The Missing £4 Billion

Making R&D work for the whole UK

Tom Forth, Open Data Institute Leeds
Richard A.L. Jones, University of Manchester

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About the authors

Richard A.L. Jones (@RichardALJones) is Professor of Materials Physics and Innovation Policy at the University of Manchester; he is an experimental soft matter physicist. In 2006 he was elected a Fellow of the Royal Society in recognition of his work in the field of polymers and biopolymers at surfaces and interfaces. He was Pro Vice-Chancellor for Research and Innovation at the University of Sheffield from 2009 to 2016, was a member of EPSRC Council from 2013 – 2018, and chaired Research England's Technical Advisory Group for the Knowledge Exchange Framework. He is an Associate Director of the Research on Research Institute.

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Tom Forth (@thomasforth) is Head of Data at The Open Data Institute Leeds, and is particularly interested in data on transport, housing, and innovation in the UK and Europe. He is a Director and co-founder of The Data City, a startup using big data and machine learning to quantify and boost economic growth and innovation in cities around the world. Tom has a PhD in computational biology from the University of Leeds and runs a digital services and data analytics company called imactivate.

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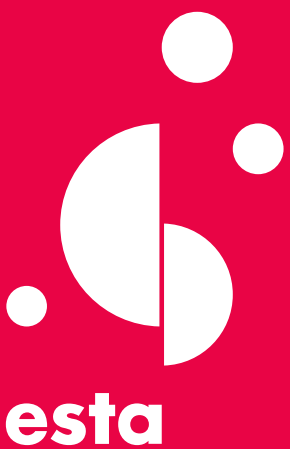

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Foreword

For many people and places across the UK, the economy never really recovered from the 2008 recession. Now the COVID-19 pandemic threatens to bring new disruption to an already fragile British economy, and to exacerbate entrenched problems that contribute to regional economic inequality.

This report examines one of these longstanding problems for the UK. The UK's expenditure on Research and Development (R&D) - an important driver of economic growth - has historically been low compared to our competitor countries. The Government has committed to significantly increasing the amount that the UK spends on R&D by 2025. This investment is needed now more than ever as we rebuild the economy across the UK.

But the UK's R&D spending, both public and private, is highly regionally imbalanced. This matters because R&D leads to innovation, and innovation creates productive industries and well paid jobs. Additional investment in innovation is essential but decisions on how and where this is spent will need to be made differently to really 'level up' the UK. We are at a rare moment where change is possible.

At Nesta, we have long championed innovation that is more inclusive - from who participates in innovation, to who benefits from it and who decides on the challenges it could solve. We commissioned the authors of this report to undertake fresh analysis on where and how R&D is distributed across the country, to bring greater evidence, understanding and informed debate on the role of R&D and innovation as a driver of growth that benefits a greater number of people and places in the UK.

The report's analysis is striking and it presents some compelling arguments. The authors have calculated that large parts of the UK, including North England, the English Midlands, and South West of England, together with Wales and Northern Ireland, have been missing out, to the tune of £4 billion a year. For regions where the state has under-invested in R&D, there is a double loss. Since the private sector tends to invest on average twice as much as public spending, those regions are missing out on the £8b billion private sector multiplier of that £4 billion too.

The authors argue that the way the UK's funding system for R&D operates is exacerbating this problem, and previous attempts to correct it have not been at a sufficient scale to make a difference. They argue for a change in direction for UK innovation policy. They see a key role for the UK's nations, cities and regions, giving them resources and capacity to build and develop their own innovation priorities, as well as new responsibilities for institutions like UK Research and Innovation.

This report highlights some important and challenging questions, but also offers some practical ways to redress these imbalances. We look forward to the conversations it generates, and to working with the UK Government and institutions across the country on how innovation can truly benefit more people and places in the UK.

Jen Rae
Head of Innovation Policy, Cities and Regions

Executive summary

The UK's regional imbalances in economic performance are exacerbated by regional imbalances in R&D spending

There are two economies in the UK. Much of London, South East England and the East of England has a highly productive, prosperous knowledge-based economy. But in the Midlands and the North of England, in much of South West England and in Wales and Northern Ireland, the economy lags behind our competitors in Northern Europe. Scotland sits in between. In underperforming large cities, in towns that have never recovered from deindustrialisation, in rural and coastal fringes, weak innovation systems are part of the cause of low productivity economies.

The government supports regional innovation systems through its spending on public sector research and development (R&D). This investment is needed now more than ever; we have an immediate economic crisis because of the pandemic, but the long-term problems of the UK economy – a decade of stagnation of productivity growth, which led to stagnant wages and weak government finances, and persistent regional imbalances – remain. Government investment in R&D is highly geographically imbalanced. If the government were to spend at the same intensity in the rest of the country as it does in the wider South East of England, it would spend £4 billion more. This imbalance wastes an opportunity to use public spending to 'level up' areas with weaker economies and achieve economic convergence.

The UK's research base has many strengths, some truly world leading. But three main shortcomings currently inhibit it from playing its full role in economic growth. It is too small for the size of the country, it is relatively weak in translational research and industrial R&D, and it is too geographically concentrated in already prosperous parts of the country, often at a distance from where business conducts R&D.

The UK's R&D intensity is too low

The UK's overall R&D intensity is low. Measured as a ratio to (pre-COVID-19 crisis) gross domestic product (GDP), the Organisation for Economic Co-operation and Development (OECD) average is 2.37 per cent. The UK, at 1.66 per cent, is closer to countries like Italy and Spain than Germany or France.

The UK government has committed to matching the current OECD average by 2027, pledging an increase in public spending to £22 billion by 2025. Looking internationally shows us that substantial increases in R&D intensity are possible. Austria, Belgium, Denmark and Korea have all dramatically increased R&D intensity in recent decades. The major part of these increases is funded by the private sector, but public sector increases are almost always required alongside or in advance of this. The ratio of R&D funding from the two sources is typically 2:1, and this is a good rule of thumb for considering how increased R&D might be funded in the UK.

The UK's R&D is highly regionally imbalanced

Looking at both the total level of spending on R&D and the ratio of public to private R&D spending is a good way to classify innovation systems within regions.

- The South East and East of England are highly research intensive with high investment by the state combined with business investment exceeding what we would expect from a 2:1 ratio.
- London and Scotland receive above-average levels of state investment but have lower-than-average levels of business investment.
- The East Midlands, the West Midlands and North West England are business-led innovation regions with business investment in R&D at or above the UK average but low levels of public investment.
- Wales, Yorkshire and the Humber, and North East England are regional economies with notably low R&D intensities in both the market and non-market-led sectors.
- South West England and Northern Ireland sit between these two groups with similarly low levels of public investment but slightly higher private sector spending on R&D.

A single sentence can summarise the extent to which the UK's public R&D spending is centralised in just three cities. The UK regions and subregions containing London, Oxford and Cambridge account for 46 per cent of public and charitable R&D in the UK, but just 31 per cent of business R&D and 21 per cent of the population.

How the current funding system has led to inequality

The current situation is the result of a combination of deliberate policy decisions and a natural dynamic in which these small preferences combined with initial advantages are reinforced with time.

For example, of a series of major capital investments in research infrastructure between 2007 and 2014, 71 per cent was made in London, the East and South East of England, through a process criticised by the National Audit Office. The need for continuing revenue funding to support these investments lock in geographical imbalances in R&D for many years.

Imbalanced investment in R&D is, at most, only part of why the UK's regional economic divides widened in the past and have failed to close in recent decades. But it is a factor that the government can influence. It has failed to do so. Where attempts have been made to use R&D to balance the UK's economic strengths, they have been insufficient in scale. For example, in the 2000s the English regional development agencies allocated funding with preference to regions with weaker economies, but their total R&D spend was equivalent to just 1.6 per cent of the national R&D budget. These efforts could never have hoped to succeed. Unsurprisingly, and in contrast to vastly larger schemes in Germany, they failed.

We need to do things differently

The sums needed to rebalance R&D spending across the nation are substantial. A crude calculation shows that to level up per capita public spending on R&D across the nations and regions of the UK to the levels currently achieved in London, the South East and East England, additional spending of more than £4 billion would be needed: £1.6 billion would need to go to the North of England, £1.4 billion to the Midlands, £420 million to Wales, £580 million to South West England and £250 million to Northern Ireland. Spending in Scotland would be largely unchanged.

These numbers give a sense of the scale of the problem, but equalising per capita spending is not the only possible criterion for redistributing funding.

We want people to explore other criteria that might guide thinking on where UK public sector and charity spending on R&D is generating the most value possible. The online tool accompanying this paper (see page 61) models different geographical distributions of public R&D spending obtained according to the weight attached to factors such as research excellence, following business R&D spending, targeting economic convergence and investing more where the manufacturing sector is stronger.

Importantly, we do not propose that UK R&D funding is assigned purely by algorithm. We have found that the scale of current imbalances in funding and the scale by which current spending fails to meet even its own stated goal of funding excellence are widely underappreciated. Our tool aims to inform and challenge, not replace existing systems.

To spread the economic benefits of innovation across the whole of the UK, changes are needed. These will include a commitment to greater transparency on how funding decisions are made in the government's existing research funding agencies, an openness to a broader range of views on how this might change and devolution of innovation funding at a sufficient scale to achieve a better fit with local opportunities.

Recommendations

The UK government's goal of increasing UK R&D intensity to 2.4 per cent of GDP combined with the widely observed 2:1 ratio of private to public funding for total R&D implies that UK public sector funding will increase from 0.55 per cent of GDP today to at least 0.75 per cent of GDP. This substantial increase in total spending gives us as a rare opportunity to change how R&D funding is assigned without creating any losers.

There should be a substantial regional devolution of innovation funding to remedy the regional imbalance in government R&D spending.

Recommendation 1. Twenty-five per cent of the uplift in public R&D funding should, in principle, be devolved to nations, regions and cities.

Recommendation 2. To achieve this, English cities and regions that can demonstrate the capacity to allocate R&D funding wisely should receive devolved funding through Innovation Deals.

Recommendation 3. Some English cities and regions will need to develop more capacity to be in a position to allocate R&D funding as effectively as possible; they should be supported in this until they can be awarded an Innovation Deal, with the funds notionally allocated to them being administered in the meantime by Research England.

We should create new science and technology institutions outside London, the South East and East of England to create a more balanced distribution of research infrastructure across the nation.

Recommendation 4. Cities and regions should consider using their devolved funding to establish translational research centres whose technological foci work with the grain of their local economies to support national missions.

Recommendation 5. New institutions should be set up in a way that creates new poles for innovation and productivity growth, attracting new private sector investment as well as supporting the existing business base.

Recommendation 6. City Centre Innovation Districts can link the skills and innovation resources of major research universities with new knowledge-intensive businesses, and can be nucleated with targeted investments and infrastructure development.

Recommendation 7. Advanced Manufacturing Innovation Districts – on sites with larger footprints, on the fringes of cities or in their satellite towns – should bring together facilities for translational research, diffusion of innovation and development of skills at all levels, attracting inward investment from international firms at the technology frontier, and rebuild the 'industrial commons'.

UK Research and Innovation (UKRI) should take a lead in driving regional R&D rebalancing, addressing the systematic factors that have led to the current geographical concentration of R&D spending

Recommendation 8. UKRI must take more corporate responsibility for the geographical distribution of its R&D investments and introduce a high-level Advisory Committee of the Nations and Regions.

Recommendation 9. Block grant funding for research and knowledge exchange in universities should be regionally weighted to reflect current regional public underfunding of R&D. The long-standing explicit preference to London in the Quality Research funding formula should be removed.

Recommendation 10. UKRI's Strength in Places Fund should be developed and expanded.

Recommendation 11. Innovate UK and Research Councils should retain their focuses on supporting existing businesses and the health of their disciplines, but should also monitor the regional distribution of their funding, particularly as it impacts on skills.

Recommendation 12. Government departments should take more account of the regional distribution of their R&D spending – for example, through the National Institute of Health Research – and be more responsive to the research agendas and needs of the UK's regions and nations outside London and the South East.

1

Introduction

As the UK emerges from the unprecedented economic crisis the COVID-19 pandemic has caused, the strength of the UK's research base should be one of the foundations for recovery. But just as the economic crisis will emphasise existing weaknesses in our economy, our research base will not be able to make its full contribution to the recovery unless its own imbalances and shortcomings are addressed.

The UK went into this crisis with serious economic and political problems. The decade of stagnation in productivity growth since the global financial crisis led to stalling wages and persistent fiscal difficulties for the government. Enduring disparities between different parts of the UK in economic performance, in household incomes and in health outcomes have contributed to a sour politics of national disunity.

The UK's science base has not been effective enough as a driver of economic growth and national well-being. There is much that is excellent about it; it performs very well for its size, particularly as measured by conventional academic measures like citations.[1]

But it suffers from three shortcomings. Its overall scale is too small for an economy of the UK's size, it is relatively weak in translational research and industrial R&D, and it is too geographically concentrated in already prosperous parts of the country which are often at a distance from where business conducts R&D.

The strength and quality of the UK's research base remains a source of national advantage, and it could play an important role in dealing with the nation's problems. But we must address these shortcomings – of scale, lack of translational focus and regional over-concentration. This paper quantifies these shortcomings and suggests how we might remedy them. It also invites the reader to suggest their own remedies while appreciating the scale of the interventions required to achieve their desired outcomes.

1.1 The UK's unbalanced R&D landscape is reflected in its unbalanced economic performance, and we've chosen it to be this way

The UK has two strengths of economy. London, the South East and parts of the East of England are among the most productive regions in Northern Europe. Meanwhile the economies of the Midlands, the North and much of South West England, together with Wales and Northern Ireland, having been largely surpassed by the parts of Germany that formerly made up communist East Germany, now have more in common with Southern Europe. Only Scotland sits in between.

The way the government invests in R&D is similarly imbalanced, with a disproportionate share being spent in London, the South East and parts of the East of England. Investments to boost productivity are focused on those parts of the country that are already the most productive.

To the extent that government R&D spending is a key part of industrial strategy, it is currently acting as an anti-regional policy, exacerbating the existing imbalances in economic performance. This is a result of choices that have been made over several decades.

At a time when even higher expectations are being placed on our research base as a driver of economic recovery, we need to re-examine those choices, recognise that we can do things differently and appreciate the scale of the changes required.

1.2 Innovation, R&D and geography

Economies grow because productivity increases – people discover new and better ways of doing things, they work out how to make new products and provide new services that generate value; in short, they innovate. Much of this innovation, such as the development of new medicines, faster computers or more efficient motors, is intrinsically technological. Other kinds of innovation – in how businesses are organised or how services are delivered – are less obviously technological in character, but they often deliver the greatest value to the economy and society by applying, testing and rapidly improving technologies.

R&D is not the only source of innovation, but it provides a formalised, funded and structured way of creating new products and developing new processes. Consistently through history, we have seen that such innovations generate economic and social value. The argument for supporting R&D, rather than leaving it entirely to business, is largely that individual businesses are not able to capture the full benefits of the R&D that they carry out. Since those benefits spill over to society more widely, it is wise for society (through government) to fund and incentivise such investment.[2] In the absence of such support, business investment in R&D will be less than optimal in terms of benefits for the wider society.

There has always been a geographical dimension to these knowledge spillovers and, therefore, to attempts to promote innovation.[3] Patents have long been granted and enforced nationally and the extension of their reach included in trade agreements. National governments and institutions remain, by far, the largest funders of R&D even as funding by pan-national bodies such as the EU increases. Most charitable foundations for science fund with preference to their own nations.

We are all used to the national politics of R&D funding that stem from the geography of knowledge spillovers, but far less attention has typically been paid to regions within nations, especially within the UK.

The mechanism of knowledge spillovers is well studied. Knowledge may be carried in the heads of employees moving from one job to another, or it may be developed in networks of specialised R&D-intensive firms supplying innovative goods and services to each other within a given region. This is the basis of the idea of clusters – and the related notion that geographical specialisation in particular industries or sectors promotes knowledge spillovers.

The idea of an 'innovation system' refers to the complex of institutions – in both public and private sectors, including places where R&D is done – where skills and knowledge are transmitted and ideas and techniques are shared, both informally and formally. We can talk about innovation systems at the regional or city level as well as at the national, or indeed supranational, level.

We have some concrete evidence that variations in R&D and wider innovation capacity between regions lead to differences in regional economic performance. Evidence from patent citations in the USA shows that spillovers are highly localised, falling off rapidly with distance beyond 25 miles.[4] There is evidence of a strong connection between the location of corporate R&D and the presence of public sector R&D. For the pharmaceutical industry, the effect is strong, with the biggest effect arising with separations of 10km or less; for chemicals the effect persists up to 80km, with stronger interactions at smaller distances. The effect is weaker in the vehicles and machinery sectors.[5]

Evidence from the USA at the county level demonstrates that universities have important long-run growth effects on their local economies,[6] with large firms (rather than university spin-outs) contributing most to the employment growth resulting from university innovation. Also, a study carried out in Finland shows that the distance to the nearest technical university influences how many people take up an engineering education and the amount of innovative activity as measured by patenting.[7]

The quality of management practices is also influenced by the proximity of sources of skilled people. An international study demonstrated that firms that are located further away from universities have workforces that are less skilled and poorly managed, with significant worsening beyond a half an hour of driving time.[8]

While the correlation between a poor skills base and poor economic performance is clear, the direction of causality is less obvious.[9] Economically underperforming places could have poor skills because their productivity is low. In this view, places can get locked into an equilibrium where a low productivity business base doesn't demand skilled people, resulting in a poor supply in response and making it even more difficult for those firms to raise productivity.

This vicious cycle can be broken by driving up the innovation intensity of a region, increasing the demand for skilled people. The resulting pool of skilled people attracts firms who can use their skills to grow and, in turn, expand and create more demand for skilled people. In this idealised cycle, while later investments are easy for the private sector to justify, the initial boost in innovation intensity is difficult to justify and much more likely to occur if funded by the state.

1.3 Revisiting the way we allocate R&D

Returning to the UK's very concentrated pattern of public R&D investment, we ask how this situation has arisen. The answer is not simple.

Choices and spending decisions are made by different people in different parts of the funding system. We do not believe that the current situation is the result of any long-term deliberate bias, but argue that the processes for assigning funding have failed to recognise their own inadvertent biases and failed to introduce reforms that would limit or undo these.

Some of the imbalances stem from significant discrete funding decisions with long-term consequences, such as where a large facility should be situated. These decisions are most amenable to study but probably only a small part of the cause of regional imbalance in R&D spending. Rather, much of the imbalance likely arises from the aggregation of many small decisions, the entirely unconscious outcome of which is a persistent spatial bias. A key feature of this is that small initial advantages in certain places can grow over time to become large ones as excellence stemming from earlier investment decisions is reinforced.

We will discuss the UK government's R&D funding system in detail, covering the way capital spending, block grants, project-based research grants and tax incentives come together to support the UK's innovation system. One corollary of the complexity of the system is that there are many possible interventions to change the shape of the UK's R&D landscape.

Comparison with other countries makes it clear that it is possible to do things differently. France, for example, also has a geographically concentrated R&D system, but in contrast to the UK, there is a close relationship between where the public and private sectors invest and a large number of areas where both public and private sectors invest heavily. Regions of France have some discretion to invest devolved funds in R&D in the hope of overturning accumulating disadvantages. In Germany, R&D has been used much more purposefully as a tool of regional economic development and national convergence.

1.4 How to achieve a more balanced distribution of R&D funding

The unbalanced geographical distribution of R&D spending is not a given. It is a result of policy choices, and those choices can be made differently to achieve better outcomes.

R&D is carried out by both the private and the public sectors. Private sector investment is substantially larger than public sector investment – by a factor of two at the national level for countries like the UK as a rule of thumb. However, the relationship between public and private sector R&D at the regional level is rather variable.

The most R&D-intensive regions of the UK – in the East of England and the South East – have high levels of spending from both public and private sectors. In these very prosperous regional economies, public and private sector spending reinforce each other, leading to vibrant innovation systems and high productivity. These provide models for the rest of the UK to aspire to.

Other regions – particularly the Midlands and the North West – have relatively high private sector investment in R&D but low levels of public sector investment. We argue that these regions have straightforward opportunities to supercharge their innovation systems, through backing the decisions of the private sector with additional public sector funding.

The poorest and least productive parts of the country – Yorkshire and the Humber, the North East of England, Wales and Northern Ireland – have relatively weak innovation systems with low investment in R&D from both public and private sectors. Here, more focused efforts will be needed to raise both kinds of investment to allow these regions to achieve their full economic potential.

Finally, in Scotland and, especially, London, high public sector investment in R&D is not matched by the private sector. Here, there needs to be a focus on understanding and removing barriers to private sector investment together with scrutiny of the value for money of public investment.

How can we rebalance the distribution of R&D? We need to be clear about how much weight we give to different criteria for allocating funding. We might focus entirely on maximising the scientific excellence of the research system; this is the current stated goal (though we argue that this ideal has been poorly fulfilled). We could give more weight to the goal of equity for its own sake; we could direct R&D investment to where the economic performance is in most need of improvement; or we could seek to support particular economic sectors, such as manufacturing.

We do not claim that there is a single ideal combination of criteria. Our goal instead is to make explicit the choices that are made and to highlight that different ones are possible. Our online tool makes it possible for the reader to explore how the geographical distribution of R&D would change as one gives different weights to these different goals.

Of course, given the complexity of the R&D funding system, achieving these different outcomes is not straightforward. We conclude with some concrete proposals as to how things could be done differently. Our focus is on the distribution of government investment in R&D, because that's where public policy can have a direct effect.

Our recommendations fall into three different groups.

- **Devolution of substantial research and innovation funding to the devolved nations and regions of the UK**. A substantial fraction of the additional funding committed by the government to R&D should be devolved on the basis of Innovation Deals, through which arms of English regional government, such as combined authorities, should demonstrate a capacity to allocate funding well.
- **Creation of new institutions in those regions that currently have low R&D intensities**. These should have a focus on translational research and the diffusion of innovations, with the goal of rapidly increasing the innovation capacity of low-productivity regional economies.
- **Changes to the way the national government science funding agency, UK Research and Innovation (UKRI), operates**. The culture of UKRI has not sufficiently taken into account the role of public R&D spending on regional economic development, and this needs to change through better data and new avenues for accountability. New funding instruments focused on place – such as the Strength in Places Fund – should be developed and expanded. Elements of existing funding formulae should be re-examined, in particular the funding preference in the Quality Research (QR) formula for institutions in London.

Section A: Analysing the UK's regional R&D imbalances, and the funding system that has led to them

How is R&D funding in the UK distributed regionally, and how does this compare with other countries? In this section, we take a detailed look at the statistics for both public sector and private sector R&D spending, to quantify the UK's regional imbalances. These imbalances are of long standing, so to understand their origin, we need to look in some detail at the way the UK government funds R&D as well as the wider policy context within which this system has evolved.

2

The UK's unbalanced R&D landscape

The UK lags in its overall R&D intensity compared with other developed economies, its R&D is highly geographically concentrated, and there is a mismatch between where the private sector allocates R&D funding and where government R&D spending is focused. Here, we quantify these imbalances and compare the UK's situation with that in other developed nations.

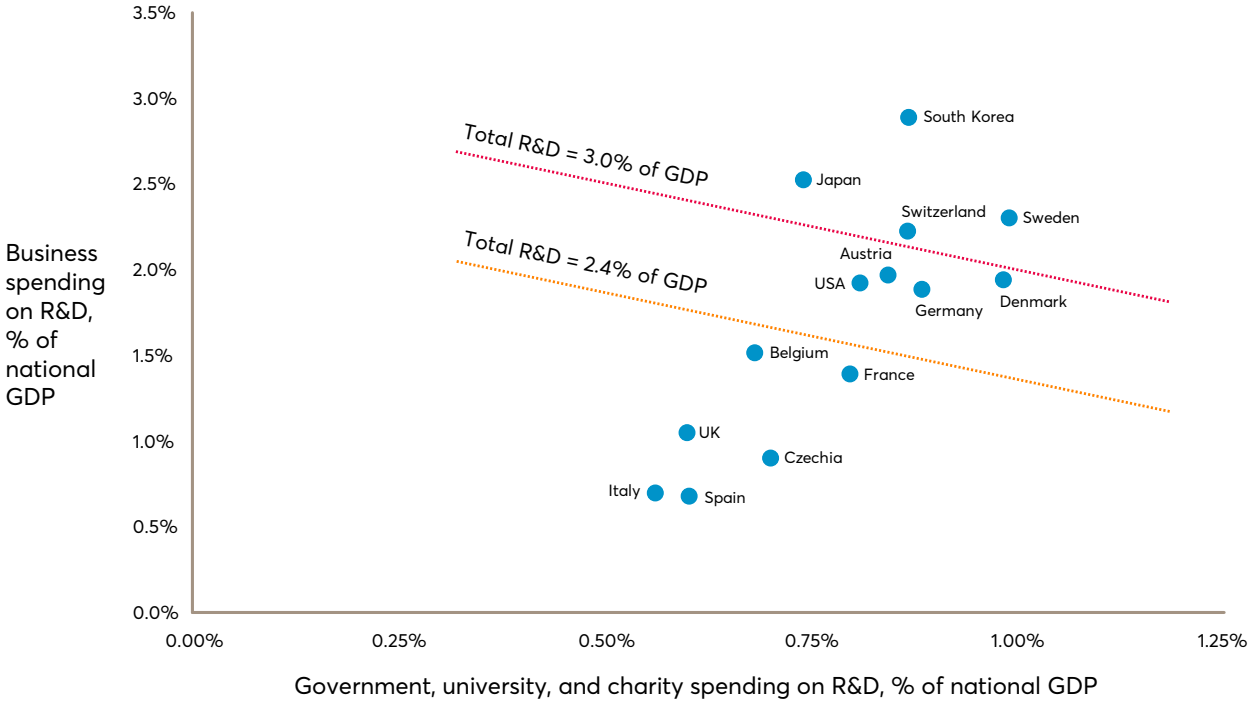
Analysis of patterns of R&D within the regions of Europe's largest countries shows the UK to be an outlier. In France, public sector R&D spending by region aligns well with private sector R&D spending. In Germany, public sector R&D spending is used as a tool to stimulate growth in regions with weaker economies. But in the UK, public sector R&D seems to perform neither task. Just looking at the data suggests that UK public sector R&D spending is designed to stimulate growth in those regions that are already the most productive.

2.1 The overall R&D intensity of the UK economy is low in comparison to other developed nations

In all developed countries, R&D is funded and carried out by a combination of the public and private sectors. Additional spending by charities is, for this paper, included within public sector spending; one of our key arguments is that market-led R&D investment by business is poorly matched by non-market-led investment, which includes charity spending.

The intensity of an economy's R&D efforts can be measured by the ratio of R&D expenditure to overall GDP, and it is instructive to compare this for both public and private sector spending. This is plotted in Figure 1. To be more precise, we separate market-led from non-market-led research. Market-led R&D is carried out in business, responding to business priorities – though as we shall see, the state often contributes to the cost of this research, reflecting the wider social benefits that are expected to flow from it. Non-market-led research is carried out in universities and research institutes, and this may be funded by the state directly, via universities, or by charitable foundations.

Figure 1: International spending on R&D in 2007-2016 (split by market-led (business) and non-market-led (government, university and charity))



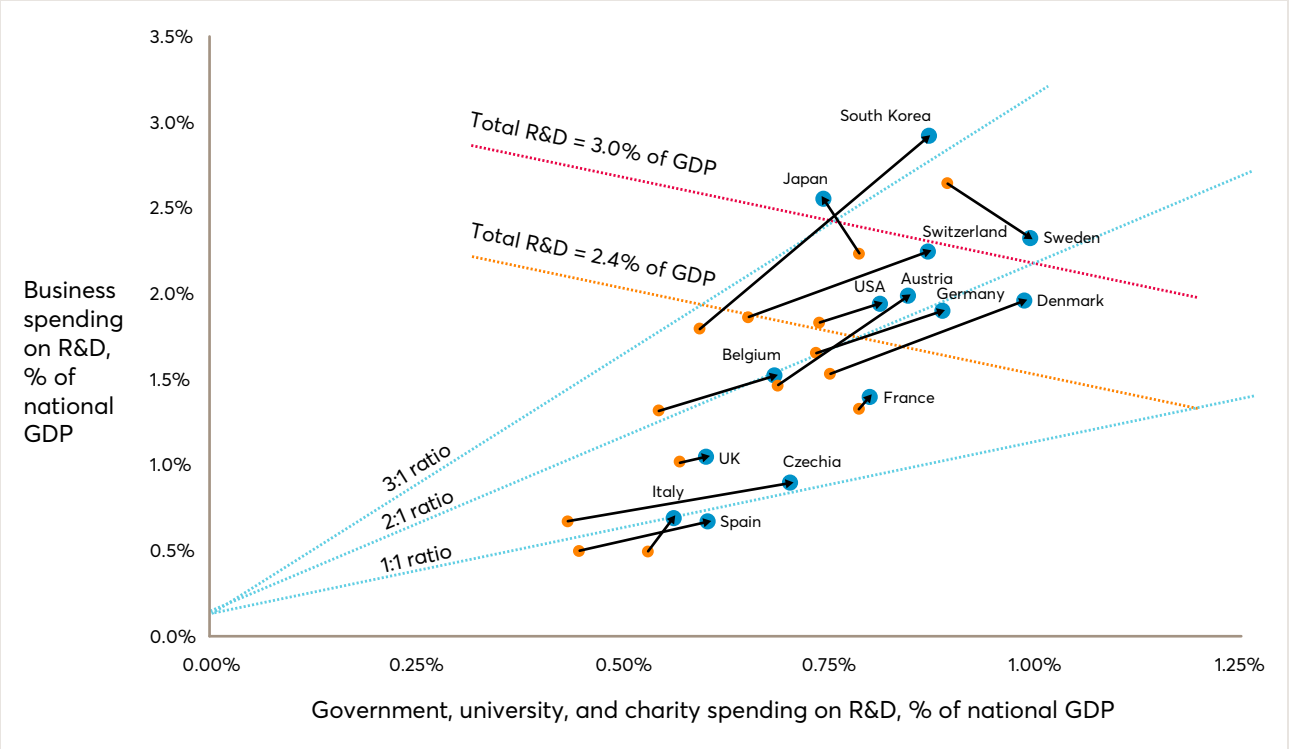
The average R&D intensity of selected nations, split between market-led and non-market-led sectors, between 2007 and 2016. R&D intensity is expressed as the ratio of R&D spending to total GDP. Source: Eurostat table rd_e_gerdreg.

The average R&D intensity of OECD countries is currently 2.37 per cent (2017 figures).[10] South Korea is a high outlier, with an R&D intensity of 4.55 per cent. A wide range of developed countries have R&D intensities between 2 and 3 per cent.

The UK has an R&D intensity of 1.66 per cent, placing it among a group of relative laggards, including Czechia, Italy and Spain. There is now a consensus that the UK should increase its R&D intensity, and the government has set a target of achieving an R&D intensity of 2.4 per cent by 2027. This is an ambitious target in that it represents a substantial 44 per cent uplift. But, as the plot in Figure 1 makes clear, such an increase would by no means place the UK in the top league of R&D-intensive nations – even assuming that other nations do not themselves increase their own R&D intensity.

In considering the policies necessary to increase a nation's R&D intensity, the split between market-led and non-market-led sectors is important. For a wide range of countries, including the UK, this hovers around a 2:1 ratio between sectors. The East Asian countries of Japan and South Korea achieve very high overall R&D intensities through a combination of higher state spending and a higher market/non-market ratio, which probably reflects fundamental differences in the structure of capitalism in those countries. On the other hand, this ratio is somewhat lower in Spain and Italy.

Figure 2: International spending on R&D, Change from 1997-2006 to 2007-2016 (split by market-led (business) and non-market-led (government, university and charity))



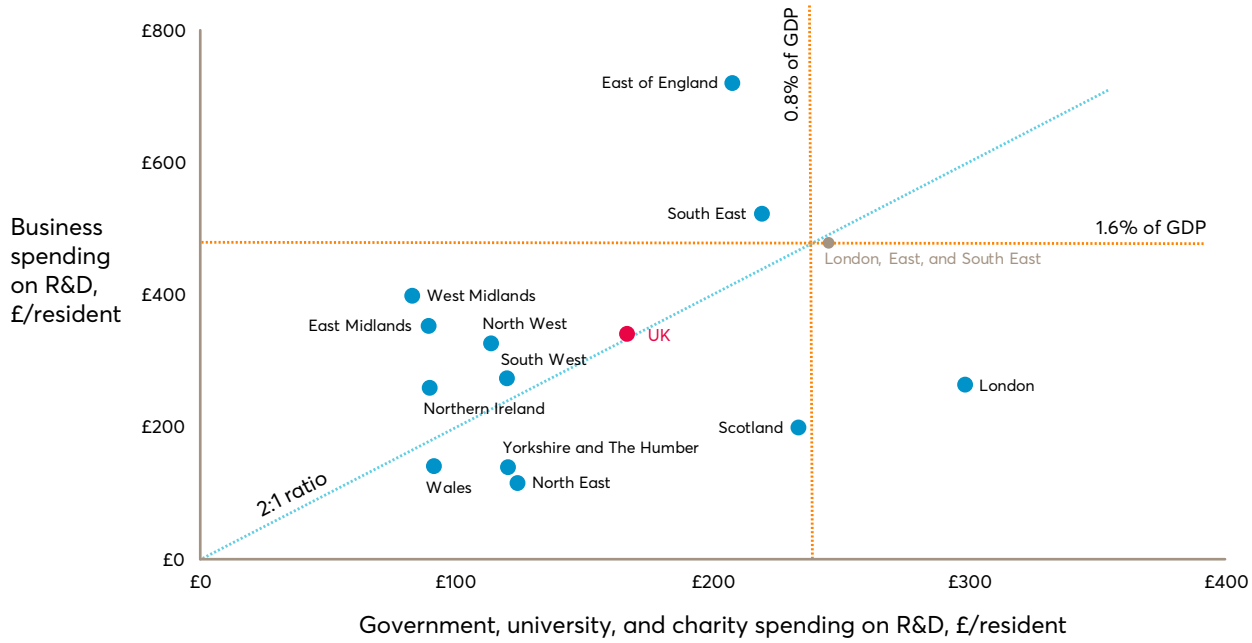
The change in R&D intensity of selected nations, split between market-led and non-market-led sectors, between the decade starting in 1997 and that starting in 2007. R&D intensity is expressed as the ratio of R&D spending to total GDP.

It is possible for countries to change their R&D intensity significantly over a decade. As Figure 2 shows, the most spectacular increase in the decades starting 1997 and 2007 was in Korea, but European countries such as Austria, Belgium, Denmark and Germany have seen significant increases too. In all these cases, increases in market-led R&D spending have been accompanied by increases in non-market-led R&D spending, with no substantial changes in the ratio between the two. The lesson for policymakers is that while it is right to attempt to design policy that maximises the private sector response to increases in public sector funding, it is unrealistic to expect any increase in overall R&D intensity without the public sector also being involved. Recent research strongly supports what we see weakly even in national aggregate data – it is the public sector that typically leads in any boost in R&D intensity, with private sector investment following behind as a result.[11]

2.2 The UK's R&D spending is highly regionally unbalanced

The overall R&D performance of the UK can be described as mediocre at best. But how is R&D distributed across the country? As Figure 3 shows, the distribution is highly uneven. Different regions have very different levels of public investment, and the ratio of public to private investment varies widely across the country.

Figure 3: Spending on R&D by NUTS1 region within the UK, 2016 (split by market-led (business) and non-market-led (government, university and charity))



Regional distribution of UK R&D spending by NUTS1 region, expressed per resident for the market-led and non-market-led sectors.

The South East and East of England stand out as highly research-intensive regions with high investment by the state combined with business investment exceeding what we would expect from a 2:1 ratio. London and Scotland stand out as recipients of above-average levels of state investment – substantially above average in the case of London – but with lower-than-average levels of business investment.

In the East Midlands and West Midlands together with North West England, business investment in R&D is at or above the UK average despite low levels of public support.

In contrast, Wales, Yorkshire and the Humber and North East England are regional economies with notably low R&D intensities in both the market-led and non-market-led sectors.

South West England and Northern Ireland sit between these two groups with similarly low levels of public investment but slightly higher private sector spending on R&D.

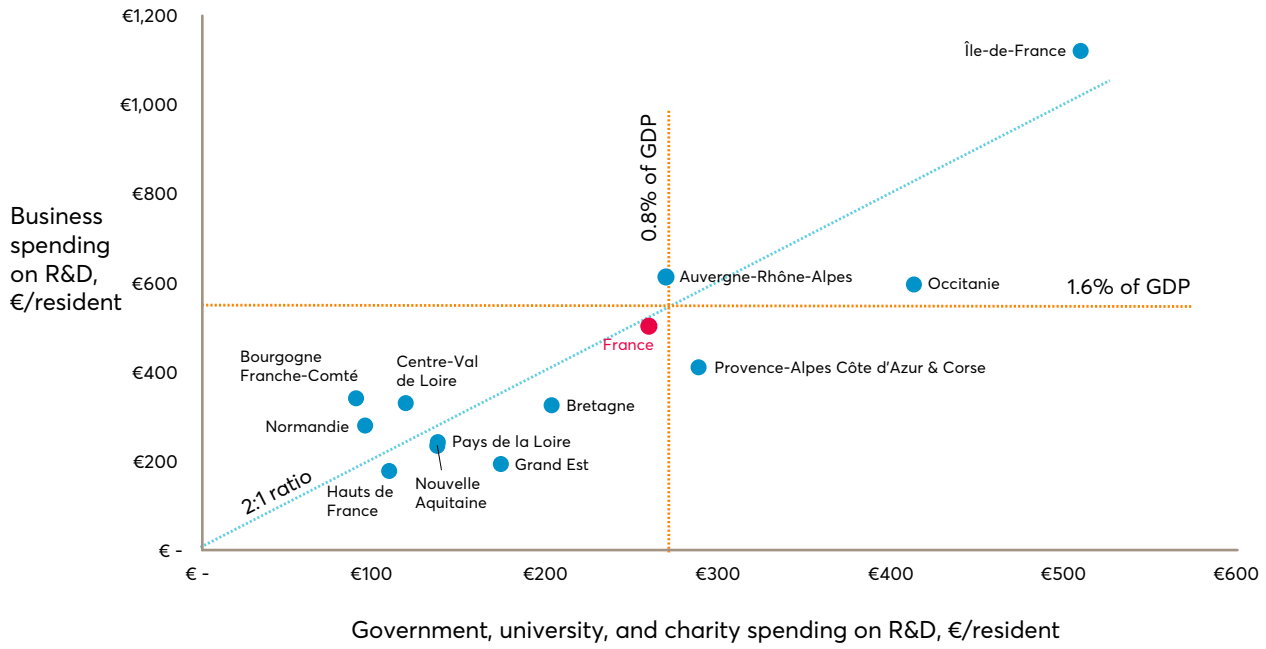
To judge whether this pattern of investment is unusual, it is informative to compare it with the same data for our largest neighbours, France and Germany.

Figure 4a shows the regional distribution of R&D spending in France. While there is a similar degree of regional concentration, with just four of around a dozen regions where total R&D spend is above the national average, there is markedly closer correlation between public and private spending. Unlike in the UK, the decisions of the French state on where to invest in R&D seem to be similar to the decisions made by French businesses. Two further differences to the pattern of R&D spending we observe in the UK are notable.

First, French regions with strong R&D activity are spread widely across the country, from Occitanie in the south-west to Provence-Alpes Côte d'Azur & Corse in the south-east and up to Île-de-France in the north-east via Auvergne-Rhône-Alpes.

Second, France has no regions (like London or Scotland) with a high concentration of public R&D spending that is not accompanied by significantly greater private spending on R&D. Paris (Île-de-France) is notably a centre of both public and private R&D spending in a way that the UK capital is not.

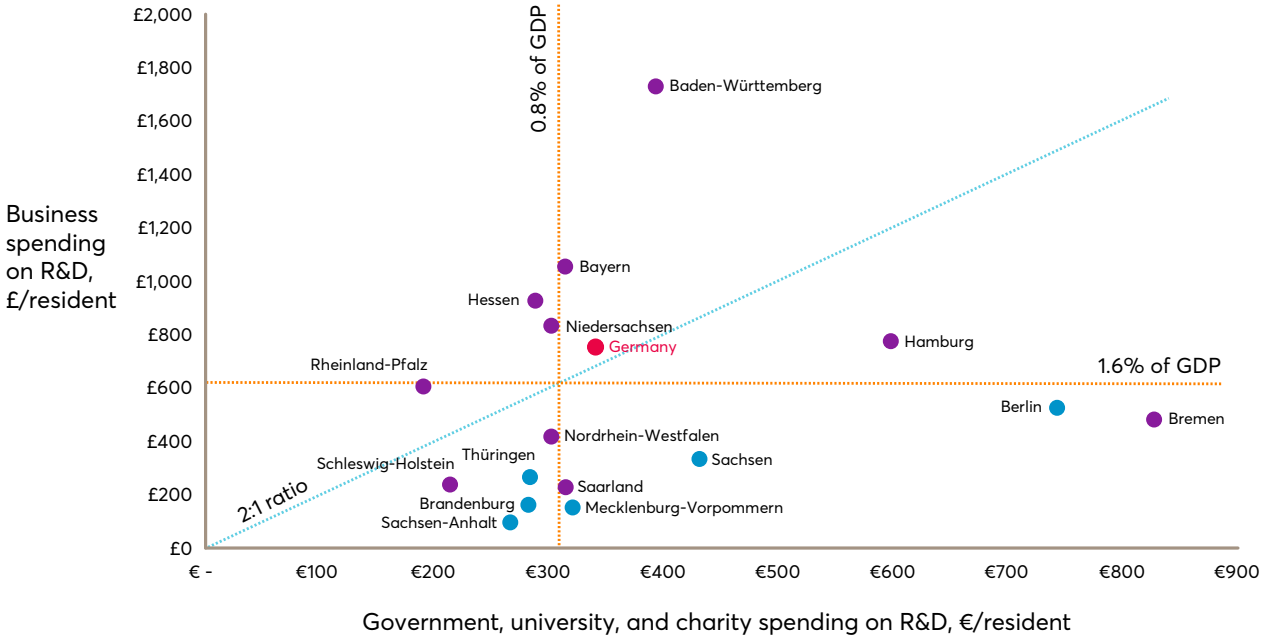
Figure 4a: Spending on R&D by NUTS1 region within metropolitan France, 2016 (split by market-led (business) and non-market-led (government, university and charity))



Regional distribution of R&D spending in France by NUTS1 region, expressed per resident for the market-led and non-market-led sectors.

The pattern is rather different in Germany, as shown in Figure 4b. It is best understood by labelling those regions formerly of East Germany separately to those formerly of West Germany. In all former East German regions, business R&D spending is well below the national average, though there has long been sustained investment in R&D by the public sector.

Figure 4b: Spending on R&D by NUTS1 region within Germany, 2015 (split by market-led (business) and non-market-led (government, university and charity))



Regional distribution of R&D spending in Germany by NUTS1 region, expressed per resident for the market-led and non-market-led sectors.

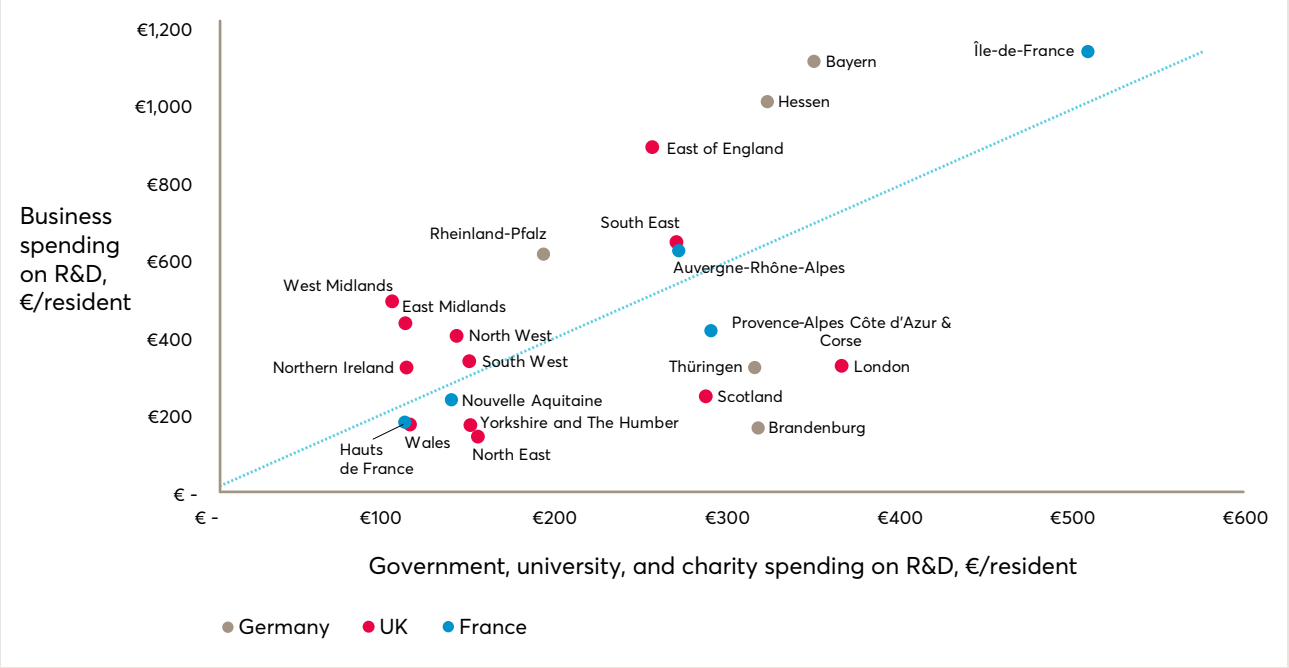
Public sector R&D investment has been used in Germany – both directly and indirectly via federal fiscal transfers to poorer states, who then choose to spend their money on R&D – to boost economic growth in regions with weaker economies.

Given the well-documented correlation with increased economic growth, it is reasonable to hypothesise that this pattern of R&D investment in Germany has played a role in the economic strength of East Germany overtaking that of the North of England in the past decade[12] and, thus, in the regional inequality of GDP falling in Germany while it has risen in the UK.[13]

2.3 The UK's weak and strong regions in an international context

Before moving on to consider whether regional imbalances in UK R&D spending are important, it is useful to put the UK's regional R&D in context by converting pounds to euros and comparing the amounts to spending similar German and French regions.

Figure 5a: Spending on R&D in NUTS1 regions of the UK compared with selected regions of France and Germany (split by market-led (business) and non-market-led (government, university and charity.) Data is 2016 for UK and France, 2017 for Germany.)



A comparison of R&D spending, expressed in € per resident for the market-led and non-market-led sectors, in UK regions and selected regions of France and Germany with similar levels of spending.[14] (Conversion is at market exchange rates in 2016: £1.00 = €1.26.)

The main features to note are that the East of England is as R&D intense, with a similar mix of public and private investment, as some of the most R&D-intensive regions of Germany – Hessen (home to Frankfurt) and Bayern (home to Munich).

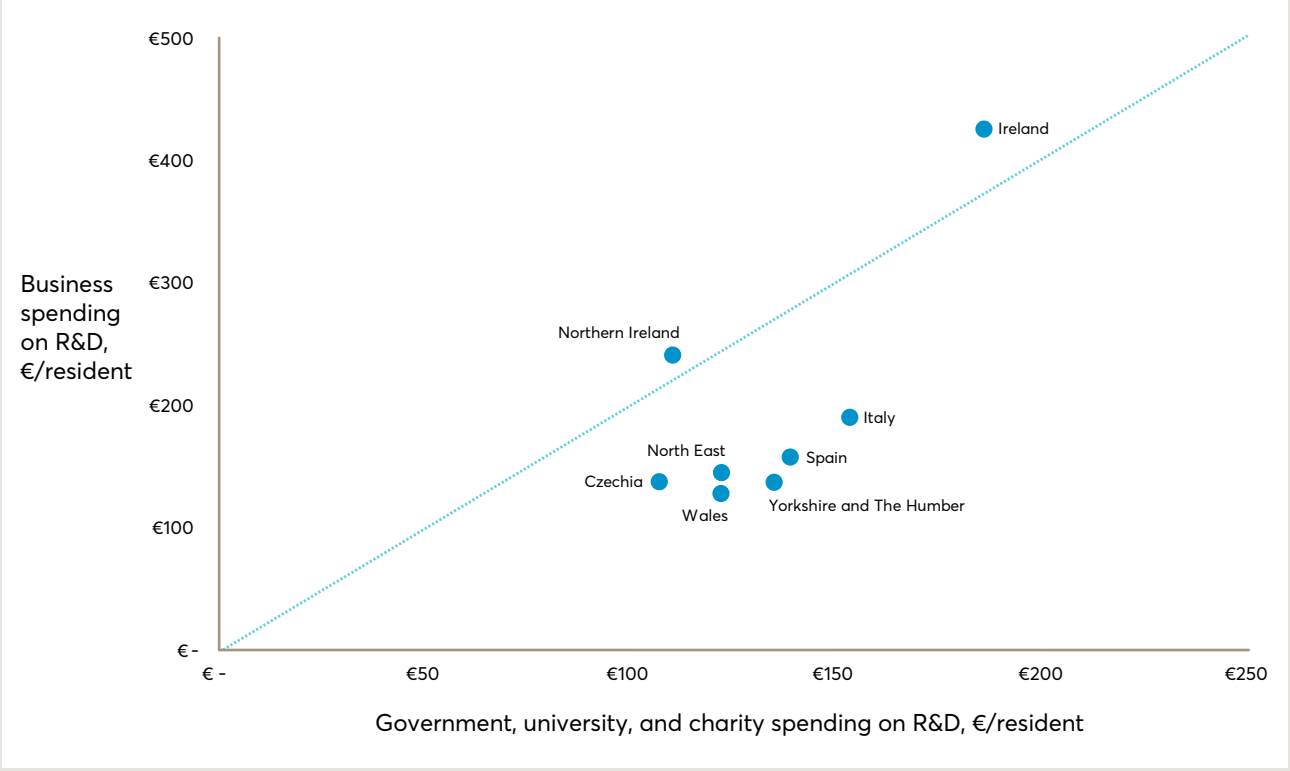
South East England is similar to France's third most R&D-intensive region, Auvergne-Rhône-Alpes (home to Lyon).

Scotland and London have R&D profiles most similar to East Germany, which is strange. High R&D spending in East Germany is a result of policy to boost economic growth in poor regions of the country, and yet Scotland and London are among the UK's most prosperous regions.

The UK's other regions show R&D profiles similar to the French regions situated away from its R&D hotspots.

The UK regions with the lowest R&D intensity are Wales, North East England, Yorkshire and the Humber and Northern Ireland. In Figure 5, we compare these regions with whole countries that have similar R&D intensities to give a sense of their position within Europe, with reference to Figure 1. We see that over the past decade all four regions have been similar to countries that we identified as having low R&D intensity – Czechia, Italy and Spain.

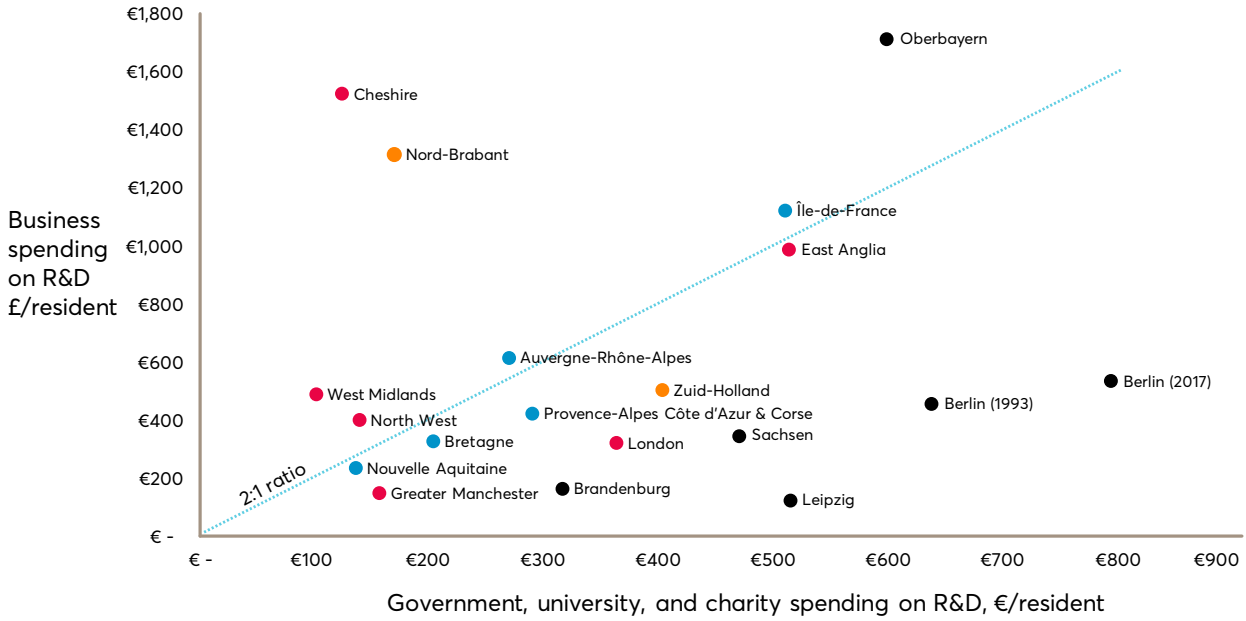
Figure 6: Average spending on R&D, 2007-2016 (split by market-led (business) and non-market-led (government, university and charity



A comparison of R&D spending, expressed in € per resident for the market-led and non-market-led sectors, in the less R&D-intensive regions of the UK and selected European countries. (Conversions are at market exchange rates.)

Finally, if we look at R&D spending at a finer level of geographical detail, regional disparities become even more marked. Figure 6 shows this at Nomenclature of Territorial Units for Statistics (NUTS) level 2 regions. East Anglia and the greater Paris region – Île-de-France – are very similar. Both are highly R&D-intensive regions with a 2:1 balance between business and public R&D. Oberbayern shows similar levels of public investment, but even greater business R&D investment. Cheshire and Nord-Brabant share the characteristic of having very high business R&D spending, but have lower public investment. Greater Manchester has a similar level of business R&D to the former East German regions of Brandenburg and Leipzig; but, in common with other former East German regions, these have received substantially greater public investment in the attempt, post reunification, to boost their economies towards the level of the former West Germany.

Figure 7: Spending on R&D by selected regions within the UK, France, Germany, and The Netherlands (split by market-led (business) and non-market-led (government, university and charity))

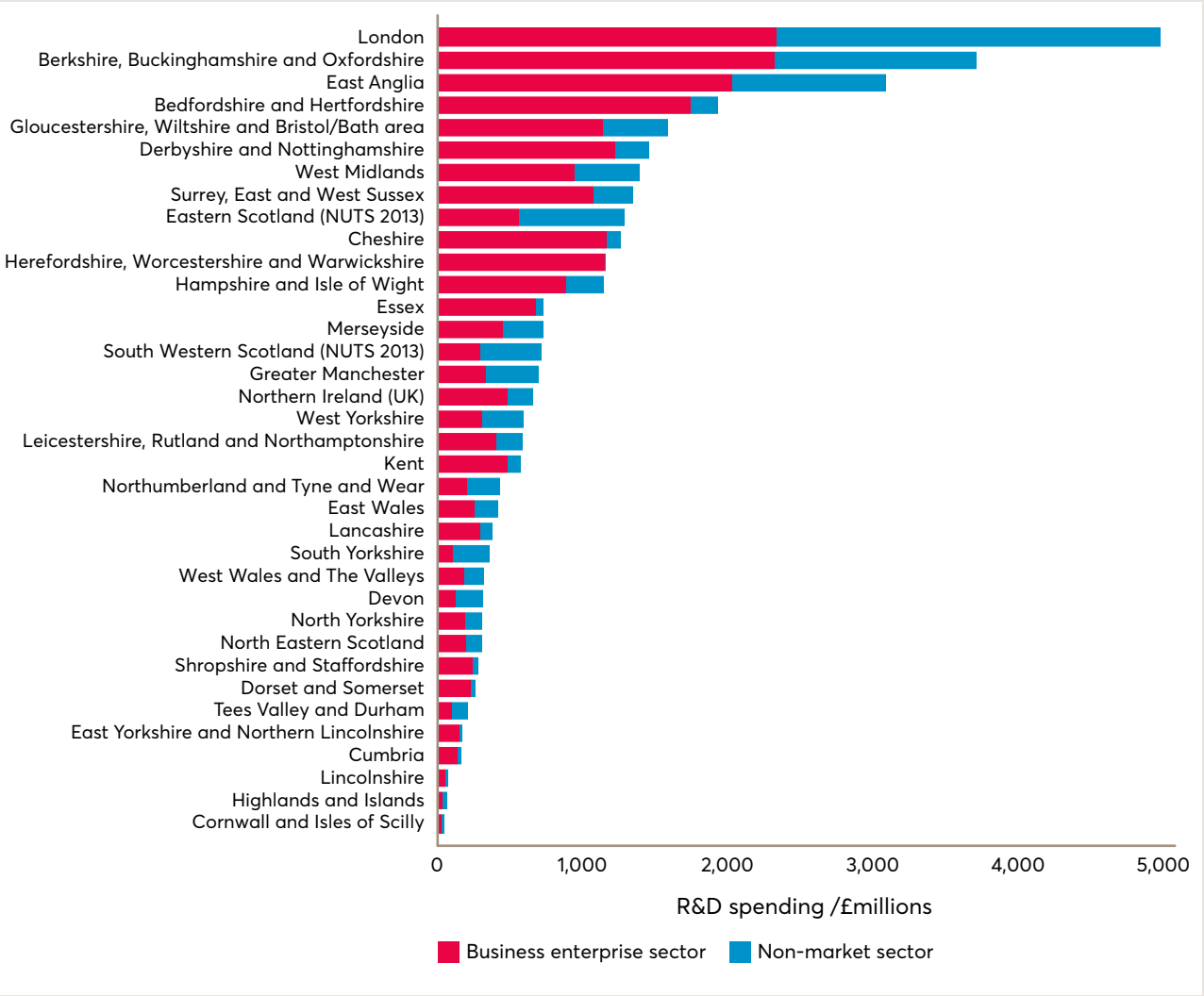


Regional distribution of R&D spending in selected NUTS2 regions, expressed per resident for the market-led and non-market-led sectors. London is represented at NUTS1 level to make a meaningful comparison with Île-de-France, which is a single region at NUTS levels 1 and 2. Source: Eurostat table rd_e_gerdreg, Dutch Central Bureau of Statistics 'R&D-uitgaven naar provincie en COROP-gebieden, publiek en privaat', and MESRI-SIES 'Dépenses intérieures de R&D des entreprises et des administrations par région en 2016'. Data is for the most recent year, 2016 or 2017, unless otherwise marked.

It is at NUTS2 level that the UK's regional R&D disparities and the imbalances between public sector and private sector spending are most marked. For example, London and the two subregions containing Oxford and Cambridge account for 46 per cent of all public and charitable spending on R&D, but just 31 per cent of business R&D and 21 per cent of the population.

As Figure 7 shows, below these three outliers, we find nine subregions with respectable levels of total R&D. These include Bristol, Hampshire, Derby, Bedford, Surrey and the West Midlands, Worcestershire and Cheshire. With the exception of East Scotland, all these subregions are characterised by above-average ratios of private to public sector R&D spending. Two subregions stand out for significant private sector R&D and almost no public sector activity – Cheshire, with its historic concentration of chemical and pharmaceutical industries, and Warwickshire, Herefordshire and Worcestershire.

Figure 8: Business and public sector R&D by NUTS2 region (except for London, presented at NUTS1 level).



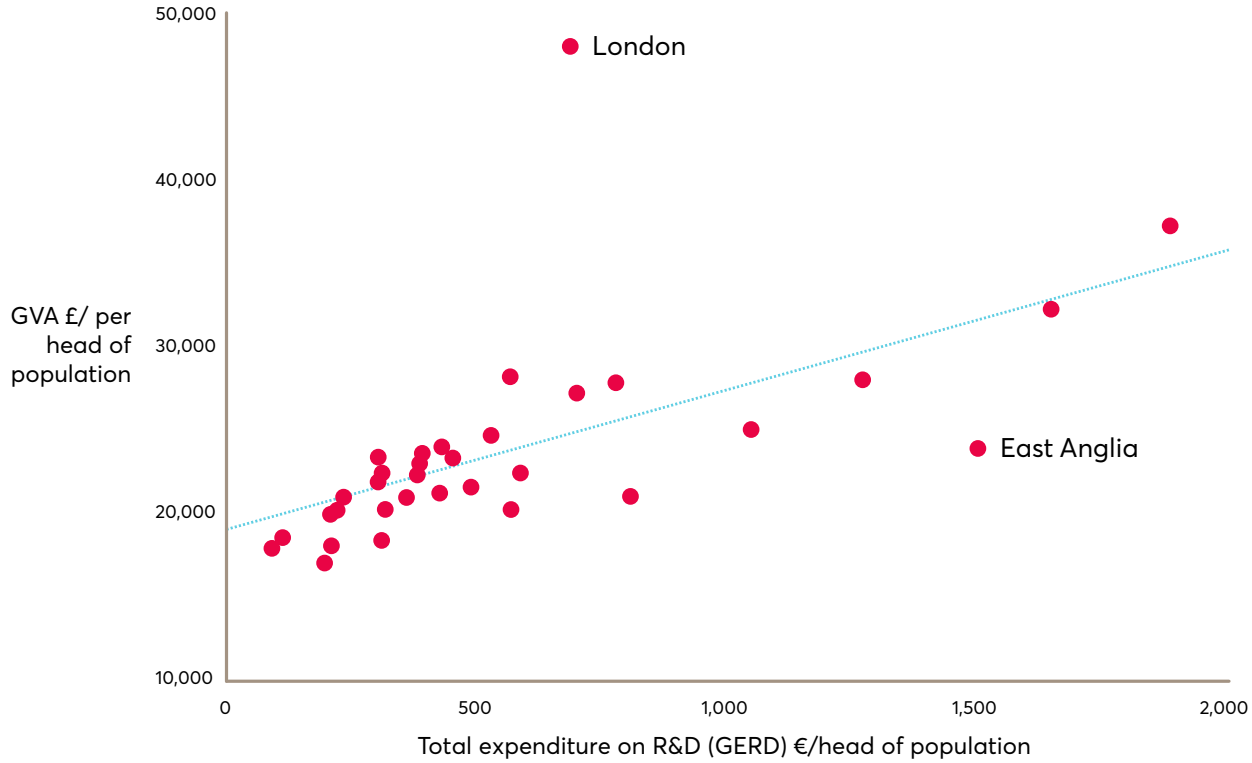
2016 data, Eurostat

Below this, we have a long tail with much lower investment in R&D, including public and private investment. This includes all of Wales, Northern Ireland, the North of England, Lincolnshire, South West England beyond Bristol, and Kent and Essex in the South East. As we will see, there is a strong correlation between those parts of the country which have been economically underperforming and this long tail of R&D investment.

2.4 The disparities in UK regional performance are a mirror of its unbalanced R&D spending

The UK is highly unequal in its regional economic performance – on most measures, it is one of the most regionally unbalanced countries in the industrialised world.[15] This is reflected in a strong divergence of growth in UK cities: small cities in the south of the country have grown fast, while the large formerly industrial cities in the North and the Midlands have grown much more slowly.[16]

Figure 9: GVA per head plotted against total R&D spending per head, by NUTS2 region (except London and Scotland, represented at NUTS1 level)



Gross domestic expenditure on R&D (GERD) data from Eurostat, GVA from Office for National Statistics.

This inequality in performance quite closely mirrors the imbalances in R&D spending by region. Figure 8 shows a strong correlation between total R&D spending per head and regional productivity, as measured by gross value added (GVA) per head. There are two obvious outliers – London, which has a very high GVA per head, and East Anglia, which despite substantial R&D spending has only an average productivity level.

Of course, we cannot deduce from this any simple and automatic relationship between regional productivity and R&D intensity. Highly productive regional economies might, for example, be characterised by the presence of international companies at the technological frontier with an R&D presence in those regions independent of the productive activities which generate value. But given the well-accepted connections between innovation and productivity growth, this association should not be dismissed.

The data in this section poses two important questions.

1. Does it matter that public sector R&D spending is geographically concentrated in ways that private sector R&D spending is not?
2. If this imbalance contributes to regional inequality of GDP, does this matter?

We believe that the answer to both questions is yes. There is considerable evidence that spillovers from publicly funded R&D are captured most strongly by nearby firms and by firms in closely related fields.[17] Therefore, the geographical mismatch between the location of public sector spending on R&D and private sector spending on R&D implies that potential spillover benefits from publicly funded research are being lost.

There will be an extra loss if, as we suspect, the locational mismatch implies that publicly funded research is not in the same fields as privately funded research or not sufficiently focused on product development.

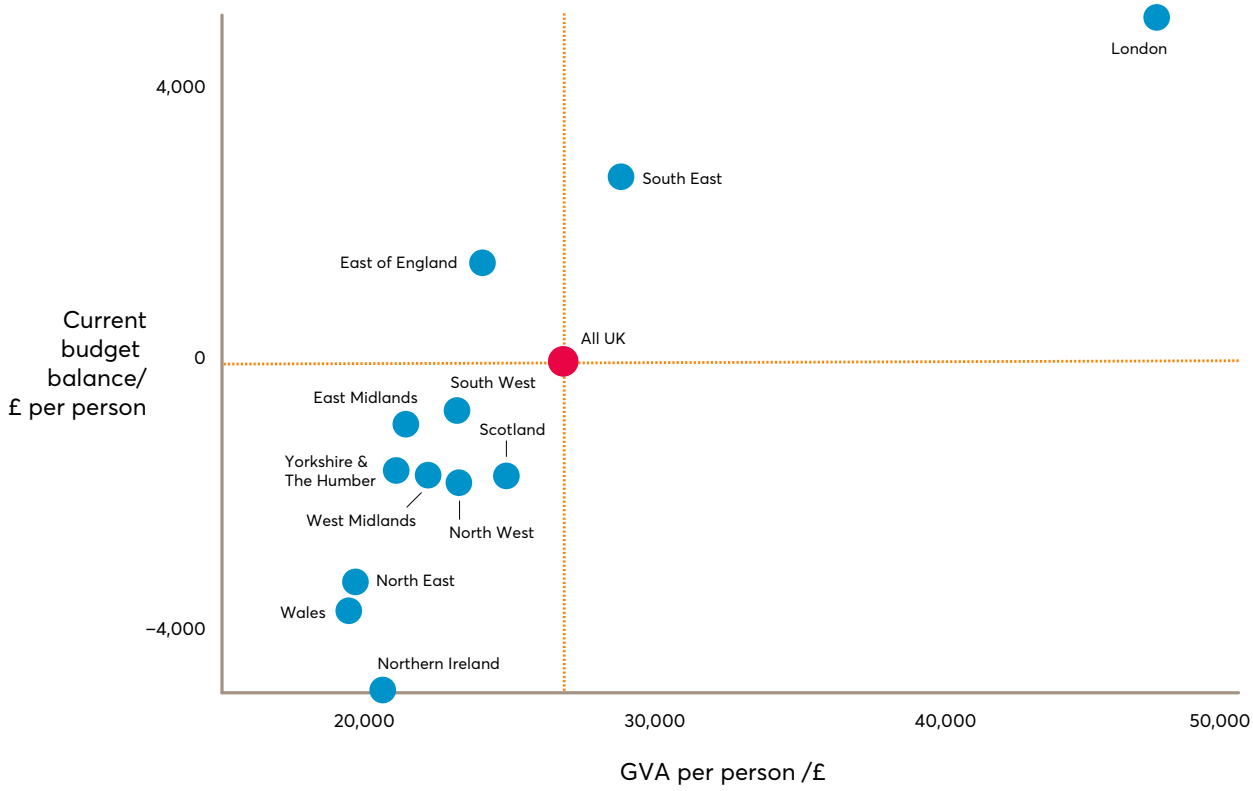
Sacrificed spillovers leading to less private sector innovation and productivity growth translates into slower growth and lower living standards for the UK as a whole. But the second question asks whether the inequality of regional GDP matters in itself.

The answer to this question is less clear. The UK maintains very substantial fiscal transfers between the regions, largely through the provision of universal public services paid for through national taxation or via direct fiscal transfers to devolved governments according to a formula designed to make similar services affordable in those nations. This means that inequalities in standards of living across the regions (as measured, for example, by gross domestic household income) are not as marked as the inequalities in productivity.

This system, whereby the more productive parts of the country (most notably London and South East England) pay for public services in less productive parts of the country, is illustrated in Figure 9. While such fiscal transfers are an essential component of national solidarity, we believe it is right to have a plan to reduce them where possible.

Arguably, living on taxes raised a long way away is demoralising, while paying taxes in a productive economy which are spent elsewhere is frustrating. Since we believe that better allocation of R&D money would lead to greater aggregate growth and to stronger growth in regions with economies that are currently weaker, reducing their reliance on fiscal transfers from more prosperous regions, we see such investments as being an excellent way to improve both the prosperity and common purpose of the UK.

Figure 10: Most of the UK is below average in economic performance, and only three regions contribute more to government than they receive. The difference between government revenue and current expenditure for NUTS1 regions is plotted against their regional productivity (GVA per person), both expressed per head of population.



Office for National Statistics data.

3

How government funds science, how decisions are made and why this leads to the imbalances we see

As we've seen, R&D spending in the UK is highly regionally unbalanced. How has this situation arisen? To answer this question, we need to understand the way in which the government funds R&D. This is a complex system with many different agencies often operating to different agendas, so the imbalance has emerged gradually rather than by design.

However, we can identify three broad factors that have contributed to the imbalance.

1. There has been a conscious process of focusing resources on fewer centres as the best response to squeezed funding, to maintain excellence (as defined by academic criteria).
2. There is some evidence of a home bias by which proximity to the place where decisions are made provides a small advantage.
3. Some very big capital investment decisions have been made on the basis of poor processes.

These specific factors combine with a more general tendency in science funding for advantages to become entrenched and magnified through the 'Matthew effect' – places with strong reputations and good infrastructure attract the best scientists, who in turn attract even more competitively awarded funding.

We are not the first to recognise this regional imbalance in research funding, and there have been previous attempts to counteract it. But these attempts have been on far too small a scale to have a material effect. For example, in the 2000s, regional development agencies (RDAs) allocated some R&D funding in England on a regional basis, but this amounted to only 1.6 per cent of the government's total investment.

We failed in the past to remedy regional R&D imbalances, because we didn't really try.

3.1 Themes in UK science policy

As a background to understanding why government support for R&D has become so regionally unbalanced, we need to look at some long-term trends in UK science and innovation policy.

One theme has been the conscious and deliberate withdrawal of the state from near-market or translational research since the 1980s. As the historian Jon Agar writes:

The critical point was that Guise [Thatcher's science policy advisor] and Thatcher regarded state intervention as deeply undesirable, and this included public funding for near-market research. The ideological desire to remove the state's role from funding much applied research was the obverse of the new enthusiasm for 'curiosity-driven research'.[18]

It is this tendency that has resulted in the unusually high reliance of UK public sector science on the university sector. A consequence of this is that the mostly widely accepted criteria for what constitutes good science have come to be predominantly academic ones – for example, the (contested) notion of 'research excellence' and the use of metrics like citations, which measure the influence of research on the academic community.[19] Meanwhile, criteria such as 'internationally excellent in significance' in the Research Excellence Framework (REF) favour research that addresses global challenges rather than those related to the place where the research is done.[20]

On this basis, it can be argued that the policy has been a success; the government regularly publishes international benchmarks of the quality of UK science, thus defined, that show strong performance. According to the 2016 study,

In 2014, the UK represented just 0.9 per cent of the global population, 2.7 per cent of R&D expenditure, and 4.1 per cent of researchers, while accounting for 9.9 per cent of downloads, 10.7 per cent of citations and 15.2 per cent of the world's most highly-cited articles.[21]

A natural corollary of the emphasis on 'research excellence', as measured by academic criteria, has been an explicit strategy in the face of funding cuts to concentrate research, with more funding given to fewer places, motivated by the view that this would lead to centres with the 'critical mass' to sustain better research. The University Grants Committee in the 1980s recommended a policy of driving selectivity and concentration by research assessment exercises, linking these to block grant allocations of funding. Meanwhile subject-specific reviews, like the 1987 Oxburgh report on Earth Science departments, recommended concentrating research funding on a few of the largest and highest-achieving departments.

Already by 2003, the evidence in favour of the 'critical mass' arguments for further research concentration was seen as weak, and such a policy was perceived as having tangible downsides in terms of exacerbating already existing regional imbalances.[22]

In fact, the outcome of the 2008 Research Assessment Exercise reflected a spread of research quality across institutions and regions that surprised some proponents of research concentration. In response, the formula that was used to translate results to funding allocations was changed to make it even more selective.[23]

3.2 The UK's complex funding landscape

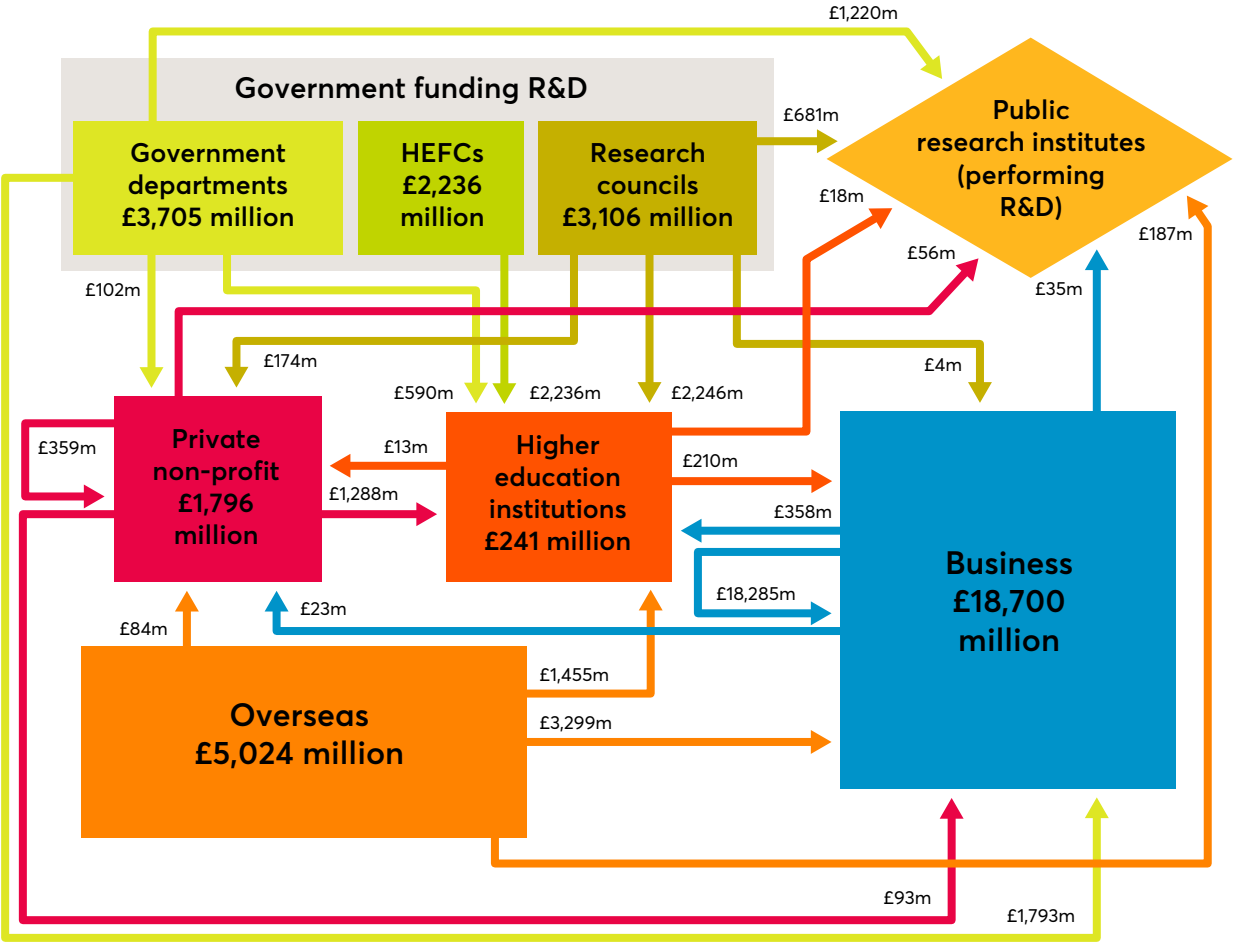
The government funds research in many ways and through a variety of instruments. The most visible research is perhaps that which is carried out in universities, primarily supported through grants worth £2.2 billion from the Research Councils – now combined into the government's funding agency, UKRI – and block grants of another £2.2 billion.

In addition, research is carried out in non-university-based government institutes, supported by government departments and the Research Councils to the value of £1.9 billion. This constitutes a smaller part of the UK's overall research landscape than this category of research in other comparable countries.

Meanwhile, the majority of R&D, worth about £24 billion, is carried out in the private sector. Most of this is also funded by the private sector. But economic theory argues that the private sector will tend to invest less in R&D than is optimal for the wider economy because of the inability of any one firm to appropriate all the benefits of that R&D. This provides a rationale for the government to support R&D in business.

Some £1.8 billion of this funding for business R&D comes from government departments, including the innovation agency Innovate UK, in the form of direct grants and contracts. However, the biggest government contribution to business R&D comes from the R&D tax credit, an unselective subsidy of qualifying activities, which in 2016–17 amounted to £4.4 billion.[24] Thus, directly and indirectly, the government pays for about a quarter of the R&D carried out in the private sector.

Figure 10: Financial flows in the UK's R&D system, 2018



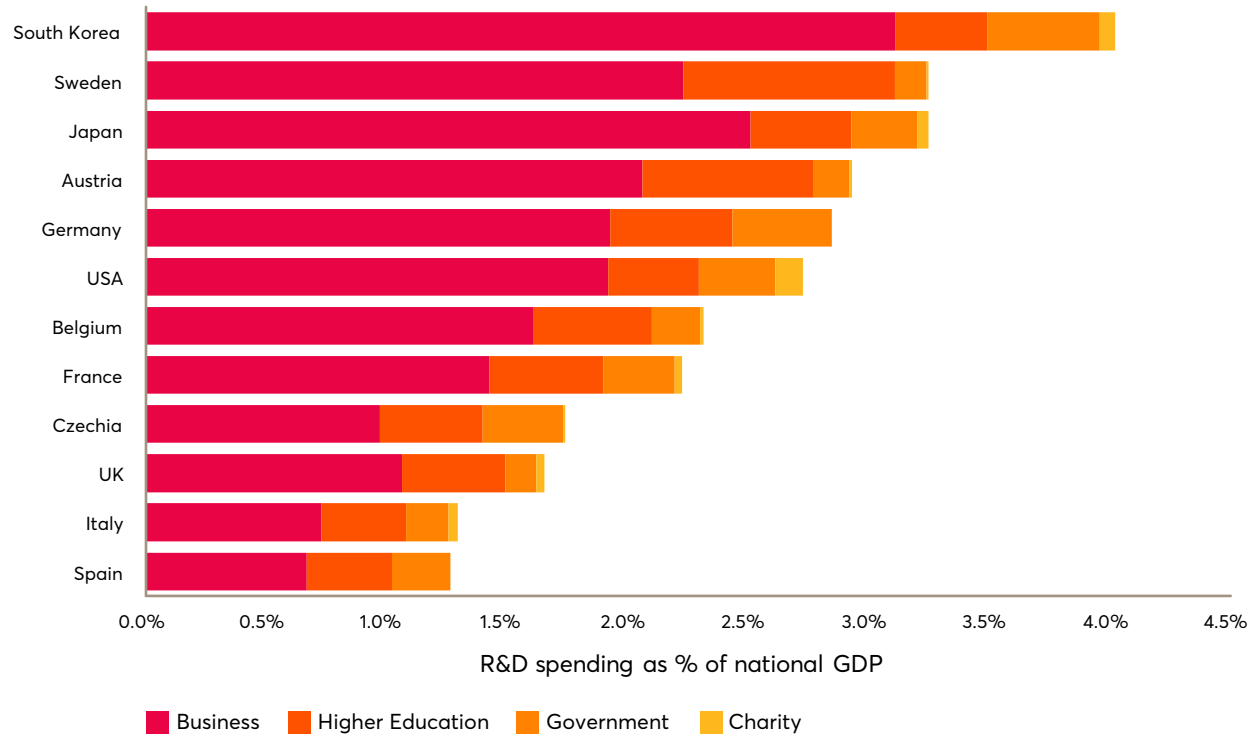
Values in boxes are the total amounts that each sector provided to other performers of R&D. Overseas funding comprises funding from the European Commission and other overseas sources: EU funding of business in 2018 amounted to £75 million. The diagram includes only direct funding flows – in addition, the government provides an indirect subsidy to business R&D through the R&D tax credit, which amounted to £4.4 billion in 2016/17. Source: Office for National Statistics.[25] Contains public sector information licensed under the Open Government Licence v3.0.

R&D, then, is carried out across the UK in a variety of different organisations, many of which guard their independence jealously, with funding provided through a wider variety of different mechanisms. The result is that no one takes a look at the whole funding landscape from the perspective of geography. In this sense, our unbalanced landscape could be argued to be a product of disinterest rather than design.

Here we look at the public sector R&D funding landscape in more detail. There are two dimensions to consider: the organisations and institutions where the actual R&D work is done; and the funding instruments through which it is supported and paid for. Broadly speaking, we can divide funding mechanisms into those that fund capacity and those that fund projects. By capacity, we mean the physical facilities in which research takes place and the basic costs of running and staffing them. By projects, we mean funding allocated to specific programmes of research.

3.3 Funding capacity – universities

Figure 12: R&D spending by sector of performance, by country



Breakdown of R&D spending by sector of performance. The UK is unusual in the dominance of the higher education sector in public sector R&D. Of the comparator countries, all except Switzerland spend more on R&D via government channels.

As Figure 11 shows, the UK is unusual in the relative importance of the higher education (HE) sector for public sector research. We begin by discussing how university research capacity is supported, remembering that support for HE is devolved to the nations.

In England, the general support for research infrastructure in universities used to be the responsibility of the Higher Education Funding Council for England (HEFCE). But following the Higher Education and Research Act 2017, HEFCE was split into two, with the research part incorporated within UKRI as Research England. The basic mechanisms of support weren't changed by this reorganisation.

Research England provided a block grant to universities in England of £1.7 billion in 2018/19.[26] Universities have wide discretion in the way they use this money, but the intention is to support laboratories and other research facilities like libraries & IT services, technical and support staff, and a fraction of the salaries of academic staff, reflecting the time they devote to research.

The largest part of this block grant (QR) is allocated on the basis of the results of a detailed nationwide assessment of the quality of research produced by each department in each university.[27] This septennial REF relies on a detailed peer review of the quality of research outputs, and it increasingly gives weight to 'impact' – the economic, social and policy outcomes from research. The results of the REF are translated into a formula which allocates funding in proportion to the number of researchers weighted by a measure of the average quality of the department's output. The formula that determines that weighting is the crucial mechanism that determines whether funding is concentrated in only a few outstanding departments or dispersed more widely.

In the devolved nations of Wales, Scotland and Northern Ireland, the role of Research England is played by national funding agencies (Higher Education Funding Council for Wales and Scottish Funding Council) or, in Northern Ireland, the Department for the Economy. These agencies have chosen to base their own funding on the results of the REF, but they are free to use a different formula to translate the outcomes into funding decisions. In addition, they can provide additional strategic spending.

The project-based funding discussed below also includes elements to cover the overheads of research. Nonetheless, it is widely accepted that research carried out in universities does not have its full costs met from these outside sources and, thus, is subsidised from other sources of income.[28] The largest of these sources is the surplus generated by non-publicly funded student fees – largely from overseas students. This was £1.4 billion in 2017/18, not much less than the total funding from the research block grant to universities.[29]

We should, therefore, talk about research in universities as being paid for not by a dual-support system but by a triple funding system, comprising contributions of similar order of magnitude from the block grant, the overheads on project funding and the surplus from overseas students. The COVID-19 pandemic, with the likelihood of substantial drops in overseas student numbers, has starkly revealed the fragility of this system.

3.4 Funding capacity – institutes and major facilities

In addition to university-based research, the government supports a range of Public Sector Research Establishments.[30] These have a range of missions, from pure science (e.g. the MRC Laboratory of Molecular Biology in Cambridge) to more applied research (e.g. the Pirbright Institute for animal health). They cover both military needs (e.g. the Atomic Weapons Establishment) and civil needs (e.g. the British Geological Survey). Some provide shared large-scale research facilities that are open to researchers from universities (e.g. Diamond Light Source).

There is a messy landscape of ownership and operating models for these establishments, with some directly owned by government departments and others, by Research Councils (and thus now UKRI). Some occupy a muddy middle ground between public and private sectors (e.g. the Catapult Centres), with a range of special-purpose vehicles having been developed for them.

Whatever their mission or ownership model, these institutes require both capital and running costs, and these will inevitably be in competition with other calls on the funds. As we will see, this part of the R&D landscape is underdeveloped in the UK in comparison to other developed countries.

3.5 Funding people and projects

Funding for people and projects is the primary responsibility of the Research Councils. These seven bodies were, until 2018, independent organisations established by Royal Charter. They have now been incorporated, together with Research England and Innovate UK, into a single organisation – UKRI. However, within that bigger organisation, they retain a certain autonomy as guardians of their discipline areas.

Their research and innovation budgets give an indication of the scale of project-based support in each area; this represents funding issued competitively in response to research proposals submitted by university researchers. These proposals may be in response to open calls, which do not specify in detail the research area to be supported (known sometimes as 'investigator led' or 'responsive mode').

Alternatively, the Research Councils may specify, in more or less detail, the goals of the research or the kinds of problem to be addressed – 'challenge-led' research. Increasingly, funds for this kind of directed research arise from outside the core Research and Innovation budgets of the Research Councils, through instruments like the Global Challenge Research Fund and the Industrial Strategy Challenge Fund.

Table 1: The budgets of the seven research councils, as taken from the 2019 Delivery Plans[31]

	Research and innovation budgets /£m	Total programme budgets /£m
AHRC: Arts and Humanities	91.5	148
BBSRC: Biotechnology and Biological Sciences	327	451.9
EPSRC: Engineering and Physical Sciences	763.7	1,094.9
ESRC: Economic and Social	142.5	243.3
MRC: Medical	562.4	745.1
NERC: Natural Environment	282.1	432.1
STFC: Science and Technologies Facilities Council	413	735.8
Total	**2,582.2**	**3,851.1**

In addition to project-based funding, some funding is allocated specifically to individual scientists, in the form of fellowships, on the basis of their record and promise. The National Academies – particularly the Royal Society – provide additional funding of this type. The funding for these fellowships is provided largely by the government, supplemented to some extent by private sector and charitable sources.

Other important actors in the UK's funding scene include the research charities – especially the Wellcome Trust (an international biomedical research charity) and Cancer Research UK. While the research that these organisations support is necessarily connected to their charitable aims, and in that sense can be described as 'challenge led', they have historically interpreted these goals to include a great deal of fundamental underpinning science.

The Wellcome Trust in particular is a major player in the UK landscape. It supports research in the biosciences and that addressing fundamental health challenges at a scale which puts it on a level with the largest Research Councils. In 2019, it spent £839 million.

The final major source of funding to be considered – although its future remains uncertain – is the EU. The EU's current R&D programme – Horizon 2020 – currently provides around €0.9 billion a year to the UK's overall R&D effort, of which 21 per cent goes to companies, 63 per cent to universities and 12 per cent to research organisations and other public bodies.[32]

To put this in context, Horizon 2020 represents about 12 per cent of university research income compared to 47 per cent from the Research Councils and other government bodies, 17 per cent from charity and 6 per cent from industry (2014/15 figures).

Much EU support takes the form of large collaborative grants in support of strategic priorities, which are increasingly being framed in terms of 'grand challenges'.[33] However, it has become increasingly important for people-based support, through the European Research Council and Marie Skłodowska-Curie Actions. The European Research Council provides 'excellence-based' funding to investigators at various career stages, and the UK has been particularly successful in winning this funding, attracting 22.4 per cent of its awards between 2007 and 2014. The European Research Council and Marie Skłodowska-Curie Actions currently provide more than half the total 'people-based' grants in the UK. The future of the UK's participation in these schemes remains undecided following its departure from the EU.

In addition to the EU's R&D programmes, the EU provides 'structural funds' in support of regions that underperform economically; the UK's regional inequalities mean that it attracts about €0.2 billion in structural funds for research and innovation, interpreted broadly to include business support and networking infrastructure.

Following the UK's departure from the EU, the government has promised that these structural funds will be superseded by a Shared Prosperity Fund. The details of how this fund will be operated and allocated remain undecided, so the degree to which it could support R&D in the regions remains open.

3.6 Subsidising business

As we've seen, the UK government currently pays for – directly or indirectly – about a quarter of the R&D carried out in the private sector, amounting to £6.2 billion a year. The broad justification for this is set out in the next section and follows from the well understood tendency of businesses to invest less in R&D than would be societally optimal because of the difficulty they have in capturing its full benefits.

There are two broad approaches used by the government in supporting R&D in business. The first is to back specific technologies through grants and contracts issued in particular by Innovate UK. The second is in essence to let the private sector make the decisions, providing (through a tax credit) a generalised subsidy for any expenditure which meets the definition of R&D.

For some decades, UK governments (and specifically HM Treasury) have been nervous about the idea of governments 'picking winners', and this has led to a predisposition to the second philosophy – as we've seen, spending based on the R&D tax credit is £4.4 million, compared to £1.8 million in direct grants and contracts.

In addition to UK government support, UK businesses have benefited from support from EU framework programmes. In the years 2014 and 2015, UK businesses received on average £189 million (€250 million) a year – about 37 per cent of the funding they received from the UK's own innovation agency, Innovate UK.

A striking feature of EU funding to business is its focus on small and medium-sized enterprises. Despite only accounting for 5 per cent of total business R&D spending in the UK, small and medium-sized enterprises received 65 per cent of the Framework 7 funding to UK business between 2007 and 2014.

Finally, one aspect of government support to business R&D that is not recognised widely enough – and is not reflected in the figures quoted above – is the degree to which small, R&D-intensive startup companies are indirectly supported by the state through the venture capital industry.

The total UK venture capital industry investment in 2018 was £626 million, of which support for early-stage companies at the seed and startup phases was £126 million. The sources of these investment funds include a very large contribution – £313 million – from government agencies.[34] Though it is hard to quantify exactly, given the balance of expenditure in typical pre-revenue technology-based companies, a substantial portion of this funding will have been used to support R&D.

3.7 Why 'place-blind' policy isn't

It has long been an axiom of science funding in the UK that it should be 'place-blind' – that it should support excellence, wherever it is found. As we shall see, this principle has not always been followed in practice. But it is important to understand that even without any conscious bias towards any particular location, there are some natural tendencies that will tend to concentrate funding in places that already have a strong science base.

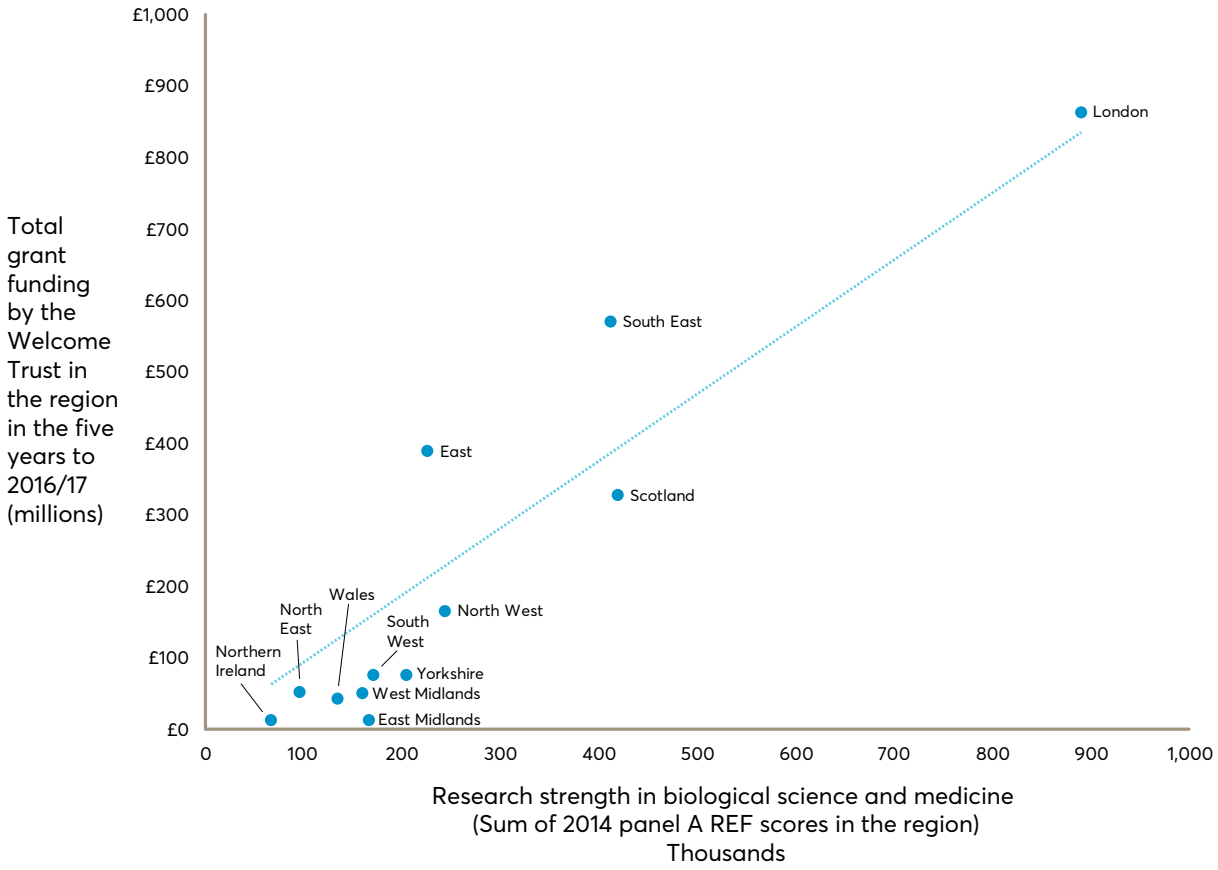
The Matthew effect is well known in social science, but it was in the context of physical science that it was first identified by Robert Merton.[35] The name derives from a passage in the Gospel of St Matthew: 'For to every one who has will more be given, and he will have abundance; but from him who has not, even what he has will be taken away.'[36]

Scientific centres that already have a good infrastructure and a strong reputation will attract the best researchers to work there. Then, through the normal processes of peer review, they will attract more resources and produce yet more excellent science, further raising their reputation and cementing their competitive advantage. As Merton wrote: 'Thus centres of demonstrated scientific excellence are allocated far larger resources for investigation than centers which have yet to make their mark.'

In addition to the intrinsic advantage that the Matthew effect provides established centres, a home bias effect might lead to a further advantage. Peer reviewers might be more likely to favour proposals from established centres, although this is not to suggest this is an example of direct conflict of interest. Even mundane factors like the ease of travel to a funding agency's headquarters may, at the margin, influence the propensity of an organisation to engage with that agency.

To illustrate the possibility of such bias, we show two examples. In the realm of science, we plot the total amount of funding awarded by the Wellcome Trust to UK organisations by region, against a measure of scientific excellence, the total REF score in biological science and medicine (since Wellcome Trust mostly fund research in these fields). If Wellcome Trust funding was solely awarded on the basis of excellence, we might expect a linear relationship. However, we see a systematic bias to the East and South East, close to the organisation's London headquarters.

Figure 13: 2017, by UK NUTS1 region compared with total REF strength in Panel A



Total grant funding by the Wellcome Trust by region in the five years to 2017[37] vs research strength in biological science and medicine in the 2014 REF.[38]

In the case of the innovation funder Innovate UK, which states its operating principle as being 'business led', we might expect its awards to follow the level of business R&D in different regions. To the contrary, in Figure 13, we show that the correlation is rather weak, with disproportionately high funding going to London and the South West, close to the organisation's Swindon headquarters. Less obviously, the North East also seems to be a disproportionately high beneficiary, though the total amounts here are rather small.

Figure 14: UK spending on R&D by Innovate UK and by business by NUTS1 region

Innovate UK[39] vs business R&D (Eurostat).

As we've seen, the majority of government support for business R&D comes through R&D tax credits. Here, the data on regional distribution is not very useful, as the spending is assigned to a region based on the location of the head office. Our best assumption is that the subsidy essentially follows the location of the business spend.

3.8 How research capital spending has reinforced regional inequalities

For one kind of science funding, it is impossible to separate funding considerations from geographical factors. This is relevant in the location of new institutions, such as large scientific facilities and research centres. These capital investments can reinforce regional inequalities in two ways.

Because they need to be staffed and run, they necessarily absorb revenue funding into the future. There has been a recent unfortunate tendency to allocate new capital funding without identifying sources of ongoing revenue funding – the 'batteries not included' problem. In the absence of specific new money to meet these costs, this money has to be found from existing fixed budgets, meaning that the money in effect has to be taken away from places that do not have new facilities.

We should also expect an indirect effect; by strengthening the science base of the region where they are located, they will lead to further funding driven by the Matthew effect, producing positive spillovers in scientific output and quality nearby.

This has been demonstrated in the case of the siting of the synchrotron radiation facility, the Diamond Light Source. Diamond Light Source was constructed between 2003 and 2007 at the Harwell Research Campus, near Oxford, to replace an earlier synchrotron light source at Daresbury, near Runcorn in Cheshire. A scientometric study demonstrated evidence of increased scientific output within 25km of the facility.[40]

For these reasons, we should expect the decisions on where to locate new facilities to be made with particular rigour, giving careful consideration to their effects on regional imbalances of R&D funding. There is evidence that this has not happened in recent years.

Table 2: Department of Business, Innovation and Skills Capital investments between 2007 and 2016. Authors' geographical analysis of investments reported in Figure 25, National Audit Office.

Region	Capital investment /£m	% of locally specific investment
London	399.9	28.6
South East	379.1	27.2
North West	235	16.8
East	210.4	15.1
Scotland	79.7	5.7
South West	42	3.0
Yorkshire & Humberside	30	2.1
North East	20	1.4
East Midlands	0	0.0
West Midlands	0	0.0
Wales	0	0.0
Northern Ireland	0	0.0
Total locally specific investment	**1,396.1**	
Satellites and ships	317.1	
Networks and distributed infrastructure	539.8	
Total	**2,253**	

Table 2 lists a series of government capital investments made by the Department for Business, Innovation and Skills (BIS) between 2007 and 2016. Excluding international investments, satellites and ships, and networks and distributed infrastructure that could not be assigned to a single geographical location, this investment amounted to £1.4 billion. Of that, nearly 71 per cent was in London, the East and the South East. The Midlands, Wales and Northern Ireland received no investment at all.

Was this based on excellence? A report from the National Audit Office suggests not, stating that: 'Since 2010, processes for sifting project proposals to identify investment priorities have not been supported by good information.' It adds that

BIS carried out a public consultation with the research community and agreed the criteria it would use to prioritise projects, but did not specify the information it needed from respondents. As a result, it did not have good-quality information to assess and prioritise new projects. A further 4 projects were announced without being assessed. BIS informed us this was because it had identified them as crucial to the UK and its international standing.[41]

Another route through which capital investments were made was through the UK Research Partnership Investment Fund (UKRPIF). Some £501 million was allocated through this fund, which was administered by HEFCE and, significantly, required matching funding from industry. The share for London, the East and the South East was lower than for the directly funded investments, but still represented more than half, at 52.2 per cent.

The National Audit Office is more positive about this process, stating 'HEFCE's approach to prioritising and approving capital projects in higher education institutions has, in most respects, been robust'. It is perhaps also significant that a process which needed matching funds from the private sector produced a more geographically balanced distribution than one driven entirely from Whitehall.

Table 3: Capital investments made in the UK RPIF programme. Authors' geographical analysis of investments reported in Figure 27, National Audit Office

Region	Capital investment /£m	% of locally specific investment
London	111.1	22.2
South East	76.6	15.3
North West	56.8	11.3
East	73.6	14.7
Scotland	59	11.8
South West	0	0.0
Yorkshire & Humberside	10	2.0
North East	0	0.0
East Midlands	10.4	2.1
West Midlands	64	12.8
Wales	29	5.8
Northern Ireland	10.5	2.1
Total	**501**	**100**

3.9 Place-based science funding interventions have been subscale and, thus, ineffective

The geographical imbalance in R&D spending in the UK is of long standing, and there have been previous attempts to counteract it. In 2004, a high degree of concentration was identified in a study by Adams and Smith,[42] and the major government strategy document published that year – Science and Innovation Investment Framework 2004–2014 – conceded that 'on the surface the [Department of Trade and Industry]'s Science Budget spend is heavily skewed towards London, the South-East and East of England'.[43]

However, the document reasserted the 'excellence principle' of 'place-blind' funding, ascribing the geographical imbalance to the pre-existing uneven distribution of HE institutions. The strategy did, however, concede that 'science and innovation have the potential to play an important role in achieving the Government's objectives of increased prosperity and reducing the current disparities between regional economic performances'.

Responsibility for introducing a regional dimension to science and innovation funding was given, in England, to the RDAs. These were created in 1998, and until their abolition by the Coalition Government in 2010, they were allocated funding for a variety of regional economic development goals. Some of this funding was allocated for research and innovation activities.

This regional innovation spending produced some useful results, but it did not make a material impact on regional R&D imbalances. The reason for this is clear from Table 3, which compares the amount of innovation spending by the RDAs with the total government and HE R&D spend over the same period. Over the whole country, the amount allocated to the RDAs amounted to only 1.6 per cent.

Only in the North East did the amount of innovation money spent by the RDA approach 10 per cent of the (rather low) total HE and government spending; in most regions, the fraction was around 2–3 per cent. This is an intervention that may have been helpful, but it was not carried out at a scale to make a material difference.

Table 4. Spending on innovation by English RDAs in the three years of the 2004 Spending Review period (2005–06 to 2007–08). Financial years for RDA spend, calendar years for Higher Education Expenditure on R&D (HERD) and Government Expenditure on R&D (GovERD) . RDA spending from The Race to the Top, HM Treasury 2007, GovERD and HERD from Eurostat.

Region	Innovation spending by RDAs/£m	Total High Education R&D spend/£m	Total Government R&D spend/£m	RDA spending as % of govt. and HE spend
East Midlands	39	848 2	63	2.8
East of England	39	1,626	1,114	1.4
London	30	4,478	947	0.6
North East	57	592	5	9.5
North West	59	1,593	264	3.2
South East	23	2,448	1,811	0.5
South West	19	803	1,049	1.0
West Midlands	24	859	105	2.5
Yorkshire & The Humber	41	1,370	158	2.7
Total	**323**	**14,618**	**5,716**	**1.6**

One cause of subscale, and thus ineffective, interventions can, ironically, be anxiety about spreading resources around the country. A sobering case study of this is provided by the story of the Micro and Nano Technology centres. The Micro and Nano Technology programme was launched by the Department of Trade and Industry in 2003, with initial funding of £90 million, intended to rise to £200 million. However, the money was distributed between 24 centres across the country, so despite a final investment of about £150 million, none of the centres made a significant impact.[44] By 2010, this area was identified by the science minister as one in which policy had resulted in 'too many small centres which are sub-critical in size.'[45]

Section B: Rebalancing the UK's R&D landscape – From principles to policy recommendations

We have quantified the degree to which public funding of R&D is concentrated in a few already prosperous parts of the country, and have looked at the structural factors in our science funding system that has brought us to this state. Now we turn to how this situation might be changed.

The government's aspirations to increase the overall R&D intensity of the nation mean that new research capacity is required; the location of this capacity should take account of existing patterns of public and private investment. We estimate the overall scale of the interventions needs to rebalance R&D spending to the levels seen in London, the East of England and the South East – more than £4 billion per year.

But there are different purposes for public R&D spending, and its optimal geographical distribution will reflect the relative weights one assigns to these purposes. These can be explored in an online tool.

Finally, we list some concrete policy changes that could, collectively, have a material impact on the UK's very persistent R&D imbalances, helping all its nations and regions to be able to reach their full potential.

4

How we could do things differently

4.1 The need to make positive interventions – doing the same thing will produce the same result

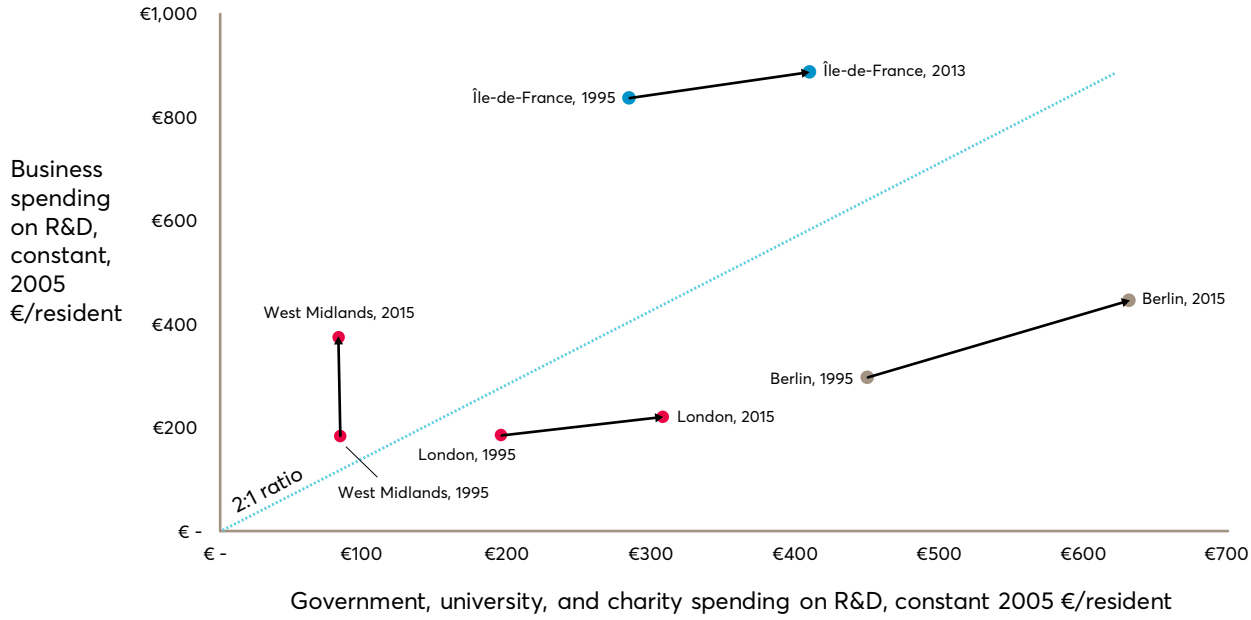
The UK's regional economic disparities have been with us for a long time, and the geographical concentration of R&D is a long-standing problem. This persistence can lead to defeatism – a common reaction is to say that we've tried to address these problems in the past but have failed. It is certainly true to say that we're not the first to identify the problems, but we argue that previous attempts to address the problem have not been serious about the scale of interventions needed.

Figure 14 shows in the bluntest terms where we think the UK has gone wrong in the past 25 years. Since 1995, R&D spending in Paris, London and Berlin has grown significantly. In Paris and London, this growth has been mostly driven by the public sector with private sector growth joining in. The private sector has contributed more, and more quickly, in Berlin.

But in England's West Midlands, private sector R&D per head has matched the growth of Berlin and grown by more than in Paris and London put together. And yet public sector R&D has remained static.

We will never know how much more growth in private sector R&D and private sector productivity we would have seen in the West Midlands had the UK public sector invested as heavily in the region as the German public sector invested in Berlin. We cannot know whether Tesla would have decided to build its European Gigafactory in Birmingham instead of Berlin. But we can compare the economic performance of Birmingham with Berlin (Berlin's GDP/resident has grown by 48 per cent since 2000 compared to 32 per cent for the West Midlands), and we should be able to see that perhaps this was a missed opportunity.

Figure 15: Spending on R&D in London, Paris, Berlin, and The West Midlands in 1995 and 2015 (split by market-led (business) and non-market-led (government, university, and charity))



R&D spending by the public sector and the private sector in 1995 and 2015 in the three capital regions of France, Germany and the UK and in the West Midlands. (Constant 2005 €s are converted at purchasing-power parity.)

4.2 The need to generate new capacity

The government has announced a commitment to 'significantly boost public R&D funding' in support of the target of total (public and private) R&D spending, reaching 2.4 per cent of GDP by 2027.[46] The March 2020 Budget demonstrated even greater ambition, committing to increase public R&D expenditure to £22 billion a year by 2025.[47] This environment of expanding spending (assuming it survives the fiscal aftermath of the current pandemic) offers a rare opportunity to make R&D spending more balanced across the country.

With that opportunity comes new pressure to make sure that this increased public R&D spending leads to proportionate increases in private sector R&D spending and, ultimately, results in the urgently needed resumption of productivity growth across the country.

But to increase R&D spending, we need to create the capacity to do research. This needs institutions where research will be carried out, well-equipped research facilities and a supply of skilled people, technicians, researchers and support staff. Currently this capacity is highly regionally concentrated.[48] Without a conscious effort to create new R&D capacity in regions that currently have low R&D intensity, extra funding will simply be absorbed in existing institutions, perpetuating the current geographical imbalances in R&D spending.

The need to expand R&D capacity gives us an opportunity to rethink the shape of the UK's innovation landscape. Currently, as Figure 11 shows, the UK is an international outlier in the degree to which public R&D is carried out in the university sector rather than in free-standing government research establishments. Of the comparison countries, all except Switzerland spend more on R&D via government channels.

A review in late 2019 by the government's Chief Scientific Advisor highlighted the importance of Public Sector Research Establishments, particularly for more applied and mission-driven research, and of supporting and enabling R&D in the private sector. It notes 'their potential role as hubs for economic growth and activity, particularly outside London and the South East.'[49] The report recommends that the government makes greater use of Public Laboratories, a conclusion supported by a report by the former Science Minister Lord Willetts.[50]

We need to build new public research institutions outside London and the South East. The focus of many of these establishments should be mission-driven and applied R&D; these should have the explicit goal of raising the R&D intensity of the private sector business base in their regions, by attracting inward investment from firms at the technology frontier, and helping the diffusion of advanced technology in the existing business base.

4.3 Four different cases

In R&D spending, as in many other areas, different places have different needs and, thus, require different responses. As overall R&D spending is increased, if that spending is going to be effective, we need to consider what new R&D capacity will be appropriate for different places given their very different landscapes of innovation.

What should the balance be between different academic disciplines to be supported? What industrial sectors need the most support in each place? What should the balance be between academically driven research and more applied R&D? For mission-driven research, what determines where we should build new research capacity in support of big strategic goals like developing new low-carbon energy sources or creating a sustainable and humane health and social care system?

A helpful starting point is suggested by Figure 3, where public sector and private sector R&D are plotted against each other. We should note that the granularity of analysis is important; we do need to bear in mind the substantial heterogeneity within the regions as well as between them. Our analysis begins by considering NUTS1 regions, but we will need to consider finer geographical divisions as well.

Figure 3 suggests a fourfold classification of R&D intensity by NUTS1 regions, considering the relative intensity of R&D in the private and public sectors:

- **High private sector R&D, low public sector R&D**
  East Midlands, West Midlands, North West England.
- **Low private sector R&D, low public sector R&D**
  Wales, Northern Ireland, Yorkshire and the Humber, North East England, South West England.
- **Low private sector R&D, high public sector R&D**
  London, Scotland.
- **High private sector R&D, high public sector R&D**
  East of England, South East England.

In each case, the response needed will be different.

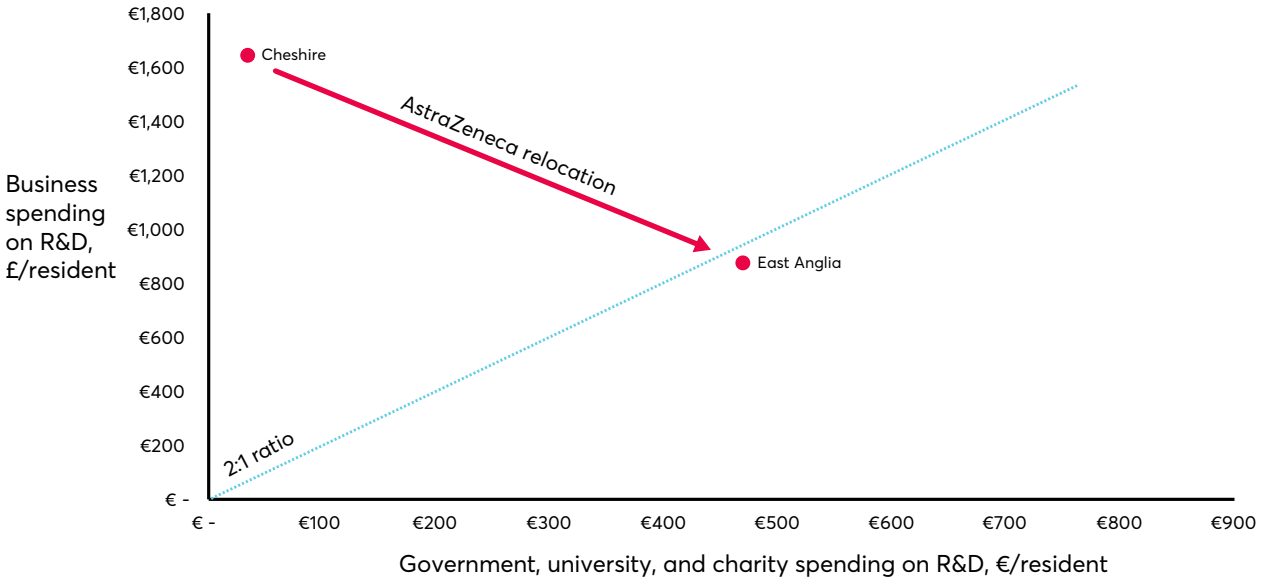
4.4 Regions with high private sector R&D but low public sector R&D

Three regions of England – East Midlands, West Midlands, North West England – have disproportionately low public sector R&D intensity given their relatively high levels of private sector R&D. Here, there is a strong case for increasing public sector R&D spending to support and grow existing private sector capacity.

In a sense, this presents the easiest situation when we come to decide what types of research to prioritise. The private sector has made many of the choices for us – these are areas with strong sectoral specialisations and existing innovative businesses that already create a demand for skilled people and underpinning research of the kind that an expansion of R&D capacity the public sector could supply.

The risk of not acting in these areas is clear too. If public sector investment in these areas is not increased, the danger is that the private sector will respond to the better availability of innovation resources and skills elsewhere by relocating their own investment.

Figure 16: Average annual spending on R&D by selected NUTS2 regions of the UK, 2009 to 2013 (split by market-led (business) and non-market-led (government, university, and charity)



Another way in which imbalances in the support of R&D between the public and private sector might be corrected.

In the North West, for example, AstraZeneca's R&D facility at Alderley Park, near Macclesfield, was an anchor of a significant pharmaceutical/biotechnology cluster. AstraZeneca's decision to relocate this centre in Cambridge was a rational response to the opportunities presented by the huge state investment in life sciences in that city.

Cheshire remains an outlier in the mismatch between private and public sector R&D, as well as an outlier in its high level of productivity in comparison with the rest of the North of England. The sustained prosperity of regions like this should not be taken for granted.

4.5 Regions with low private sector and low public sector R&D

Two regions in the North of England, the North East and Yorkshire and the Humber, and the two devolved nations of Northern Ireland and Wales stand out as having low levels of R&D investment in both the private and public sectors. Not coincidentally, these have the lowest productivity per person (as measured by GVA per head) of the UK's NUTS1 regions.

Another English region – the South West – falls into the same part of the diagram in aggregate, but this conceals a very high degree of heterogeneity within the region. At NUTS2 level, Gloucestershire, Wiltshire and Bath/Bristol has one of the highest values of

GVA per person in England and a high intensity of both public and private R&D. Meanwhile Cornwall and Isles of Scilly has, in contrast, the second-lowest value of GVA per person in England and is the least R&D-intensive region of the UK.

These are places with some of the poorest productivity records in the UK, so there is a very strong case for the government to invest more in R&D. But this needs to be carefully targeted to make sure that is most effective at growing the kind of innovation capacity in the private sector that is likely to lead to improved economic performance.

However, in the absence of much private sector R&D, it may be more difficult to choose what sectors to focus on. Here local knowledge is likely to be crucial in identifying existing niches that can be built on with co-ordinated and sustained investment from the public sector.

The identification of compound semiconductors as one such niche in South Wales provides an interesting example where a potential cluster based on existing industry strength has been supported through investment in local universities and the establishment of a translational research centre.[51]

The Advanced Manufacturing Research Centre at Sheffield provides an exemplar of the way investment in translational research and skills can both attract inward investment from firms at the technological frontier and develop the innovation capacity of the existing business base.[52]

In some places, building on existing industry strength may not be enough. Here, the government should aspire to building entirely new capacity in areas of strategic importance for government, such as low-carbon energy, healthcare-related research and transport.

4.6 Regions with low private sector and high public sector R&D

Two regions – London and Scotland – have a combination of high public sector R&D with rather low business R&D.

New investments in public R&D here need to be subject to rigorous scrutiny for their value for money in comparison with the equivalent investments in less R&D-intensive parts of the country. Future interventions should have the specific goal of driving up business R&D and maximising the returns on the current high levels of public investment.

Here, the approach of the Scottish Government is commendable. Recognising the problem, their stated policy priority is to double business R&D between 2015 and 2025 through interventions such as increasing direct support for business R&D and creating a National Manufacturing Institute for Scotland centred around translational research and skills.[53]

4.7 Successful regions with high public and private R&D investment that have constraints on growth

Two regions of England – the East and the South East – have the desirable combination of high R&D investment by both the private and public sectors. These regions have the highest productivity in the UK outside London, and in many ways should be considered exemplars of the kind of prosperous, knowledge-based economies that the rest of the country should aspire to.

Here, further economic growth is constrained, not by any intrinsic shortcomings in the innovation systems but by other factors, such as the planning constraints that lead to very high housing costs and the poor state of the transport infrastructure in key cities like Cambridge.

The other key issue raised here is the degree to which prosperity spreads out from the key centres of London, Oxford and Cambridge to the rest of their regions. In the South East, parts of Kent (like the Medway towns) are as economically weak as many deindustrialised northern towns, while the prosperity of Cambridge does not penetrate far into East Anglia. At NUTS3 level, Breckland & South Norfolk is comparable to Wolverhampton and Barnsley in terms of GVA per head.

4.8 Cities, towns and rural and coastal peripheries

This last point underlines the fact that while our discussion so far has been centred on the regions, even within those regions there is substantial variation. There are different kinds of places which underperform economically, the reasons for these underperformances are varied and specific to the different places, and a single remedy – for example, increasing R&D intensity – may be appropriate for some places and not for others.

As we have already noted, one major problem for the UK is the relative economic underperformance of its major core cities, particularly in the North and the Midlands. Some towns and smaller cities – particularly in the South East – have prospered, but, in contrast, many formerly industrial towns in Wales, the North of England and the Midlands have not recovered from the deindustrialisation of the 1980s and 1990s. Meanwhile rural and coastal peripheries remain some of the least productive parts of the UK. Regional innovation policy needs to take into account the varied needs and capacities of these different kinds of places.

5

Modelling choices for the UK's R&D future

The regional imbalances of R&D in the UK are of long standing, and they will not be corrected without interventions on a very substantial scale. But it is important to stress that there are choices to be made. The government can support R&D with a range of different goals in mind. Some of these goals may cut across each other, so decisions need to be made about how to prioritise them.

There is not a single optimal solution to this problem, and our purpose is not to suggest that there is. Instead, we want to make those choices more explicit and convey the scale of the change they would lead to. In this section we show, with the help of a simple modelling tool, how different balances of priorities lead to different geographical distributions of government R&D spending.

5.1 Scale of the increases required

In designing policy, it is important to understand the scale of the problem, to avoid repeating previous mistakes of making interventions that may be positive in direction but are too small to make a measurable difference. To set the context, we carry out the thought experiment of asking how much additional annual revenue spending would be required in the regions to bring their spending per capita up to the average value for the most R&D-intensive – and most prosperous – part of the UK, the three regions of London, the South East and the East of England (which we refer to as the greater South East).

Table 5 illustrates this calculation. For public sector spending, we include both R&D carried out in government laboratories and that carried out in HE, but we leave out the R&D carried out in the private non-profit sector.

The sums needed to level up are substantial. For the North as whole, nearly £1.6 billion extra annual spending in government laboratories and universities would be needed; for the Midlands the total is only a little less, at just over £1.4 billion. The South West, Wales and Northern Ireland together would need another £1.2 billion. The exception here is Scotland, which already has a per capita public R&D investment greater than that of the greater South East of England.

The total additional public R&D spending to level up spending per capita by region to the value in the greater South East is just over £4 billion, to be added to £10 billion of existing spending.

Likewise, in the private sector, levelling up would imply an additional £9 billion expenditure to be added to the existing £24 billion spend. The experience of other countries that have raised their R&D intensity significantly in recent decades suggests that private sector R&D is very likely to follow where public sector R&D leads.

Roughly speaking, then, levelling up public and private sector R&D to greater South East England levels would require an increase of a bit more than 40 per cent in recurrent annual spending. By coincidence, this almost exactly coincides with the proportional increase in spending needed to raise the overall R&D intensity from 1.7 per cent to 2.4 per cent, in line with the government's stated 2027 target.

The problem with setting a target for spending on R&D in terms of a proportion of GDP rather than a cash amount is that we do not know how big GDP will be in 2027; this uncertainty of course is magnified hugely by the ongoing impact of the COVID-19 pandemic. Helpfully, the March 2020 Budget set out an ambition for growth in public spending on R&D in cash terms, committing to increasing public R&D expenditure to £22 billion a year by 2025.[54]

The economic future of the UK remains deeply uncertain, and the impact of the pandemic on the public finances will be severe. What we can say now is that the necessary scale of increases to rebalance R&D spending across the UK are very large, but not incommensurate with the overall scale of the increase in R&D spending that the government has been planning.

Our argument is that an increase in R&D spending that is focused on improving productivity growth and driving up productivity in the regions will itself contribute to the post-pandemic economic recovery by driving increased national GDP growth.

Table 5: In the South East, the East and London, in 2016, government and HE R&D was worth £219 per person, with business adding another £478. This table calculates the additional spending in the regions and nations that would be required to bring their per capita spend in line with the South East, the East and London. Note that spending in the private non-profit sector (largely concentrated in the greater South East) has been omitted entirely. Eurostat data, supplemented by Office for National Statistics data, and author calculations.

Region/nation	Govt. +HE R&D/£m	Business R&D/£m	Govt. +HE per head/£	Business per head/£	Extra needed to level up: Govt. +HE /£m	Extra needed to level up: business /£m
East of England	953	4,393	156	720		
London	2,395	2,296	275	263		
South East	1,875	4,693	209	522		
North East	288	302	110	115	289	956
North West	817	2,346	114	326	762	1,096
Yorkshire & The Humber	646	750	120	139	540	1,835
East Midlands	418	1,655	89	352	614	592
West Midlands	463	2,303	80	398	805	461
South West	638	1,500	116	273	568	1,126
Wales	271	435	87	140	410	1,050
Scotland	1,223	1,072	227	199		1,504
Northern Ireland	160	481	86	259	248	407
Totals	**10,147**	**22,224**			**4,234**	**9,026**

5.2 The need for clarity of purpose

The exercise of estimating how much additional spending would be required to roughly equalise R&D investment per head of population across the country is instructive to establish the scale of the problem. But there is no fundamental reason why spending per head of population is the correct or only possible metric. We should be clear about the purposes of R&D spending – and indeed the balance between those purposes given that they might be in tension.

Are we interested solely in 'excellence' as measured academically? Should we take the view that business understands the markets and so public sector money should follow the private sector investment? Should we prioritise boosting the productivity – as measured by GVA per person – of underperforming regions?

Choices need to be made. These choices have, in the past, been made implicitly, perhaps even unconsciously. We think that they should be discussed and made explicit. To demonstrate this, we have made an online tool (see Box 1) that allows users to modify the importance of these different priorities and see the effects of doing so.

Here we provide a summary for five key scenarios. In all five, we have increased public sector spending to 0.8 per cent of GDP, an increase of £4.9 billion per year, consistent with the UK government's stated ambition of increasing national R&D intensity to 2.4 per cent of GDP, assuming that business continues to spend £2 on R&D for every £1 that the public sector spends.

Our five scenarios are named as follows:

Everyone is equal

Excellence above all

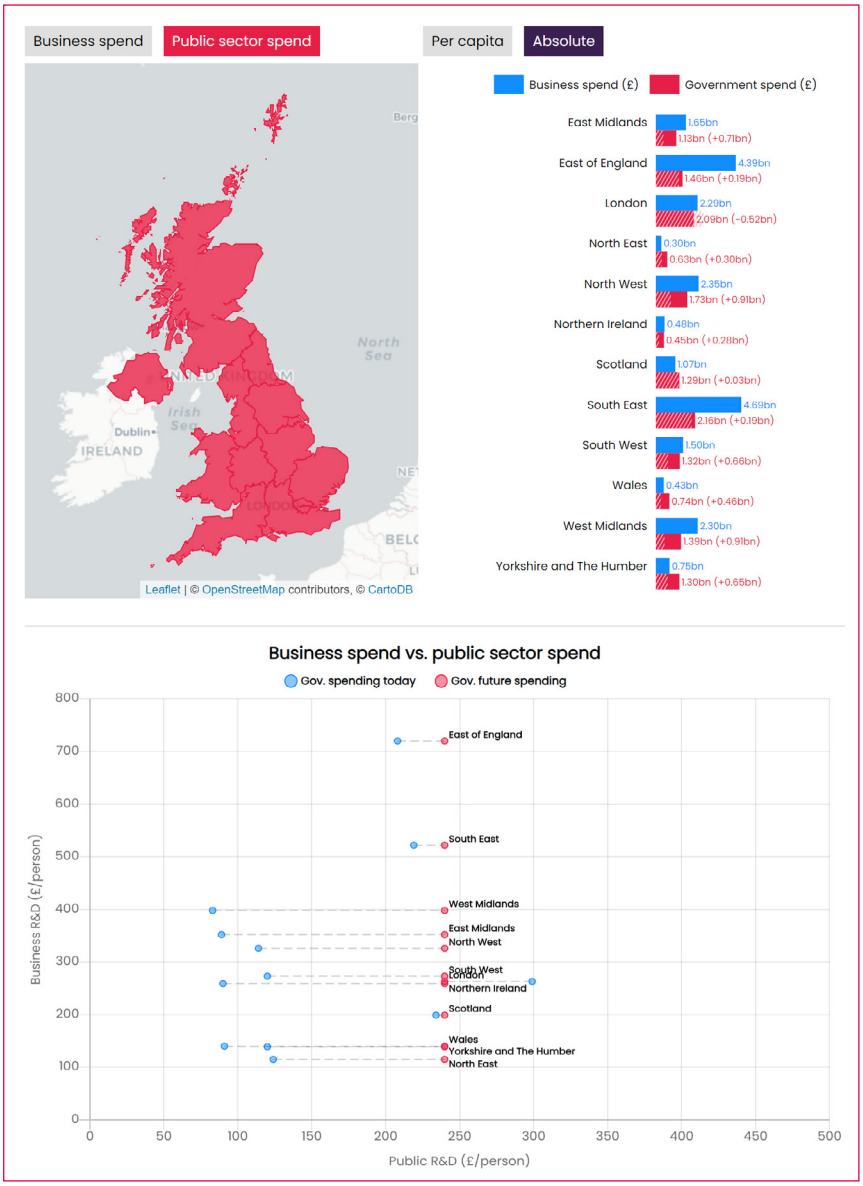
Follow the business money

Levelling up

March of the makers

Everyone is equal

In this scenario, the UK government commits to investing in R&D equally in every nation and region of the UK. Since overall public sector spending on R&D has risen from 0.55 per cent of GDP to 0.8 per cent of GDP, every region except London sees an increase in funding. Spending in the two current hotspots for UK public sector R&D spending, the greater South East of England and Scotland, remains largely unchanged.

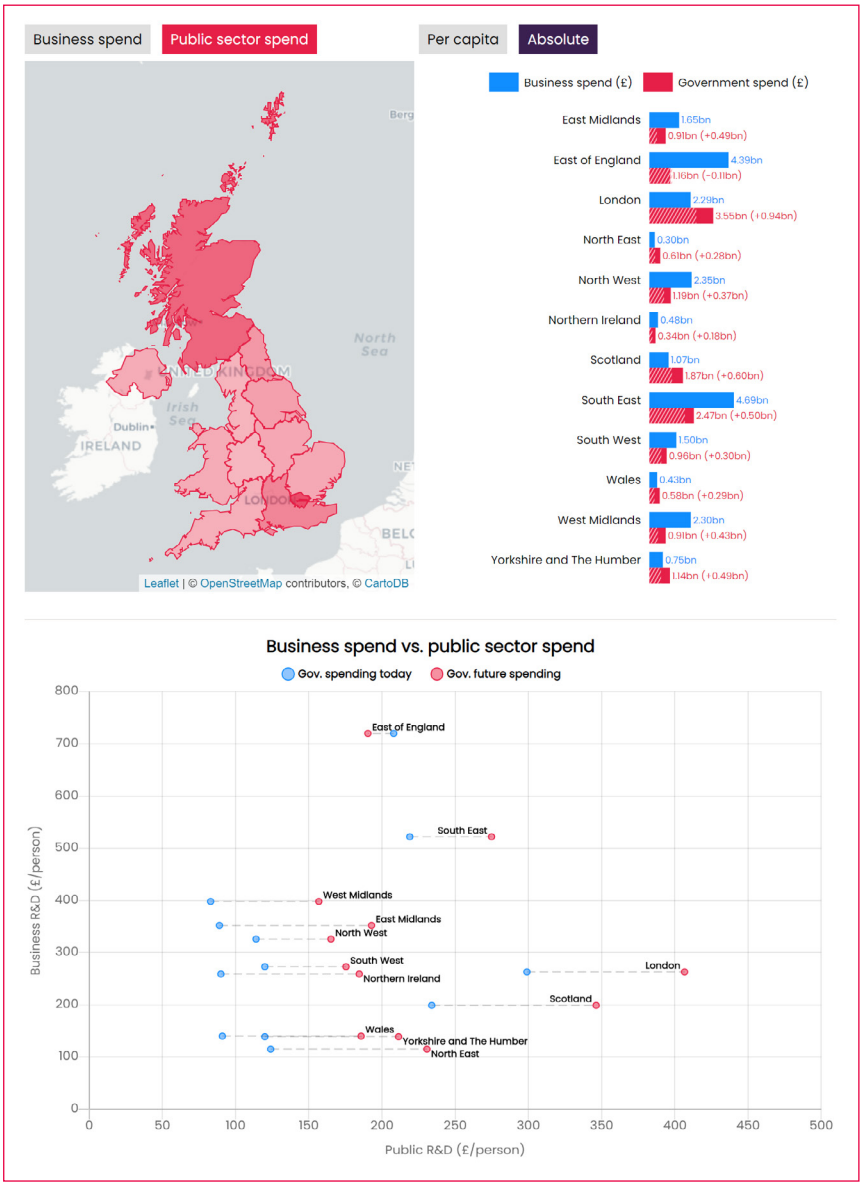


Excellence above all

In this scenario, the UK government commits to investing in R&D in proportion to research excellence as defined by the REF 2014. This is close to the ambition that most of the UK's research institutions and government have for how R&D spending is assigned within the UK, with consideration only of excellence and not place.

We have calculated research strength for every region using the same formula as is used to assign QR funding within the UK, but only considering the output score and applying neither inner or outer London weightings in the current formula.[55]

In this case, all regions except the East of England see an increase in funding. London and Scotland see among the largest per capita increases in R&D funding, but due to their existing high funding, this is much lower in percentage terms than the increases in regions such as Yorkshire and the Humber and North East England.

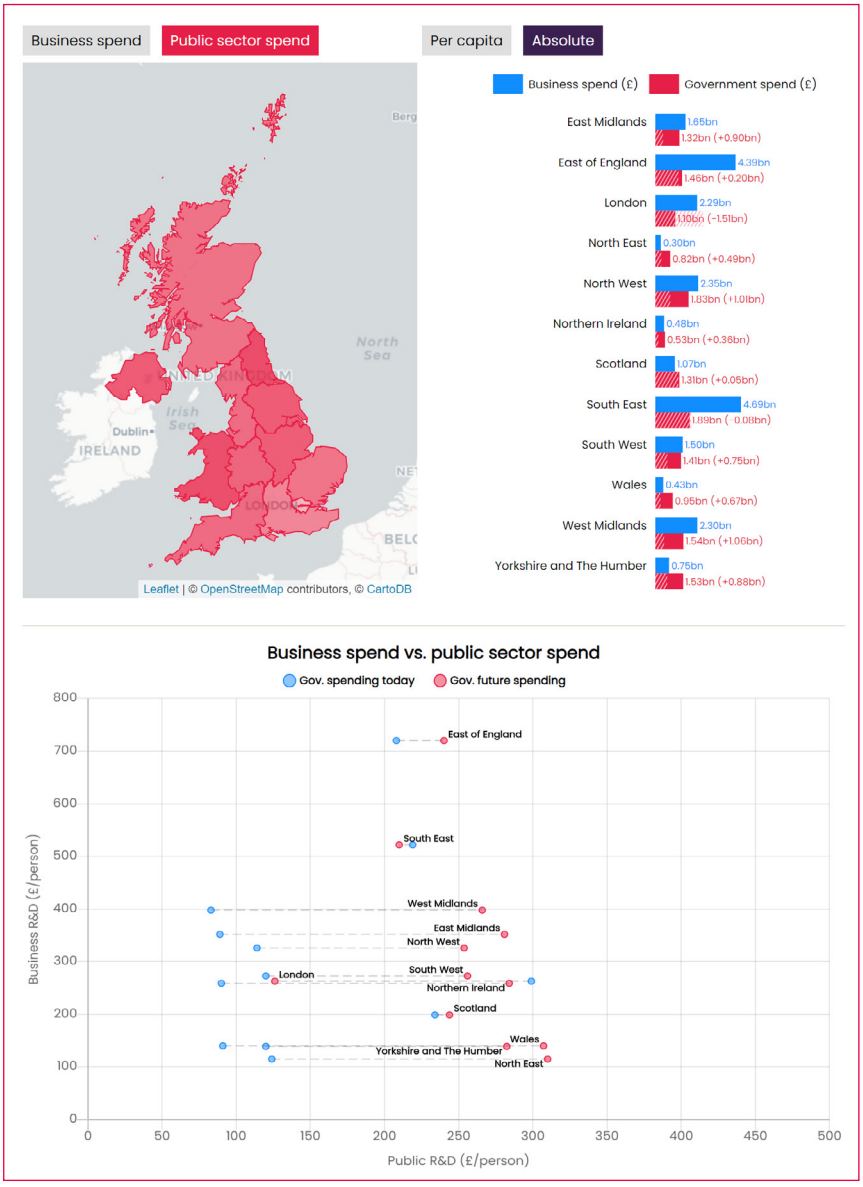


Follow the business money

In this scenario, the UK government commits to investing in R&D in proportion to business investment in every region. Despite overall public sector spending on R&D rising from 0.55 per cent of GDP to 0.8 per cent of GDP, low R&D nations and English regions such as Wales, North East England and Yorkshire and the Humber see little increase or fall in public sector spending on R&D.

London and Scotland, both with low business R&D intensity despite high public sector spending on R&D, see large falls in public sector R&D spending. Big winners are Northern Ireland, the Midlands and North West England, but the largest winner in absolute terms is the East of England, where very large private sector spending on R&D is now supported by the public sector.

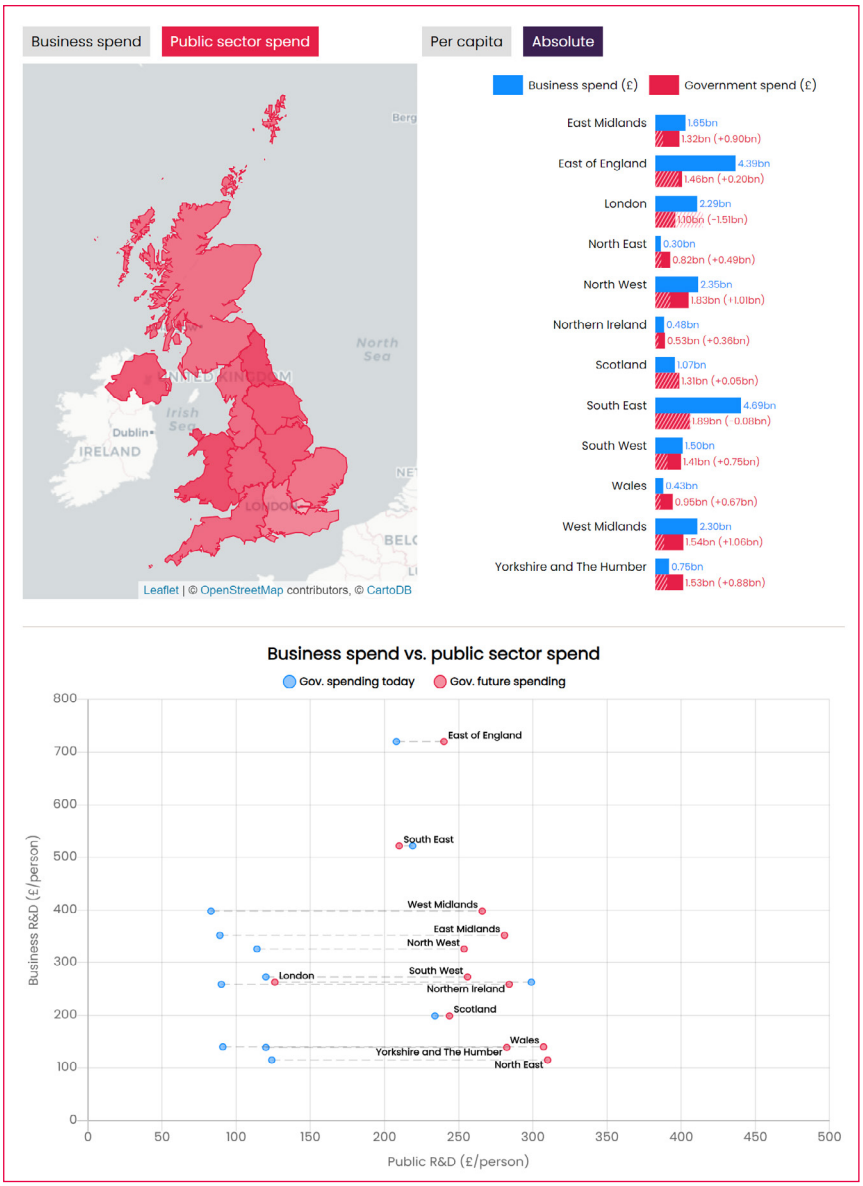
This scenario produces a pattern of spending with similarities to France, where public spending on R&D is spatially correlated with private spending on R&D.



Levelling up

In this scenario, the UK government commits to investing in R&D in inverse proportion to the GVA per resident of each region or nation of the UK.

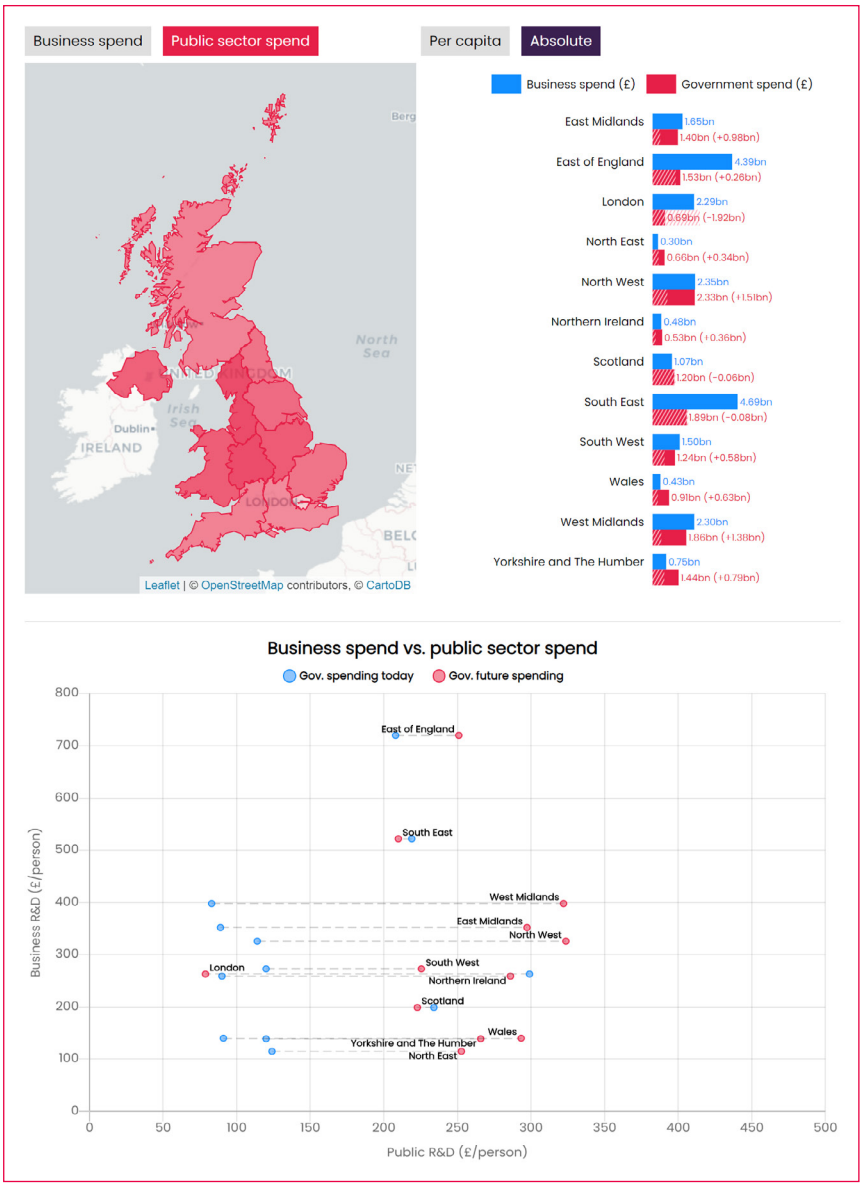
This scenario produces a pattern of spending with similarities to Germany, where low GVA regions that were formerly part of East Germany receive extra spending on R&D to stimulate economic growth. Regions and countries such as Northern Ireland, Yorkshire and the Humber, Wales and North East England with economies of a similar strength to East Germany receive very large boosts in R&D funding. Funding is cut from London and South East England.



March of the makers

In this scenario, the UK government commits to investing in R&D in proportion to the GVA produced by manufacturing in each region or nation. This is argued for by researchers such as Sridhar Kota and Tom Mahoney, who believe that any types of R&D, and especially the development portion, require close proximity to the manufacturing that they seek to improve.[56]

This scenario leads to large increases in spending on R&D in the Midlands, North West England and Wales.



The 'Design the Future' online tool

The tool starts by showing the current pattern of spending on R&D by region on a map and on a bar chart. Explore the current situation by toggling between private and public sector spending, and switching between absolute and per capita measures. Hover over each region for further R&D related statistics.

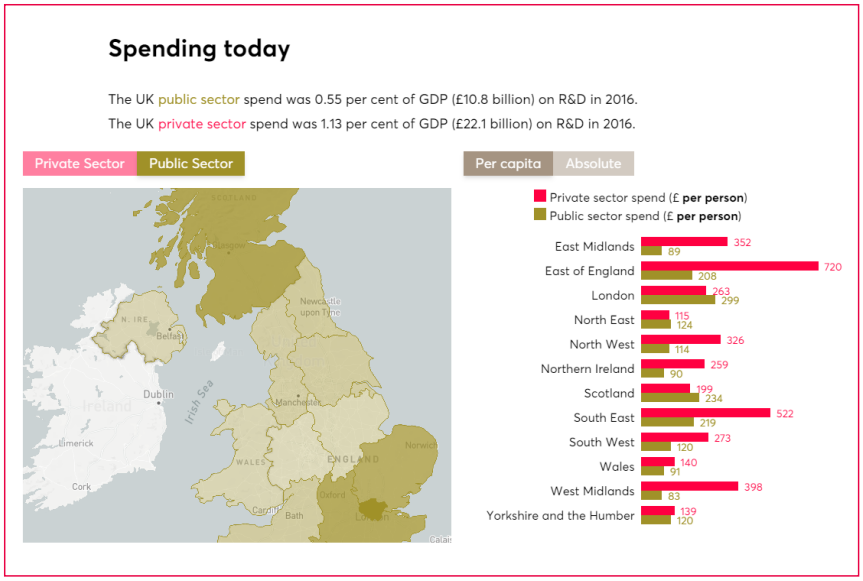
Scroll down to explore some key observations about the UK's current R&D distribution. At the bottom of the page, the user can design their preferred future where five factors are considered with their chosen weights of importance and used to calculate the regional spread of R&D spending by the public sector.

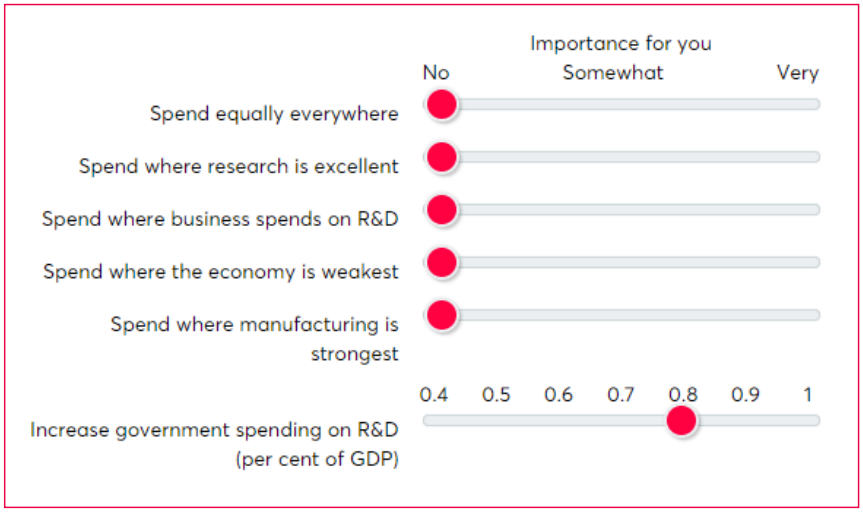
The five factors are:

- Spend equally everywhere.
- Spend where research is excellent.
- Spend where business spends on R&D.
- Spend where the economy is weakest.
- Spend where manufacturing is strongest.

With the additional freedom to set government spending on R&D at any percentage of GDP, from the 0.55 per cent it was in 2016 to the 1.0 per cent that would be required to match Sweden and Denmark, there are thousands of possibilities to choose from.

We urge readers to play with the tool and get a feel for what placing different weightings on the objectives of government R&D spending does to regional spending. The tool also shows the preferred scenarios of the report authors, with explanations for their preferences.





6

Recommendations to policymakers

6.1 Regional variations in R&D tax incentives could have a role, but may have a zero-sum character

As we have described, the majority of government support for business R&D comes through the R&D tax credit. The unselective nature of this mechanism is attractive to those who doubt the government's ability to make rational choices about what technologies to support. Should the government use this system to promote business R&D spending in specific geographical regions by introducing differential rates of relief depending on where the expenditure takes place?

Such an approach is certainly possible, and it could be quickly implemented. The downsides, however, include the problems of distinguishing between the places where the R&D expenditure actually takes place and the location of the registered offices from which the expenditure is reported.[57] Even if this problem is overcome, such interventions have an intrinsic zero-sum character, which is likely at best to redistribute business R&D rather than growing it in total.

Currently the government has already increased the R&D tax credit rate from 11 per cent to 12 per cent, and it plans a further increase to 13 per cent. It also suggests that the kind of expenditures that qualify for the tax credit may be broadened. Given that business R&D is more widely geographically dispersed than public R&D, this subsidy, in contrast to current directed public spending, is unlikely to make regional R&D imbalances any worse. However, we do not believe that this kind of intervention can, by itself, make the difference we need.

6.2 There should be a substantial regional devolution of innovation funding

The advent of UKRI offers an opportunity to look at research funding through a more explicitly regional lens. However, given the scale of the challenge of correcting the imbalances – which needs to be measured in £ billions of annual revenue funding – it seems unlikely that minor tweaks to the existing system can fully address the need to create new research capacity in the regions. Change on the scale required needs a fundamentally different approach involving devolution of innovation funding on a substantial scale to cities and regions.

There are two serious objections to such devolution that need to be confronted. The first is the question of whether the existing regional bodies have the analytical capacity to be able to make good decisions about how to spend the money, without being captured by special interests. This is a valid question, particularly in light of the patchy nature of English devolution, and the response must be that in the absence of such capacity, it needs to be built up.

A second, related, objection identifies the risk of there being many duplicated subscale initiatives – along the lines of the ill-fated Micro and Nano Technology initiative. This can be avoided through a combination of development of analytical capacity and some degree of central oversight. It will be important that cities and regions are clear-sighted about their potential areas of comparative advantage. Nonetheless, mistakes will be made, just as they have been within our current system.

We recommend the following.

Recommendation 1. At least 25 per cent of the uplift in public R&D funding should, in principle, be devolved to nations, regions and cities.

To overcome the long-standing imbalances in R&D intensity across the UK, we should devolve a substantial fraction of the planned uplift in public R&D funding – amounting to some £ billions a year – to nations, cities and regions. This should be used preferentially to build new capacity for innovation in regions of low public sector R&D intensity.

Recommendation 2. English cities and regions that can demonstrate the capacity to allocate R&D funding wisely should receive devolved funding through Innovation Deals.

To qualify to receive their share of this funding, regions will need to demonstrate that they have the analytical capacity to make good decisions on how to spend it. We believe that the devolved nations already have this capacity. Responsibility for assessing whether cities and regions should qualify to receive devolved funding in Innovation Deals should be held by Research England.

We anticipate that the largest and most established Combined Authorities with elected Mayors (e.g. Greater Manchester, Liverpool City Region and the West Midlands) would already qualify for Innovation Deals. Other cities and regions should be supported to build the necessary capacity until they are in a position to bid for their own Innovation Deals.

Cities and regions should be free to spend their money outside the administrative boundaries if that meets their economic goals, and joint bids with other authorities should be encouraged.

Recommendation 3. Some English cities and regions will need to develop more capacity to allocate R&D funding effectively; they should be supported in this until they can be awarded an Innovation Deal, with the funds notionally allocated to them being administered in the meantime by Research England.

While parts of the country remain without Innovation Deals, their portion of the funds in principle to be devolved should be retained by Research England, to be allocated by a light-touch quality assurance process.

While historically France is a very politically centralised country, like the UK, it has in recent decades decentralised spending decisions. Today approximately €1 billion per year is spent by regional and city-region governments on R&D[58] with an additional €0.6 billion spent supporting HE. Because this funding is decentralised and controlled by either subnational assemblies or mayors, the rate of R&D investment varies considerably. For example, the Grand Est region spends just 1.5 per cent of their budget on R&D, while the Bretagne region spends 4.5 per cent.

It is very notable that regional assemblies and city region governments allocate a third of their R&D spend to technology transfer, well above the national average.

The combination of the flexibility for regional assemblies and city regions to invest in R&D if they see that they have opportunities, and their tendency to invest in knowledge transfer to aid local businesses may explain part of what we observed in Figure 4a – French public and private sector R&D investments are well-aligned spatially.

6.3 We should create new science and technology institutions outside London, the South East and the East of England

Redressing the imbalance in R&D spending across the UK will require the creation of new research institutions. Given the consensus that the UK's research system is most lacking in centres carrying out translational or mission-driven research, this should be the priority for new capital spending, and the presumption should be that such centres will be located in regions with low public sector R&D intensity currently.

Recommendation 4. Cities and regions may use their devolved funding to establish translational research centres whose technological focus works with the grain of their local economies to support national missions.

In many cases, it should be the funding devolved to cities and regions that supports the establishment of these institutions, and the choice of technology focus for them will be informed by the need to work with the grain of local economies, while aiming to increase their innovation capacity and support the implementation of national missions such as low-carbon energy. The process that has led to Science and Innovation Audits and Local Industrial Strategies will provide helpful starting points.

Recommendation 5. New institutions should be set up in such a way that creates new poles for innovation and productivity growth, attracting new private sector investment as well as supporting the existing business base.

While translational research centres, along the lines of the existing Catapult Centres, will form the core of these new institutions, a holistic view should be taken, as argued by the CBI in their call for Catapult Quarters to be set up around anchor institutions like Catapults and other research and technology institutions.[59] The aim should be to create new poles for innovation, bringing together R&D, translational research and innovation, knowledge diffusion and skills development, with the goal of attracting new private sector investment as well as supporting a region's existing business base.

Recommendation 6. City Centre Innovation Districts can link the skills and innovation resources of major research universities with new knowledge-intensive businesses, and can be nucleated with targeted investments and infrastructure development.

The idea of an Innovation District can be helpful here.[60] An Innovation District is a dense, city centre site, often associated with major research universities, which attracts private sector R&D and knowledge-intensive businesses through the presence of translational research centres, purpose-built premises to suit startup and scale-up companies, and access to highly skilled workers. Targeted investments should be made to nucleate such innovation districts in major cities.

Recommendation 7. Advanced Manufacturing Innovation Districts – on sites with larger footprints on the fringes of cities or in their satellite towns – should bring together facilities for translational research, the diffusion of innovation and the development of skills at all levels, attracting inward investment from international firms at the technology frontier, and rebuild the 'industrial commons'.

A variant on the Innovation District theme focuses on knowledge-intensive businesses, such as advanced manufacturing, that need more space than a city centre Innovation District can provide. The idea of an Advanced Manufacturing Innovation District is to co-locate one or more translational R&D centres, with strong connections to nearby research universities, with centres for networking and management training and continuing professional development, together with facilities for training at all levels, from apprenticeships to PhDs, in collaboration with local universities and further education colleges.

These Advanced Manufacturing Innovation Districts may be located on the edges of cities and in towns, where their goal should be to rebuild what the US management theorists Shih and Pisano call the 'industrial commons.'[61] The success criteria should include their ability to attract FDI from international companies at the technological frontier and their ability to lead to significant upgrading of the local business base.

6.4 UKRI should take a lead in driving regional R&D rebalancing

The creation of UKRI – as a single body overseeing £7 billion of government spending annually on R&D – presents a new opportunity to correct the UK's long-standing regional imbalances in R&D. Eight of the nine bodies from which UKRI was formed – the seven Research Councils and Innovate UK – have not up to now had a brief to consider the regional dimension of their work, so the new overarching structure of UKRI should be designed to correct that omission.

We welcome the commitments in UKRI's initial Strategic Prospectus 'to enable regions right across the UK to realise their potential to drive innovation-led economic growth.'[62] However, we note that with the single exception of the Strength in Places Fund, commitment in principle has not yet been matched by concrete proposals to correct these imbalances.

As UKRI continues to develop its full strategic plan, we make the following suggestions.

Recommendation 8. UKRI must take more corporate responsibility for the geographical distribution of its R&D investments and introduce a high level Advisory Committee of the Nations and Regions.

Responsibility for the problem must ultimately rest with the UKRI board. It was an unfortunate signal that the founding board was made up of members who were, with a single exception, from London and the South East. We hope that subsequent board appointments broaden its geographical diversity.

Addressing the problem must start with the availability of good data on funding, broken down by geographical region. We recognise that UKRI has made significant progress on this front, and this emphasis should continue.

There needs to be a place in the advisory structures of UKRI where the voices of regions and devolved nations are heard. We recommend the establishment of a Committee of the Nations and Regions, which reports directly to the UKRI main board. This should include representatives from the innovation functions of devolved governments and key combined authorities/elected mayoralties. Its terms of reference should include oversight of the data on regional R&D spending, connectivity between local industrial strategies as they are developed and UKRI's broader corporate strategy.

The only component of UKRI which has a track record of considering the relationship between university research and regional economic growth is Research England, which originated from the research side of HEFCE. Research England's leadership and operational role in considering the regional dimension of research spending should be made explicit and strengthened; this will require the development of even stronger links to the devolved governments.

Recommendation 9. Block grant funding for research and knowledge exchange in universities should be regionally weighted to reflect current regional public underfunding of R&D.

Research England currently supports research in English universities through mainstream QR – that is, through a formula based on excellence as measured by the REF. The total funding administered through this heading is £1,095 million.[63] As the overall public research budget is increased, QR should be increased in proportion, but with regard to the distribution of regional R&D.

Currently there is a regional dimension to this funding scheme, but this works to entrench regional inequality rather than correct it. Institutions in London receive an extra £34 million to account for the additional costs of doing research in the capital. This London weighting should be abolished and replaced by a new regional weighting, drawn from additional sums assigned to the QR stream, which reflects the proportional underfunding of public research in each region. Such funding would reward excellence and allow universities in regions with low public R&D intensity to build new capacity.

The definition of 'quality' which underlies the formula used to allocate QR funding arises from the results of successive REFs, which assign quality ratings to research ranging from 0 (low) to 4 (high). Choices need to be made about the weights to attach to research assessed in the REF, and these choices will determine how selective the funding formula is in directing funding only to those units whose research is of the highest quality thus judged. Following the next REF, Research England should carefully study the effects of different weightings on the regional distribution of research funding.[64]

It should be recognised that while poor-quality research should not be rewarded, an excessively selective formula represents a direct implementation of the Matthew effect and will penalise many research groups whose research may well be of considerable regional importance.

In addition, Research England supports knowledge exchange activities in universities through Higher Education Innovation Funding, planned to rise to £250 million by 2020/21. This fund is being expanded, and the allocation method will be revised to take account of the new Knowledge Exchange Framework, which measures the knowledge exchange performance of universities on a number of different dimensions. The allocation method should be designed in such a way that takes account of not only the ability and willingness of the institution to engage with knowledge exchange activities, but also the need for this kind of engagement. One starting point would be to weight all or part of the Higher Education Innovation Funding allocations by the degree to which business R&D in a region is below average.

This kind of formula funding, which in England is administered by Research England, is in Scotland, Northern Ireland and Wales a matter for the devolved governments. We believe that the same considerations we make in this paper for the UK as a whole largely apply to each nation and region individually. As such, we hope that our work is useful to devolved governments in considering their own strategies

Recommendation 10. The Strength in Places Fund should be developed and expanded.

Currently, the only specifically place-focused funding stream in UKRI is the Strength in Places Fund. This is a useful initiative, but it suffers from two shortcomings. It is still too small to make a material impact by itself, and as a competitive scheme it relies on already existing activities judged as excellent, and thus doesn't allow innovation capacity to be built up in places that are started from a low base. Nonetheless the existence of the fund has been an important stimulus for cities and regions to devise coherent strategies for promoting innovation in focused areas; it should be retained and expanded to improve the success rates.

Recommendation 11. Innovate UK and Research Councils should retain their existing focus on supporting existing businesses and the health of their disciplines, but should monitor the regional distribution of their funding, particularly as it impacts on skills.

The UK's innovation funding agency Innovate UK, given its 'business-led' philosophy, has a particular responsibility to ensure that its spending at least matches the regional distribution of business R&D spend. The introduction of Innovate UK's regional offices is a welcome development, and the regional distribution of Innovate UK funding should be monitored to assess progress.

The Research Councils rightly maintain a focus on excellence in their core disciplines. However, they do have an important role in delivering training through PhD programmes, and the regional distribution of centres of doctoral training should be monitored.

Recommendation 12. Research spending by government departments – for example, the National Institute of Health Research – should take more account of regional distribution of their spending and be more responsive to the research agendas and needs of the UK's regions and nations outside London and the South East.

Outside UKRI, one of the most important sources of R&D is the National Institute of Health Research, which allocates research grants and builds research infrastructure on behalf of the Department of Health and Social Care in support of its mission 'to improve the health and wealth of the nation through research'. In 2018 it spent more than £750 million, of which more than half (52 per cent) went to London and the South East, in contrast to 20 per cent in the North.[65]

This pattern of spending is anti-correlated with the substantial inequalities in health outcomes in the UK. In London, life expectancies are 2.8 years higher than in the North West, while at a finer spatial scale the inequalities are even more marked and strongly correlated with measures of deprivation.[66] As one of us has argued before, research agendas for healthcare research should be informed by a more typical range of geographical perspectives.[67]

Making R&D work for the whole UK:

Rebuilding our innovation system for prosperity and resilience across all our nations and regions

The UK government concentrates too high a proportion of its R&D spending in London, the East of England and the South East of England. As these are already the most prosperous parts of the UK, this situation contributes to the entrenchment of the deep-seated economic inequalities of the UK.

Our goal should be for all parts of the UK to be prosperous and productive, contributing at their full potential to the national economy. If the economy is to recover fully from the current acute pandemic-induced crisis, we need to address its more long-standing problems: poor overall productivity growth and many parts of the country economically underperforming.

The UK invests too little in R&D; before the current crisis, there was a widely shared consensus that this needs to change. Increases in spending need to be led by the government, with the private sector following.

However, government support for R&D amounts to a significant sum of money at a time when many areas of public spending have been squeezed, even before the huge deterioration in public finances that the pandemic will cause. This scale of public funding dictates the need for public consent.

The evidence suggests that there is substantial public support for this government investment in innovation. But within this general support, questions do arise about prioritisation and the purposes of innovation, and about who will benefit from it. A recent Nesta study suggests a strong preference for prioritising the kinds of innovation that benefit many people, and a majority support innovation being aimed at solving wider social problems as well as purely directed towards economic goals.[68]

Specifically, on how the benefits of innovation should be distributed geographically, there is a clear finding: 'Over two-thirds (67 per cent) say that governments should focus on making everywhere in the country more prosperous, even if this means progress in better-off areas is slower than it might have been otherwise.'

We are not yet convinced that such a trade-off is necessary: our view is that building innovation capacity more widely across the country will make everywhere more prosperous. But it is striking that so many would prioritise regional economic rebalancing even at the cost of holding the most prosperous and productive areas back.

If, as we strongly believe should happen, an increase in public investment in R&D forms part of the plans for rebuilding the UK's economy, we need to be much more explicit about the different goals of this investment and the way these goals should be balanced.

Maximising the excellence of research in purely academic terms is not the only thing that matters; public investment needs to consider its role for promoting productivity growth and regional development.

Our innovation system needs to have the capacity to deal with huge, slow-burning challenges like climate crisis – meeting the 2050 net zero greenhouse gas target will require far-reaching changes to our economy. It needs to contribute to the resilience of the nation in dealing with more acute crises – the current pandemic will not be the last such emergency.

Responding to these new priorities will require changes in the way our science funding system works. The national funding agency, UKRI, is a relatively young organisation; cultural and organisational changes are required to give it the whole-nation perspective it needs.

But, in science and innovation funding, as in so many other areas, the UK's excessive centralisation has not served it well. We need to devolve serious amounts of funding to the nations and regions of the UK, at the same time building capacity in those places to make the best decisions about how to invest those funds. This should result in a greater diversity of institutions for R&D, building on existing strengths to rebuild the innovation systems of those parts of the country that currently do not fulfil their economic potential.

R&D – both publicly and privately funded – drives prosperity and resilience, and all parts of the UK should be able to benefit from it.

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58 Victoria Embankment
London EC4Y 0DS

+44 (0)20 7438 2500
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