. Environmental and health impact of unrecovered API from pharmaceutical manufacturing wastes: A review of contemporary treatment, recycling and management strategies. Sustainable Chemistry and Pharmacy. https://doi.org/10.1016/j.scp.2022.100865 (2022).

99. Stark, D., et al. Why digital supply chain visibility should be a pharma priority. EY Parthenon. https://www.ey.com/en_uk/insights/life-sciences/digital-supply-chain-visibility-is-a-pharma-priority (2023).

100. UK Government. UK secures £400 million investment to boost clinical trials. GOV.UK. https://www.gov.uk/government/news/uk-secures-400-million-investment-to-boost-clinical-trials (2024).

101. Wahlich, J. Review: continuous manufacturing of small molecule solid oral dosage forms. Pharmaceutics: 13: 1311 (2021).

102. Sundarkumar, V. et al. Developing a modular continuous drug product manufacturing system with real time quality assurance for producing pharmaceutical mini-tablets. Journal of Pharmaceutical Sciences 1134: 937–947 (2024).

103. Shaik, A. et al. Development of modular manufacturing systems. A review. The International Journal of Advanced Manufacturing Technology, 76: 789–802 (2015).

104. UK BioIndustry Association. Medicines Manufacturing Industry Partnership (MMIP). https://www.bioindustry.org/policy/manufacturing/mmip.html (2024).

105. UK BioIndustry Association. Tech Bio: How data-driven life sciences companies are transforming drug discovery and patient care. https://www.bioindustry.org/policy/strategic-technologies/techbio/techbio.html (2021).

106. The Association of Medical Research Charities. Facilitating adoption of off-patent, repurposed medicines into NHS clinical practice. https://www.amrc.org.uk/blog/facilitating-adoption-of-off-patent-repurposed-medicines-into-nhs-clinical-practice (2017).

107. Williams, A. & Mulryne, J. What does the new UK government mean for life sciences? Bioslice Blog. https://www.biosliceblog.com/2024/07/what-does-the-new-uk-government-mean-for-life-sciences/ (2024).

108. Financing Growth. Labour's Plans for Financial Services. https://labour.org.uk/wp-content/uploads/2024/01/Financing-Growth.pdf (2024).

109. Peel Hunt. Labour's Financial Services Review – Tibi or not Tibi. https://www.peelhunt.com/news-insights/articles/labour-s-financial-services-review-tibi-or-not-tibi/ (2024).

110. Rt Hon Patricia Hewitt. Review of integrated care systems. https://www.gov.uk/government/publications/the-hewitt-review-an-independent-review-of-integrated-care-systems (2023).

111. Barlow, James & Burn, Jamie. All change please. Putting the best new healthcare ideas into practice. (2008).

112. British Generic Manufacturers Association. Strengthening the resilience of the global supply chain. (2020).

113. UK Government. Life sciences companies supercharged with £277 million in government and private investment. GOV.UK. https://www.gov.uk/government/news/life-sciences-companies-supercharged-with-277-million-in-government-and-private-investment (2023).

114. Delle Technology. Concerns Over NICE Methodologies in the Pharmaceutical Industry. https://odelletechnology.com/concerns-over-nice-methodologies-in-the-pharmaceutical-industry/ (2024).

115. PATT 2.0: NICE Priorities & Pharma Impact. Remap Consulting. https://www.remapconsulting.com (2024).

116. O'Mahony, J. F., Paulden, M. & McCabe, C. NICE's Discounting Review: Clear Thinking on Rational Revision Meets Obstacle of Industrial Interests. Pharmacoeconomics 39, 139–146 (2021).

117. Dayan, M. et al. The future for health after Brexit. Nuffield Trust. https://www.nuffieldtrust.org.uk/research/the-future-for-health-after-brexit (2024).

118. UK Government. MHRA Grants First Approval via the New International Recognition Procedure in 30 days. GOV.UK. https://www.gov.uk/government/news/mhra-grants-first-approval-via-the-new-international-recognition-procedure-in-30-days (2024).

119. Reform of the EU pharmaceutical legislation. European Commission. https://health.ec.europa.eu/medicinal-products/pharmaceutical-strategy-europe/reform-eu-pharmaceutical-legislation_en (2023).

120. Hofer, M. et al. Plan For A New EU Pharmaceutical Legislation: What Will It Mean For Pharmaceutical Innovation? OHE. https://www.ohe.org/insight/plan-for-a-new-eu-pharmaceutical-legislation (2024).

121. EU competitiveness: Looking ahead. European Commission. https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en (2024).

122. Bogaert, P. et al. European Parliament adopts its Position on EU Pharma Law Review. 8 Key Takeaways for Industry. Inside EU Life Sciences. https://www.insideeulifesciences.com/2024/04/16/european-parliament-adopts-its-position-on-eu-pharma-law-review-8-key-takeaways-for-industry/ (2024).

Appendix Methodology

Biopharma ecosystem database

A firm-level database was created to help characterise the biopharma ecosystem. This consists of all national and international companies that are involved or supporting the development, manufacture or supply of medicines in the UK, including pharmaceuticals and biopharmaceuticals. It doesn't include the emerging data science sector supporting biopharma R&D.

The database was created by combining two datasets:

- the bioscience and health technology sector statistics 2019 'Biopharma core' dataset provided by the Office for Life Sciences (OLS)
- the GMDP database by the Medicines and Healthcare Products Regulatory Agency (MHRA).

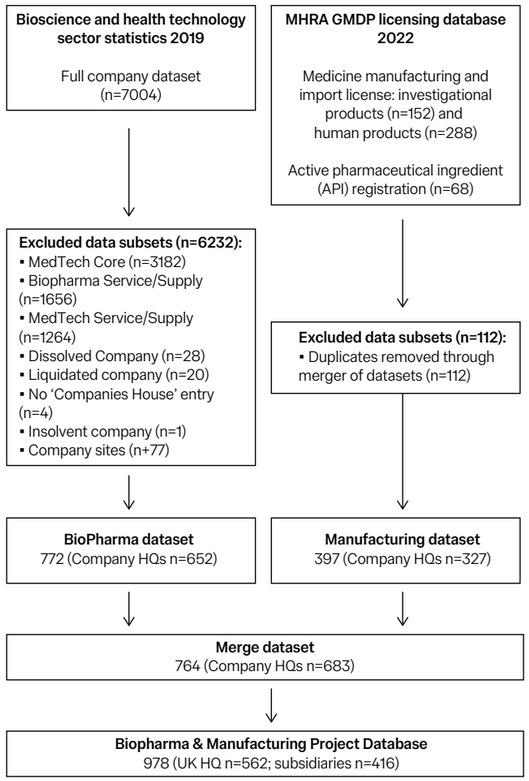


Figure 1: Flow chart of the BioPharma Ecosystem project database combining the data of two datasets.

The merged firm-level database was cleaned by (1) using only the group account for all UK head-quartered companies, (2) using single company accounts for all companies and subsidiaries of companies with overseas headquarters, (3) removing companies with Companies House 'Overseas' registrations, and (4) removing companies without available economic information or large companies without a life science focus (e.g. British American Tobacco) (Figure 1).

This approach was able to capture a wider range of companies than the current ONS industry classification for the "manufacture of pharmaceutical products" (SIC 21). Of the 977 companies in our ecosystem database, approximately 20% had SIC21 annotated as their primary SIC code.

The database is broken down into five segments:

- Biopharma: 591 businesses involved in developing and/or producing pharmaceutical products.
- Manufacturing: 141 businesses with import and manufacturing license for medicines in the UK with registered activity of medicines manufacturing.
- Supply: 105 businesses with import and manufacturing license for medicines in the UK with registered activity of import, quality control and packaging.
- Biopharma and manufacturing: 82 businesses involved in developing and/or producing their own pharmaceutical products and with registered activity of medicines manufacturing.
- Biopharma and supply: 58 businesses involved in developing and/or producing their own pharmaceutical products and with registered activity of import, quality control and packaging.

The database contains firm-level data on financial performance, employment, productivity / contribution to the UK economy (gross value added and gross value added per employee), capital market financing, enterprise R&D spending, manufacturing sites and capabilities, as well as R&D output including patents.

The database contains firm-level data on financial performance, employment, productivity / contribution to the UK economy (gross value added and gross value added per employee), capital market financing, enterprise R&D spending, manufacturing sites and capabilities, as well as R&D output including patents.

The analysis spans 2016 to 2021 and nominal values are reported, i.e. they have not been adjusted for inflation or economic multipliers.

Other data

Financial and economic variables were extracted at a firm level from Bureau van Dijk and aggregated for analysis (table 8). It should be noted that financial data was not available for all companies, with more limited data on younger and smaller companies as highlighted previously for Bureau van Dijk databases.[73]

Direct GVA was calculated using the formula GVA = employee costs + operating profit (EBIT) + depreciation + amortisation, which is consistent with the national accounting methods used by the ONS and other reports.[8] The estimated GVA was consistently higher than the ONS reported figures, which could be explained by the different pool of companies that were considered

Dataset	Sources	Variables
Biopharma ecosystem	1. BEIS- Office for Life Sciences bioscience and health technology sector statistics 2019 (Biopharma core subset) 2. GMDP MHRA database (Manufacturing and Import authorisations for human use & API registrations; data extracted at the end of 2022)	▪ Company name ▪ Geography/postcodes ▪ Manufacturing capabilities ▪ Supply capabilities
Headquarters *	ORBIS Intellectual Property/ ORBIS EUROPE/ FAME (Bureau van Dijk)	▪ R&D headquarter location ▪ Domestic headquarter location (if applicable) ▪ Investment parent (if applicable) ▪ Geographic profile
Financial data **	ORBIS Intellectual Property/ ORBIS EUROPE/ FAME (Bureau van Dijk)	▪ Turnover ▪ Profit ▪ Employment ▪ Business R&D investment ▪ GVA components (employee costs + operating profit/EBIT + depreciation + amortisation)
Private capital market financing **	Pitchbook	▪ Type of investment ▪ Number of investments ▪ Size of investment ▪ Stage of business
Patent data/ R&D location **	ORBIS Intellectual Property (Bureau van Dijk)	▪ Patent categorization ▪ Patent inventor location ▪ Number of citations
R&D output *	1. Clarivate Web of Science, Elsevier Scopus 2. Clinicaltrials.gov, EudraCT, ISRCTN registry 3. ORBIS Intellectual Property (Bureau van Dijk) 4. MHRA, EMA & FDA	▪ Publications (company listed in affiliations) ▪ Patents ▪ Clinical trials ▪ Marketing Authorisations

* data available for all entries ** data might not be available for all entries

Table 8: Overview of datasets and variables of the UK BioPharma Ecosystem project database

R&D location / patent inventor location

The location of the patent inventor was used as a surrogate for the location of the R&D for all companies in the database; when R&D expenditure was reported, it was allocated to R&D locations as determined by the patent analysis. The analysis covered patent families (groups of patents associated with the same innovation and submitted in more than one country) that were filed between 2016 and 2021.

The dataset comprised a breakdown of patenting activity for each company that was aggregated at country level to obtain information on inward, outward, and home R&D activity. R&D location / patent inventor location was also used to estimate the home, inward, and outward investment in monetary terms. For this calculation, global R&D investment figures by company headquarters were divided and R&D expenses were allocated to geographic distribution of patent inventors as outlined above. This data was not available for all companies; the estimate is based on data from 227 of 652 companies in the database (35%).

EU Scoreboard

The EU R&D Investment Scoreboard is published annually and provides an annual list of the companies with the highest enterprise R&D spending worldwide (top 2500 companies) and in the EU (top 1000 companies). It contains company count and financial performance data. We combined all EU Scoreboard datasets between 2014 and 2020 and used it to benchmark and observe the development over time of UK headquartered biopharma companies compared to other countries and their biopharma industry on R&D investment, sales, employment, and patenting activity. The methodology was consistent in the years 2014-2020, before the methodology was changed amid Brexit.

Clinical trial data

NIHR Innovation Observatory Scan Medicine database was used to collect data on clinical trial sites and their location of all publicly registered clinical trials (phase 1-3) that were initiated, recruiting or completed during 2017 and 2021.

Private capital investment

Pitchbook database was used to extract all data related to international private capital investments in two sectors: biotechnology and pharmaceuticals. These sectors are defined and managed by Pitchbook. The biotechnology sector is defined as companies engaged in research, development, and production of biotechnology. Includes embryology, genetics, cell biology, molecular biology, and biochemistry, among other activities. In this category, 44% of companies are also listed as performing ‘drug discovery’, i.e. researchers and developers of new drugs, including the identification, screening, and efficacy testing of drug candidates.

The pharmaceutical sector is defined as manufacturers and distributors of established drugs / pharmaceuticals, including any large drug company that primarily manufactures medicines (they may also be engaged in drug research and development). In this category, 33% of companies are also listed as performing ‘drug discovery’, i.e. researchers and developers of new drugs, including the identification, screening and efficacy testing of drug candidates.

Professor James Barlow and Dr Mathias Hofer

Revised by Esther Havenaar

With Professor Nilay Shah, Professor Paola Criscuolo, Dr. Anne Ter Wal

Imperial College London