DELIVERING THE 2.4 PERCENT:

Unlocking UK Pharma R&D Investment through Evidence-Based Policies

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Executive Summary

Introduction

With the Industrial Strategy published in 2017, the Government committed to meet a target of the OECD-average of 2.4% of UK Gross Domestic Product (GDP) invested in Research and Development (R&D) by 2027, with a longer-term goal of reaching 3%. Whilst there is universal agreement that increasing R&D investment in the UK is a worthy goal, there is an ongoing discussion over how to achieve it.

To stimulate this debate, the Office of Health Economics (OHE) was commissioned to produce a report on how the UK Government and the UK pharmaceutical industry can collaborate to deliver the life science's share of the 2.4% goal.

This report is in two parts

1. Part 1: The Scale of the Challenge
   Providing evidence to support the case that the pharmaceutical industry will be a key partner for the UK Government in achieving its stated ambition of increasing R&D investment to 2.4% of GDP by 2027 and to 3% in the future.

2. Part 2: Policies that Drive Innovation
   Generating evidence on the most appropriate policies that will help support the pharmaceutical industry and therefore the UK Government to achieve this goal by analysing six countries that already spend over 2.4% of their GDP on R&D.

Five key messages emerge from studying comparator countries:

1. The government must increase UK wide R&D investment by more than 50% in less than a decade, whilst its been stagnant for the same time period in the past. The **2.4% target is ambitious** given this recent history, but generally achievable as it represents the OECD average.

2. Whilst public R&D investment must increase substantially, the **UK should leverage greater private sector R&D investment** to achieve a private-public ratio of between 3 and 4 to 1 compared to the current 2:1 ratio.

3. Policies must focus on **increasing the amount of Experimental Development** because this is closer to commercialisation, and the private sector are more likely to invest in this later stage research and development activity.

4. There are only a few policy instruments that stimulate private R&D spending. While the UK Government may be pulling many of the right policy levers to stimulate private R&D investment, it may need to **pull much harder on these policy levers** and prioritise public spending in these policy areas, if the UK is to achieve this ambitious goal.

5. The **pharmaceutical industry is a key private sector partner** because their business model relies on constant innovation and they, therefore, invest the most on R&D especially with more than half of its R&D budgets allocated to the Experimental Development phase. Comparator countries have focused on supporting and encouraging existing R&D investing industries.

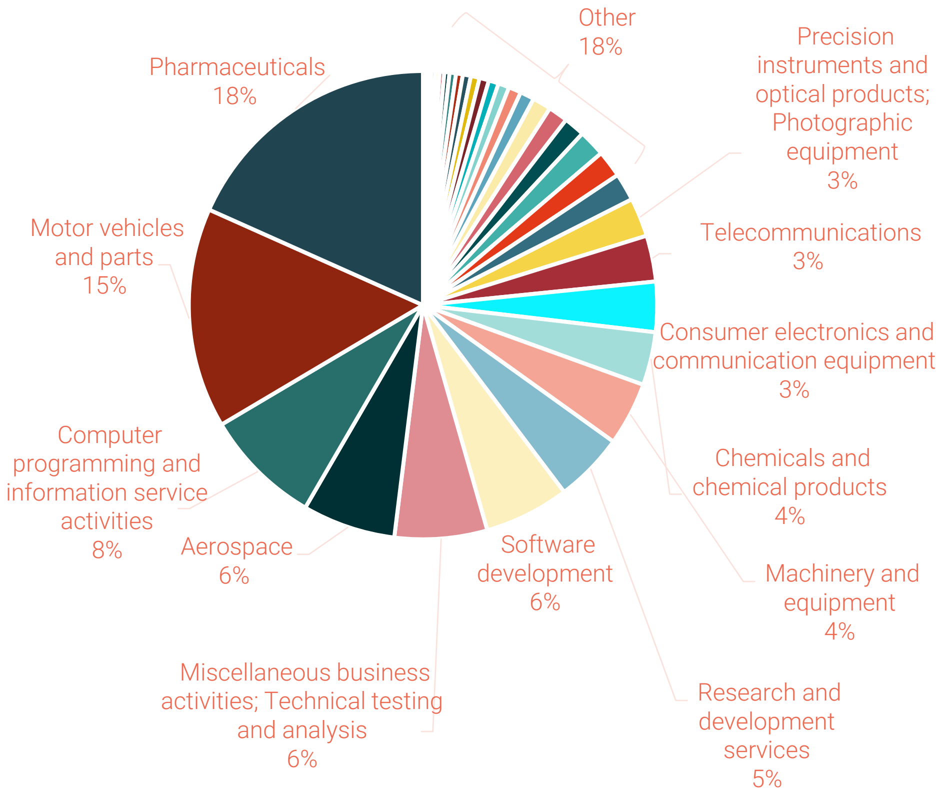
Part 1: The scale of the challenge

R&D generates new products, services, and economic prosperity in the form of more jobs and increased tax revenue. Investments in R&D can also address the UK's low productivity challenge. These outcomes make a compelling case for the UK investing in and supporting investment in R&D.

However, compared to similar countries, the UK exhibits a significantly lower R&D-intensity - measured as R&D expenditure as a percentage of GDP. While the commitment of the Government to the 2.4% target is, therefore, a worthy goal, there is an ongoing discussion over how to achieve it.

The pharmaceutical industry is key to achieving this. As the graph below shows, the pharmaceutical sector has historically been the largest investor in R&D in the UK spending significantly more in absolute numbers than the next biggest sector in terms of business expenditure on R&D.

Share of total business expenditure on R&D performed in UK business per sector 2017 [in percent]. Source: ONS



The focus of the study is to use a comparative analysis of the world's most innovating countries, those investing more than 3% of their GDP on R&D, to identify what policies have made them successful in driving such significant levels of R&D expenditure. This first part of the report found:

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The 2.4% target is ambitious

Since the mid-1980s, the UK has diverged from the average R&D intensity of OECD countries. As a result of the stagnating spending levels, R&D intensity in the UK today stands at around 1.7% of GDP. That leaves a significant gap between the UK and the top-performing OECD countries that spend more than 4% of their GDP on R&D.

However, there is evidence that change is possible. Countries such as South Korea, Austria and Belgium have successfully arrested a pattern of stagnating or even declining R&D investment to reach levels above the OECD average. With increased targeted public investment in R&D funding and policies that stimulate private sector R&D investment, the Government's ambition to reach the 2.4% target is ambitious yet generally achievable.

UK wide R&D investment will need to increase by more than 50%

Reaching this target will require a sustained effort. An increase of R&D investment by more than 50% in absolute R&D spending levels in less than a decade is needed – an increase in a range of £14.6 Billion p.a. to £22.5 Billion p.a., from the £34 Billion p.a. spent in 2017. A sustained increase in public R&D investment that is efficiently allocated to deliver high impact is needed. The Government has a clear economic case for increasing investment; their own figures show that each £1 of public investment in R&D generates around £7 of net benefit to the UK through the generation of increased GDP.

Such a goal cannot be achieved through a single action undertaken by the public sector alone. The private sector is the biggest funder of R&D within the UK and contributes more than 60% of the total funding. In order to increase R&D investment, the Government will need to consider investment and policies that stimulate private sector R&D investment. The 2.4% target cannot be met without the private sector increasing their future R&D expenditure in the UK.

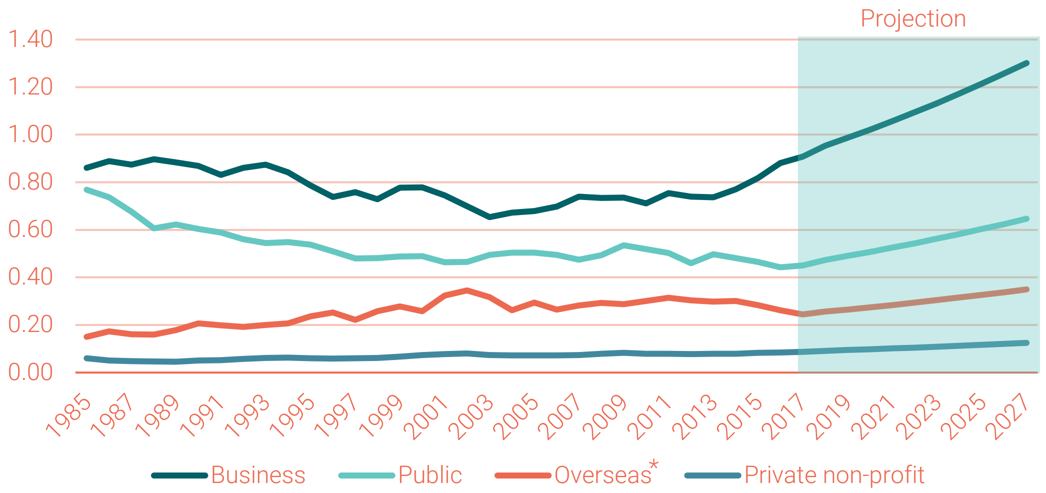
It requires a significant change in the ratio of private to public R&D investment

Most countries that invest more than the OECD average of GDP on R&D have a private sector to public sector ratio of over 3 to 1. The UK currently has a ratio of 2 to 1, suggesting that in addition to increasing public R&D investment, the Government will also need to adopt policies known to incentivise and attract greater private sector investment in R&D.

The pharmaceutical industry is a key private sector partner to reach the target

There are many industries that contribute to business expenditure on R&D in the UK, but given UK R&D investment is highly concentrated both within industries and within firms, engaging with these key investors is essential. For more than a decade, the pharmaceutical industry has invested the most in R&D in the UK. Today, they invest over £4bn per year representing over a fifth of private-sector R&D investment, in a sector that is twice as productive as the UK average. This makes the sector an attractive target for policies aimed at increasing private spending on R&D.

Projection of total R&D funding in the UK per sources of funds as a share of GDP to reach 2.4% target [in percent]. Source ONS and projection by authors



* contains all funding streams from abroad, such as R&D performed by foreign affiliates when funded by the foreign parent company or research funding programs from the European Union.

What happens next?

Two important questions remain to be answered, namely what policies will change the private to public R&D investment ratio in order to reach the goal and what the benefits and costs to the UK of adopting these policies would be.

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Part 2: Policies that drive innovation

The second part of the report gives recommendations for a UK policy framework that stimulates R&D investment based upon what has been successful in other comparable countries.

The US was selected due to its leading role as an innovator, especially in the pharmaceutical and biotechnology field and a comparable environment for R&D fuelled by an excellent academic base. Korea was selected as its policies unlocked the largest private sector investment in R&D. Belgium and Austria were included as two European countries that managed to boost their R&D intensity from a starting point below the OECD average to stable spending levels above it.

Successful innovation policies draw from a wide array of potential policy instruments to either stimulate the demand for or the supply of innovation. However, only a few instruments stimulate R&D spending itself, which are listed in the table below.

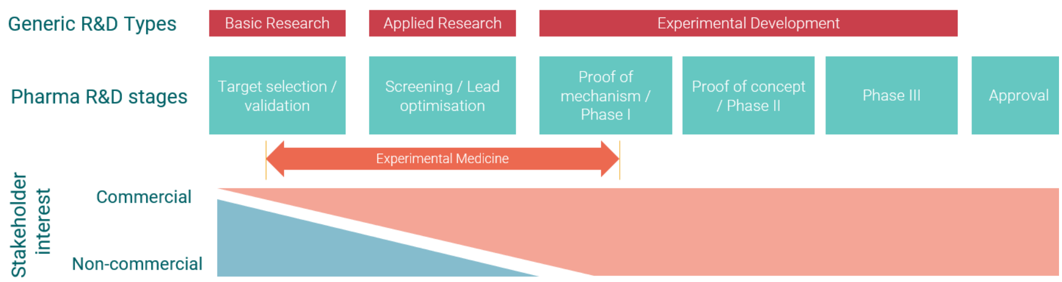
Instruments to stimulate R&D

Supply Side	Demand Side
Fiscal incentives for R&D	Public procurement policies
Direct support (for R&D and innovation) to firms	
Policies to support collaboration	
Pre-commercial procurement	
Innovation inducement prizes to increase R&D activities	

Increasing the level of Development in the UK Research & Development expenditure

There are three cross-sector globally recognised categories of R&D: basic research, applied research and Experimental Development. These categories are mapped to the different stages of the pharmaceutical development process below. The private sector in general and the pharmaceutical industry specifically invest more heavily in "Experimental Development" than in other categories of R&D. This is partly because it is closer to commercialisation but also because it is more costly due to its complexity and scale.

R&D types, pharma stages and stakeholder interest. Source: OHE Consulting, based on (OECD, 2015a, p.44), PwC (2012) and Maselbas (2013)



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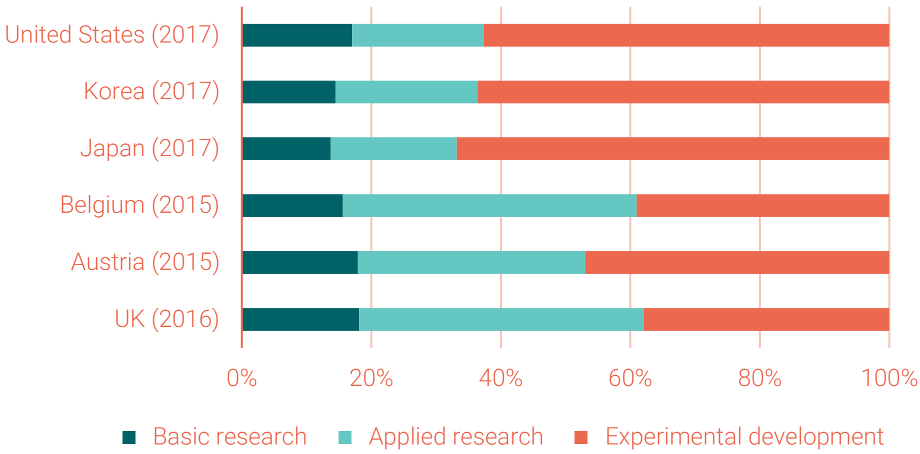
In comparison to the other countries the UK's Gross Domestic Expenditure on R&D (GERD) by sector of performance, is relatively little with respect to "Experimental Development", the kind of R&D that is mostly carried out by companies. High levels of Experimental Development in the countries analysed correlated with the largest private to public funding ratios ranging from 7:1 to 20:1. Korea, Japan, and the US have been particularly successful in this area. Our analysis concludes that in order to increase the level of private-sector R&D investment, the policy focus should be on facilitating later-stage development in the UK.

Gross domestic expendtiture on R&D by sector of performance*. Source OECD



* Germany does not report its gross domestic expenditure on R&D by sector of performance and is therefore excluded from the graph.

How did others do it?

The qualitative case studies highlighted the main differences, individual highlights, and potential learnings or noteworthy initiatives of the individual countries in comparison to the UK. Each policy instrument depends on its contextual application and scale. However, a reoccurring pattern of countries that reached the 2.4% and beyond is a high share of Experimental Development with large private to public spending ratios in combination with either strong generic fiscal incentives or direct support of R&D at a large scale.

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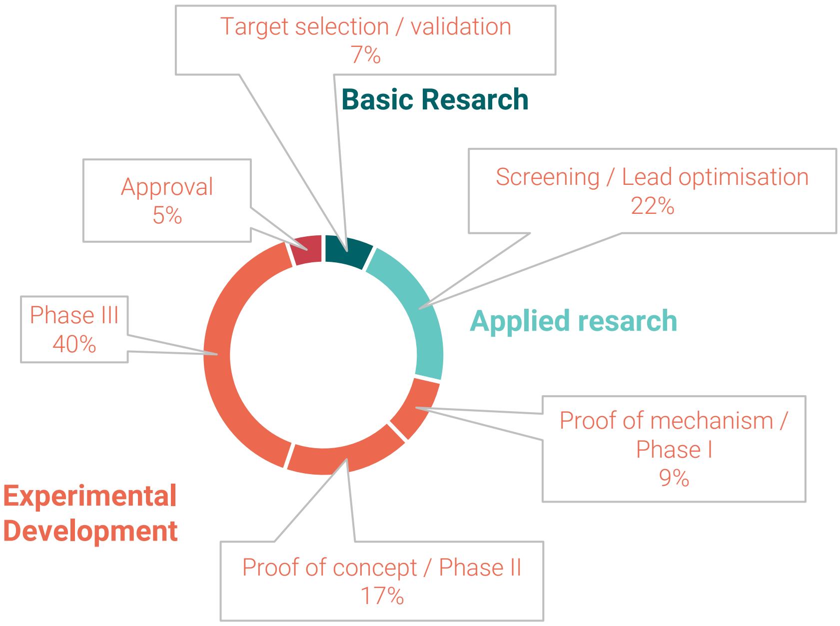
	Country-specific key enablers for reaching R&D intensity of 2.4% and beyond
US	▪ Strong market incentives created by demand from both private and public sectors for innovation create strong pull incentives for firms to invest in R&D. ▪ An entrepreneurial spirit of academics that is fuelled by the availability of public direct funding programs (i.e. Small Business Innovation Research) and venture capital, promotes industry-academia exchange and positively impacts technology transfer. ▪ Much of the performed R&D is done within the phase of Experimental Development (> 60% of all performed R&D vs. 40% in the UK) at a private to public funding ratio of over 10:1.
Korea	▪ An innovation system developed over five decades, starting by building up a strong academic science base and complemented by policies that attracted industrial R&D. ▪ Strong fiscal incentives combined with direct support for R&D focused on the Chaebols, Korean's multinationals with strong financial power. ▪ More than 60% of R&D is performed within the Experimental Development phase with a private to public funding ratio of 7:1.
Belgium	▪ Three types of generous R&D tax incentives that make up more than 70% of Belgium's public support for R&D. ▪ The tax relief is provided through a payroll withholding tax exemption, an R&D tax credit, and R&D tax allowance. Depending on the instrument, machinery, equipment, buildings, as well as labour costs, are admissible. ▪ Compared to the UK, no ceilings are in place for all three types of fiscal reliefs.
Austria	▪ Strong government ambitions to reach the top in international R&D intensity rankings led to a push of a mixture of direct R&D support and generic fiscal funding measures that were well received by domestic and foreign companies. ▪ Austria exhibits a relatively low overall private to public funding ratio. However, in the Experimental Development phase, the ratio is currently 20:1.
Germany	▪ Direct support for R&D through project-based funding, institutional funding and structural funding that promote collaboration between different stakeholders (academia and industry) and that run on a very large scale in the absence of any fiscal funding instrument. ▪ World-renowned research organisations (such as the Fraunhofer Association or Max-Planck-Institutes) that fund and perform research, bridge academia and industry and are themselves funded through a mix of public and private sources.
Japan	▪ Large domestic industry corporations fund 75% of all annual R&D activities inhouse and rely relatively little on public support. ▪ Government policies are set in the 5-year Science and Technology plan which currently aims at wider participation and benefit of society from innovation. ▪ Industry focusses on Experimental Development with a private to a public funding ratio of 15:1.

The corresponding results were used as an input for the formulation of policy recommendations that make use of the UK's relative strength in the life sciences.

The global pharmaceutical industry is a very large investor in development.

The pharmaceutical industry should be of particular interest to the UK for two reasons: it has the largest R&D expenditure in the UK private sector, and it spends more than half of its R&D budget on "Development".

Share of total budget spent by industry enhanced by type of R&D. Source: PwC (2012) with adaption based on Maselbas (2013)



Compared to other sectors where government grants can be shown to have displaced private investment in R&D, most empirical evidence suggests that public funding of the pharmaceutical sector is associated with an increase in private investment, rather than crowding it out. Furthermore, there is significant heterogeneity in firm size which avoids later dependency on a few large R&D investors. Finally, pharmaceutical R&D investments may generate spillover effects in other fields like Artificial Intelligence and Machine Learning that have the potential to enable large productivity gains beyond the life science sector.

Areas of policy focus to attract and generate more biopharmaceutical development expenditure.

Based on our analysis and country comparators, we conclude that the following factors can build business conditions and policy options that unlock additional R&D investments in the development phase from the pharmaceutical industry.

Maintaining strong generic fiscal incentives

- Fiscal Incentives work in incentivising *generic* private R&D spending and attracting foreign direct investment, but do not allow Governments to focus investment on specific industries (e.g. pharmaceutical), types of R&D (e.g. Experimental Development), or missions (e.g. antimicrobial resistance). They were particularly important in turning around R&D intensity in Austria and Belgium.

- The UK should as a minimum maintain the competitiveness of its existing fiscal incentives, by futureproofing the scheme to ensure that it supports where the industry needs to invest in the future (e.g. in big data and data science). Given the scale of the 2.4% challenge, it may wish to do more, particularly to enhance its large company scheme which benchmarks less well than that for SMEs. As the innovation ecosystem in the UK consists of both large and small companies, a balanced approach to support both is needed.

Grow investment in the Development stage of R&D

- Countries like the US have demonstrated that policies that focus on "Development" will attract greater private sector investment. Highly targeted policies are required such as the direct funding of R&D (e.g. Grand Challenges), and public procurement policies (e.g. advanced market commitments).

- Policies can be linked to mission-oriented innovation policies (e.g. a specific vaccine or condition) and to specific industries (e.g. pharmaceutical) ensuring that R&D investment is aligned with societal needs and interests.

- With the life science sector, public-private collaboration in the field of clinical trials offers an effective lever.

Strengthen the entrepreneurial role of the academic sector

- Incentivise academics and their institutions to commercialise basic and applied research results, crowding in additional private sector investment to commercialise the research in the development stage.

- Ensure the availability of public funding and (corporate) venture capital for early-stage projects, and that there are the right entrepreneurial skills (e.g. Brussels life science incubator) and infrastructure (e.g. viral vector capacity) to enable effective technology transfer.

Ensure the supply of world-class talent

- Maintain and enhance the attractiveness of UK Universities to national and international students and provide the next generation of researchers across all stages of the R&D pipeline.

- Create training schemes that deliver, before other countries, the skills requirements in emerging capability gaps in Life Sciences.

Conclusion

R&D is the most important input for innovation and innovation itself is crucial for ensuring the UK grows sustainably and solves the grand challenges of our time. While the UK is a highly innovative country, its R&D intensity lags those of other innovative countries - this creates a long-term risk.

To reach the Government's 2.4% target there needs to be both, a significant increase in public R&D funding, and adoption of policies and incentives to attract significantly more private-sector R&D investment. Countries that have achieved the UK's stated aim have done so by crowding in substantially more private sector investment, with private to public investment ratios of more than 3:1 in comparison to the UK's 2:1.

Several countries that exhibit a high level of R&D intensity make successful use of policy instruments that may be suitable to stimulate private spending on R&D, but these policies must be analysed within the cultural, economic and political contexts of the country. Those policies that are most likely to work in a UK context, were put forward as recommendations. A special emphasis has been placed on the pharmaceutical industry as it is the largest single investor in R&D in the UK. If private spending on R&D is to be increased, policies need to aim for enlarging the share of Experimental Development in the UK. The pharmaceutical industry allocates over 50% of its research budget to this research phase during clinical trials and – as the UK's largest single investor in R&D - is an excellent target.

Nevertheless, companies choose their R&D location not only according to the biggest financial incentives but due to multiple location factors. Other countries have demonstrated how excellence in academia and the entrepreneurial behaviour of academics leads to increased private spending in R&D. The Government should, therefore, ensure that the supply of world-class R&D talent continues and that the academic sector gets stronger incentives to aim for the commercialisation of their research.

1 Part 1 – The scale of the challenge

1.1 Mind the gap: The UK invests significantly less into R&D than the OECD average

Research and Development (R&D) is the process of creating new knowledge, and there is a compelling case for investment in R&D. According to the OECD (2016, p.152), "R&D comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge (including knowledge of man, culture and society) and the use of this knowledge to devise new applications. R&D covers three activities: basic research, applied research, and Experimental Development."

Among other benefits, R&D leads to new products and services, and economic prosperity in the form of more jobs and increased tax revenue. It may also address the UK's stubbornly low relative productivity.

All three main UK political parties supported increasing total investment in UK R&D at the last election, and through the Industrial Strategy, the Government has committed to meet a target of 2.4% of Gross Domestic Product (GDP) invested in UK R&D by 2027, with a longer-term goal of reaching 3%.

R&D investment in the UK currently stands at around 1.7% of GDP, just over £30bn per year. The Government is promising a 50% increase by 2027, which is an ambitious target and, whilst there is universal agreement that increasing R&D investment in the UK is worthwhile, there is an ongoing discussion over how to achieve that goal.

The pharmaceutical industry in the UK is critical to the strength of the UK economy. With over 62,000 employees and investing over £4bn per year, the pharmaceutical industry invests more than any other in R&D. Whilst UK productivity remains a key economic challenge, life sciences workers are twice as productive as the UK average (PwC, 2017b).

In measuring how much a country invests in R&D, there are two variables of interest: absolute levels of R&D investment, and R&D intensity, defined as R&D as a proportion of GDP[1]. R&D is measured by Gross Domestic Expenditure on R&D (GERD), and consists of the total expenditure (current and capital stocks) on R&D carried out by all resident companies, research institutes, university and government laboratories, etc. Whilst it includes R&D funded from abroad it excludes domestic funding for R&D performed outside the domestic economy.

An international comparison of the UK against other OECD countries illustrates that current R&D expenditure is significantly lower in the UK. This gap is the main driver for the Government's target of investing 2.4% of GDP in R&D by 2027.

1.1.1 Where is the UK today?

In 2017, the latest year in which there are data available, the UK spent 1.69% of GDP on R&D. This was 0.7 percentage points behind the OECD-average of 2.4% and 2.9 percentage points behind Israel which has the highest R&D intensity in the OECD (see Figure 1). It is not a question of the size of the

[1] Data from the Office of National Statistics was released in Q1 2019 and covers a time period including the year 2017. Data that includes the year 2018 will be released in the next cycle (Q1 2020). The data presented is in constant prices. Data from the OECD was analysed up to the year 2017 to allow for better interpretation between charts.

economy either, as the UK's R&D intensity was also below the average of the largest five OECD countries, which is 1.89% of GDP.

This picture is not new. Since the mid-1980s, the UK has diverged from the OECD average R&D intensity. Numerous reasons are offered by commentators. Some blame the decline in business sector R&D investment and a broader shift to innovations that do not require large R&D capacities. One argument made in the literature is that the death of corporate laboratories such as ICI or GEC had a significant negative impact on R&D intensity in the country (Jones, 2013). Whilst this may have been historically true, the following sections show that declining business expenditure was arrested and then reversed since 2010.

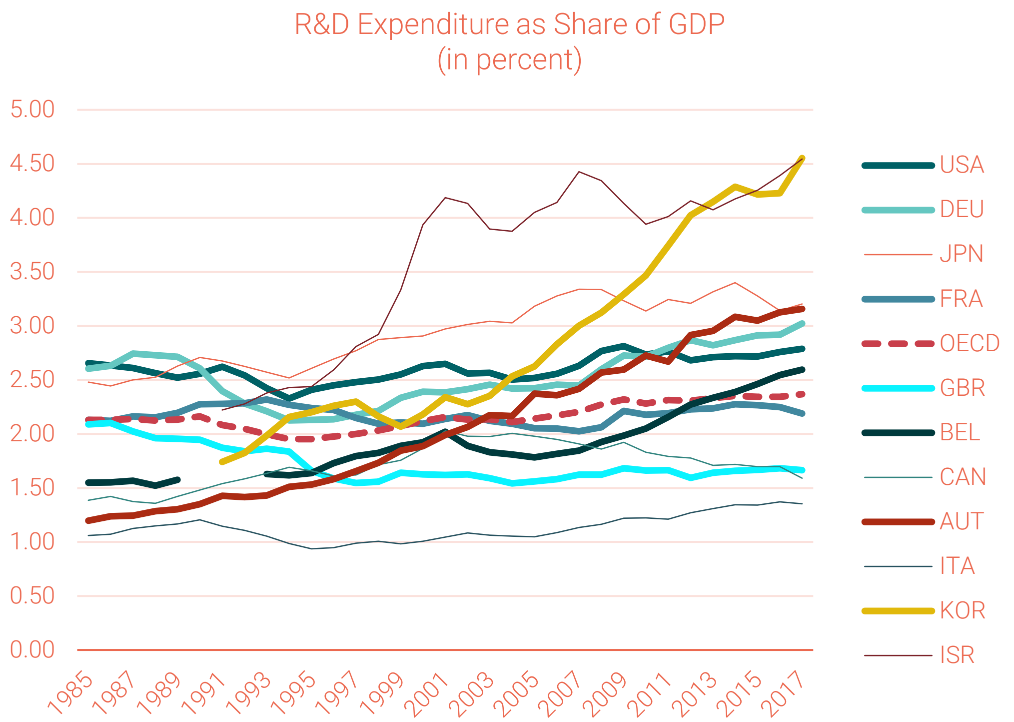


Figure 1: R&D Expenditure as Share of GDP of selected countries.
This indicator is measured in USD constant prices using 2010 base year and Purchasing Power Parities (PPPs) and as a percentage of GDP. Source: OECD.

Over the past 20 years, countries that have continuously invested above the OECD average in R&D are the UK's industrial partners and competitors such as the USA, Germany, and Japan. Meanwhile, South Korea and Israel invested above average and have rapidly increased R&D investment over the past decade. More recently, Belgium and Austria grew levels of R&D investment above the average OECD and in doing so they have demonstrated that it is possible to recover from a historic trend towards relatively low R&D investment.

In summary, there is a large gap between the UK and the OECD average level of R&D intensity and a significant gap between the UK and the OECD's top investing countries in R&D. Therefore, there is a substantial challenge facing the UK.

1.1.2 Why is it important to do more?

R&D and innovation benefits society by creating knowledge and jobs, and by exploiting the related outputs to improve quality of life and wellbeing, ultimately leading to a more prosperous economy.

R&D can also help improve productivity and therefore increase export competitiveness, both of which are significant concerns for the UK in a post Brexit era. As increasing employment and growing the economy generates more tax revenues, Government support for R&D investment either directly or indirectly through policies such as tax incentives, will generate a virtuous cycle.

Given the important role of R&D and innovation with respect to economic growth, it is, therefore, necessary that the UK does more to stay competitive in a globalised world. The Government has a clear economic case for increasing investment; their own figures show that each £1 of public investment in R&D generates around £7 of net benefit to the UK through the generation of increased GDP (Innovate UK, 2018). However, the Government sees the challenge that neither itself nor the private sector is investing enough in R&D, which in return reflects negatively on the nation's productivity, which is stagnating since 2010 (see Figure 2). Even after adjusting for the structure of the UK economy – which is dominated by services rather than the traditionally R&D-intensive sectors like manufacturing – investment is still comparatively low (OECD, 2017b, p.170).

Therefore, in 2017 the UK government announced, as part of the Industrial Strategy's aim to improve productivity and to create better and higher-paying jobs across the UK, to "work with industry to boost spending on R&D to 2.4 per cent of GDP by 2027". The 2.4% target set by the government is ambitious, given the UK's history of decline in R&D spending as a share of GDP. Reaching the target would put the UK marginally above the current OECD average (2.3%), but still behind the leaders e.g. US (2.7%), Japan (3.1%) and South Korea (4.3%).

However, looking at countries such as Belgium and Austria, it seems possible to arrest a pattern of stagnating or even declining R&D investment and reach a level above the OECD average. Hence, the 2.4% target is realistic. Understanding what policies have been successful in similar economies and which are most appropriate to the UK is a key part of achieving this ambitious goal.

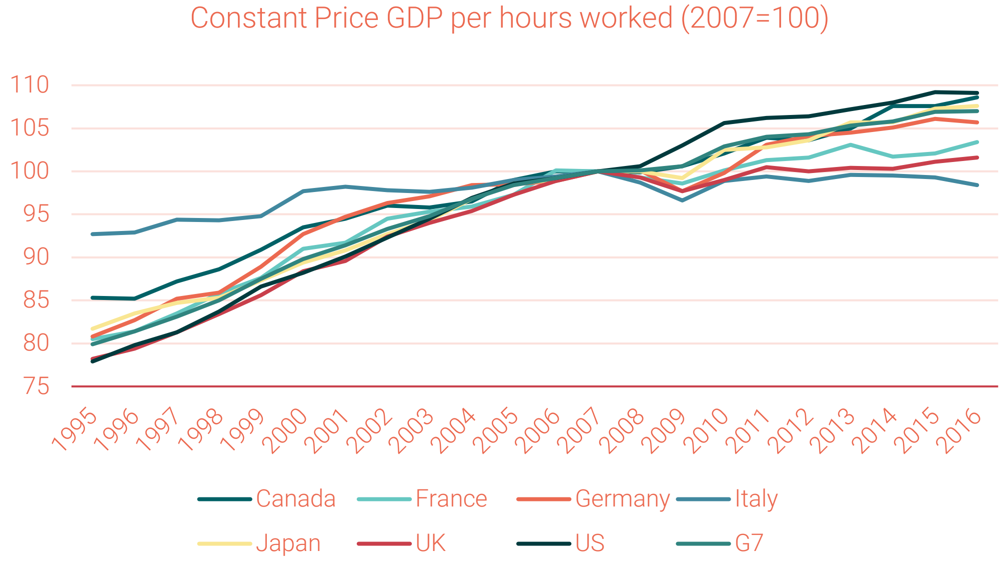


Figure 2: International comparisons of productivity.
Source ONS.

1.2 Who pays: the majority of investment is made by the private sector

Before considering ways in which to increase the UK's R&D[2] intensity it is instructive to understand who pays for and who performs R&D in the UK. The Government is likely to have more success in growing already R&D intensive firms and industries than to attract and grow an entirely new sector of the economy to a scale required to increase R&D investment by 50% in less than a decade.

Whilst there has been some volatility in R&D investment, there has been a significant decline in public investment over time which has been offset in recent years by growing business sector investment. Overall, the business sector contributes most to both financing and performing R&D in the UK.

1.2.1 Who performs R&D in the UK?

R&D is performed across many sectors in the UK, including the business or commercial sector, higher education and research councils, governmental institutions, and private non-profit organisations. However, in the UK, the private sector (business and private non-profit) is the engine of R&D activity with 68% of R&D activity performed in that sector in 2017 (see Figure 3).

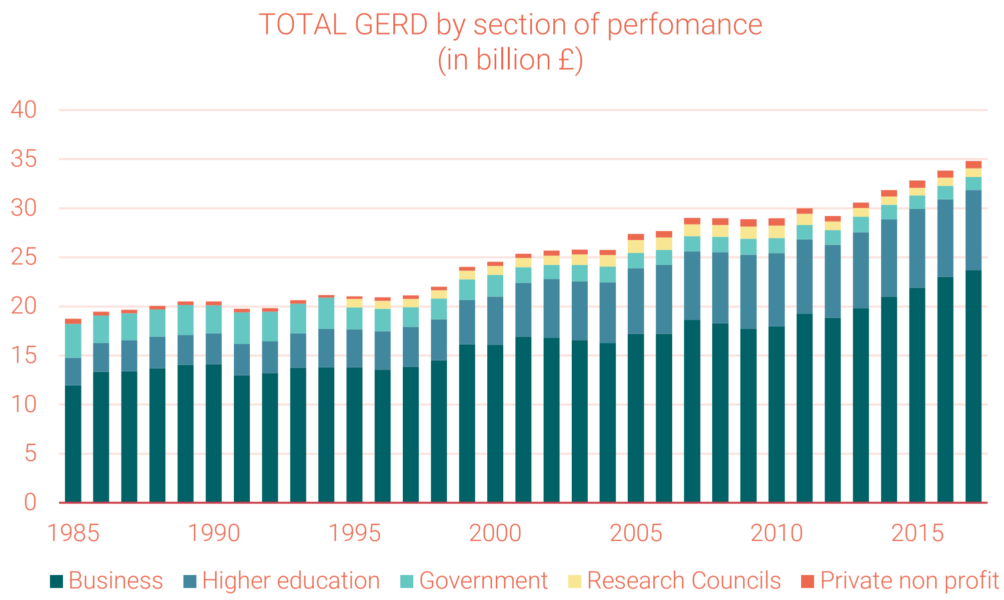


Figure 3: Gross domestic expenditure on R&D (GERD) by sector of performance.
Source ONS.

Figure 3 illustrates a general trend of significantly declining government performed R&D. The underlying cause of this decline is almost certainly the policy of privatisation of many R&D intensive industries including, for example, the aerospace (e.g. British Aerospace in 1981 and 1985) and telecoms (e.g. British Telecom in 1984, 1991 and 1993) companies in the 1980s through to the defence sector (e.g. QinetiQ in 2003 and 2008) in the early 2000s (Hough, Rhodes and Butcher, 2014). Over the past almost 40 years, there has been significant growth – almost four-fold – in the amount of R&D performed by higher education institutions (HEI) (i.e. universities), more than offsetting the reduction in government performed R&D over the period. Two noticeable events may

[2] Please note that unless stated otherwise, all analyses focus on R&D expenditure as a whole and not on a specific industry sector.

have contributed to the growth in HEI R&D activity. First, the widening of the HEI sector through the Further and Higher Education Act of 1992 that saw 35 polytechnics conferred university status (see UK Government (1992)). And, second, the significant growth in research funding to universities from the EU Framework Programmes. These EU Programmes have grown from Euro 3.8 billion (1984-7) to Euro 77 billion (2014-20) (see Council of the European Communities (1983) and European Parliament and Council of the European Union (2013)). The UK is a net receiver of Euro 3.4 billion over the period 2007 to 2013 from EU research and science funding (National Audit Office, 2017)

In comparison, the business sector increased the amount of R&D activity steadily. Only once since 2000, namely in 2009, did the R&D activity in the business sector fall from one year to the next.

1.2.2 Who funds R&D in the UK?

The pattern of funding of UK R&D is similar to the pattern of R&D activity with a noticeable exception; overseas funding has grown substantially. There are two potential reasons. First, the significant growth in EU research funding to UK HEIs since the Framework Programmes were introduced in 1984 discussed previously. Second, increasing globalisation has resulted in multinational corporations investing more in UK R&D operations (Crescenzi, Gagliardi and Iammarino, 2015).

The biggest funder of R&D within the UK is the private sector, and since 2010 funding from this sector has not been reduced (see Figure 4). Generally, the trend shows that R&D investment from the public purse is more volatile than private sector investment with periods of declining funding. The historic growth in absolute levels of R&D investment has come from a growing private sector and overseas investment.

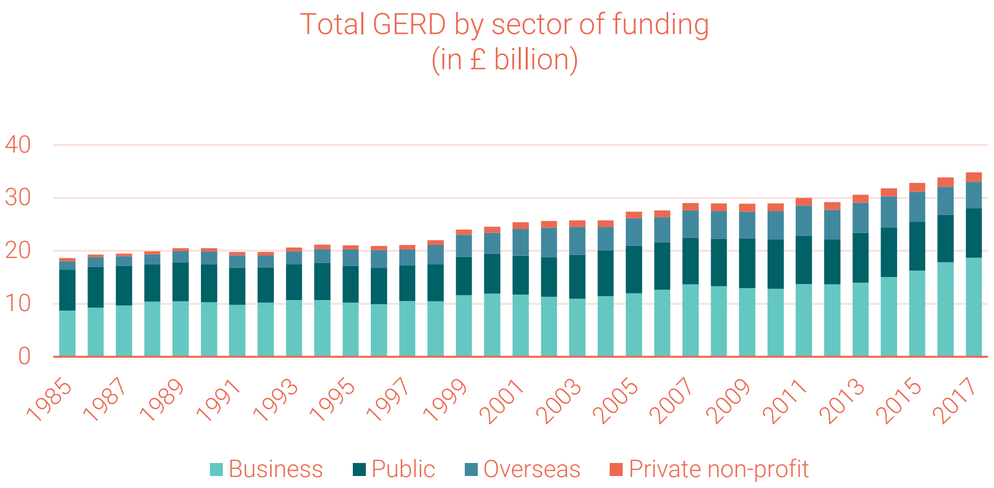


Figure 4: Total GERD by sector of funding. Overseas contains all funding streams from abroad.
Source ONS.

The private sector funds over 60% of R&D in the UK (see Figure 5). Approximately 30% is from public sources such as directly from the government, or indirectly from research councils or spending through higher education[3]. Hence, the ratio of private to public spending sources is approximately 2:1, which is comparable with some other major economies such as the USA or Germany. Historically, the UK's public sector provided a large proportion of R&D investment and the growth in private sector R&D investment might be a result of a number of factors, such as the significant internal incentives for domestic firms to invest in R&D most notably due to export competitiveness,

[3] The Higher Education Funding Council for England (HEFCE) distributed public money for teaching and research to universities and colleges. It closed on 1 April 2018.

or the privatisation programme that shifted some large R&D investors from the public to the private sector.

After the financial crisis in 2008, business spending on R&D declined from £13.6 billion in 2007 to a low of £12.8 billion in 2010. Over that period, public spending across all sources was relatively stable at £8.9 billion in 2008 and increased to £9.4 billion in 2013. However, between 2013 and 2017 business R&D expenditure grew significantly by 34% to £18.7 billion per annum, while at the same time public spending declined by 2%.

More recently public spending on R&D increased by 3.8% in 2017, the latest year of published data. In the Autumn Statements of 2016 and 2017, the Government announced an increase in R&D expenditure primarily by reallocating part of the National Infrastructure Productivity Fund. Together these announcements will see an additional £2.3 billion of public investment a year by 2021/22 (HM Government, 2017b) increasing public R&D expenditure to a predicted £12.5 billion that year.

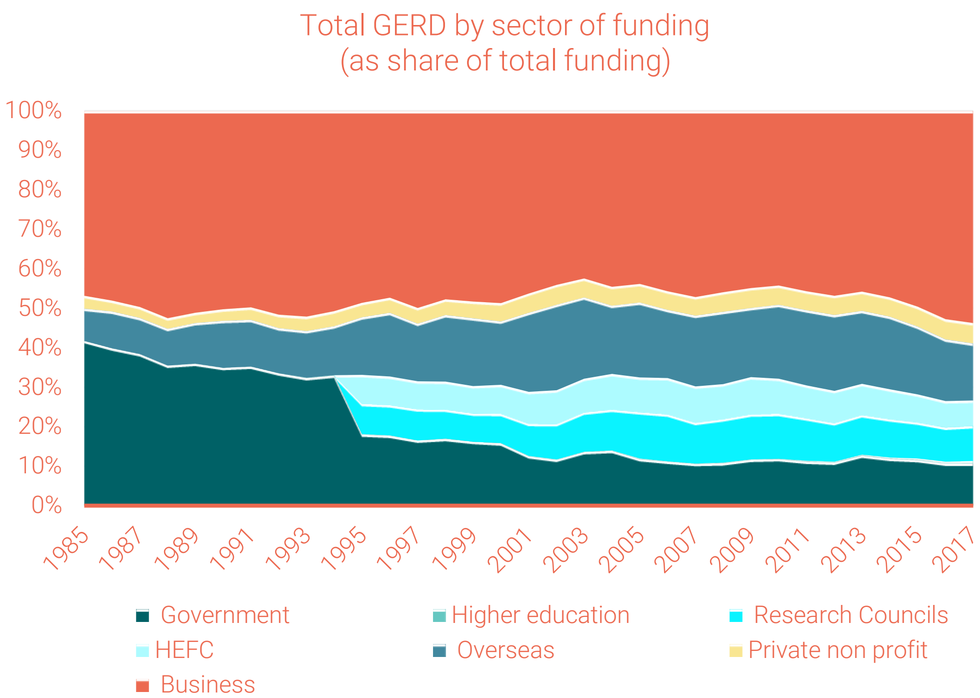


Figure 5: TOTAL GERD by sector of funding. Overseas contains all funding streams from abroad.
Source ONS.

A more useful metric is to consider the investment by sector as a share of GDP – as shown in Figure 6, the sector equivalent of the so-called R&D intensity. Adopting this measure, both business and public funding jointly declined until 2003, although business investment was more volatile whilst public funding exhibited a mostly steady decline over the period. Especially since 2010, their paths diverged further with business funding returning to the peak levels of the mid-eighties whilst public spending declined even further, and hence increasing private-sector R&D investment has counterbalanced declining public investment in R&D.

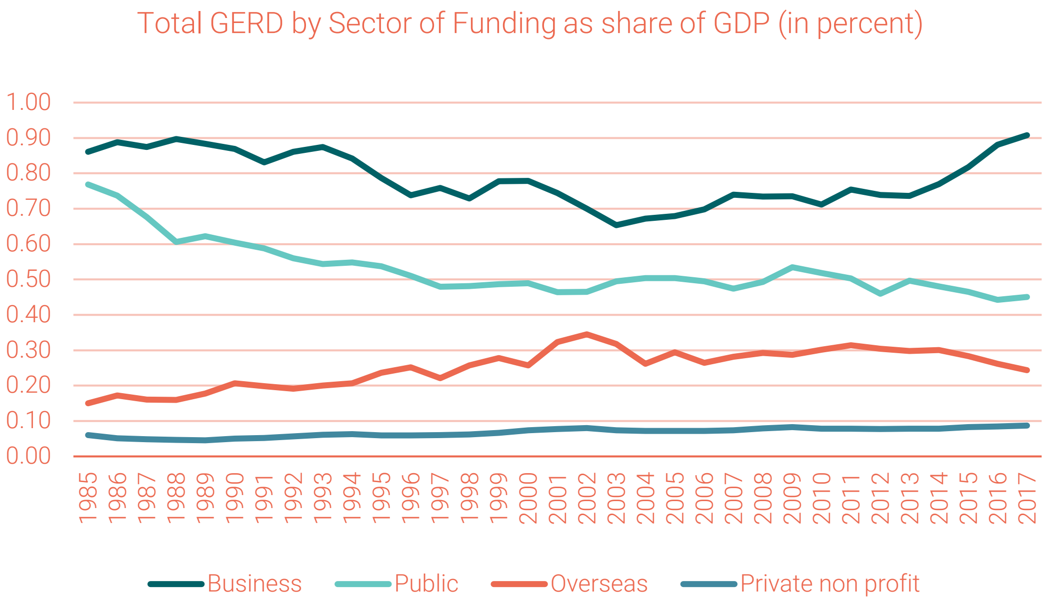


Figure 6: Total GERD by sector of funding as a share of GDP.
At constant prices. Public spending includes spending through government, higher ed., HEFC and research funding). Overseas contains all funding streams from abroad. Source ONS.

1.3 What is required to reach the 2.4% target?

Increasing R&D investment by more than 50% in less than 10 years will require a substantial shift in behaviour, and therefore new approaches to unlocking R&D investments.

Reversing a historic decline in public R&D investment to fill the gap between the UK and the OECD average would appear challenging both in terms of budgetary impact and in terms of ensuring efficient and impactful allocation of public R&D funding.

A further consideration for Government is whether the aim is to encourage a broad economy-wide increase in R&D investment, or whether to focus on sectors and industries that are research-intensive. Identifying the industries that can help the Government achieve the goal and adopting policies to unlock further R&D investment would allow targeted government interventions that would maximise the probability of success whilst minimising spending.

1.3.1 Leverage the private to public R&D funding ratio

Hitting the 2.4% target by 2027 requires significant additional R&D investment from all sectors of the economy. As the economy is expected to grow over that period and the target is tied to GDP the absolute or nominal value of R&D investment required will grow substantially over that period.

The necessary increase in R&D investment will depend on future GDP growth and the size of overseas R&D investment. For instance, with a stagnating economy with no GDP growth, UK R&D

investment would need to increase from £34.8 billion in 2017 to £49.4 billion in 2027; with average GDP growth of 1.4% per annum[4], it would need to increase to £57.3 billion in 2027.

Currently, the private[5] to public R&D investment ratio is approximately 2:1. Based upon the current ratio, business sector investment in R&D would have to increase by £7.8 Billion between 2017 and 2027 (stagnating GDP) and £12.1 Billion (GDP growth of 1.4% per year), respectively (see Figure 7); in 2017, it was £18.7 Billion. Public spending, which totalled £9.3 Billion in 2017, would have to increase by £3.9 Billion or £6.0 Billion between 2017 and 2027, with a stagnating economy or a growing economy (1.4%) respectively. Expressed as a share of GDP it requires public spending to increase by 0.2 percentage points and the business sector by 0.39 percentage points (see Figure 8). Estimates of the necessary increase in public R&D investment vary. For example, the Campaign for Science and Engineering has estimated that the Government will need to invest an additional £9 billion[6] per annum by 2027/28 in addition to the £2.3 billion per annum increase by 2021/22 (CaSE, 2018). To put this into perspective, this is equivalent to more than doubling the size of UKRI and NIHR combined.

The UK has an exceptionally strong science base and a higher education sector that is truly world-leading. With less than 1% of the world's population and just 4% of the world's researchers, the UK earns 12% of international citations and 16% of the most cited papers (The Russell Group, 2018). Increasing public investment in R&D, especially through the traditional research-intensive channels that the UK has a comparative advantage in, will be critical to meeting the 2.4% target. A review of NIHR funding by Rand Corporation in 2016 found the programme to be "transformative" (Morgan Jones et al., 2016) and increasing funding to such channels should be welcomed. However, there may be concerns about the capacity of the higher education sector to absorb such significant increases in funding and to have these funds allocated efficiently and effectively. Additionally, the Public Accounts Committee recently raised concerns over the imbalance between basic and more applied and translational research in the UK when compared to other countries (Committee of Public Accounts, 2018).

In addition, the 2.4% target puts pressure on already scarce public budgets at current investment ratios, which would be exacerbated further by reaching the longer-term 3% ambition. Encouraging higher levels of private sector investment and therefore benefiting from the multiplier effect will deliver excellent value for money alongside increased public investment in R&D activities. The success of this is dependent on the Government and industry working together to develop fiscal policies.

If the Government maintains a ratio of 2:1 (private to public investment) and does not develop policies that change the level of crowding in[7] of private investment above £1.36 per £1 spent (Economic Insight, 2015), then public support for R&D is likely to be closer to the CaSE estimate of £11.3 billion per annum by 2027/28. The Public Accounts Committee recently suggested that the Government could do more to encourage private sector R&D investment (Committee of Public Accounts, 2018).

[4] 1.4 % as been chosen as an assumption for the annual GDP growth rate as it was the latest available value for year on year growth in Q4 2018 provided by the ONS. It is also close enough to the average projected annual growth rate of the Office of Budget Responsibility of 1.48% until 2023 (Office for Budget Responsibility, 2019).
[5] Please note that private expenditure includes private not for profit spending.
[6] Please note that CaSe modelled the long-term target of the government of R&D Intensity (3% of GDP).
[7] Crowding in is the increase of private investment due to the increase in debt-funded government spending.

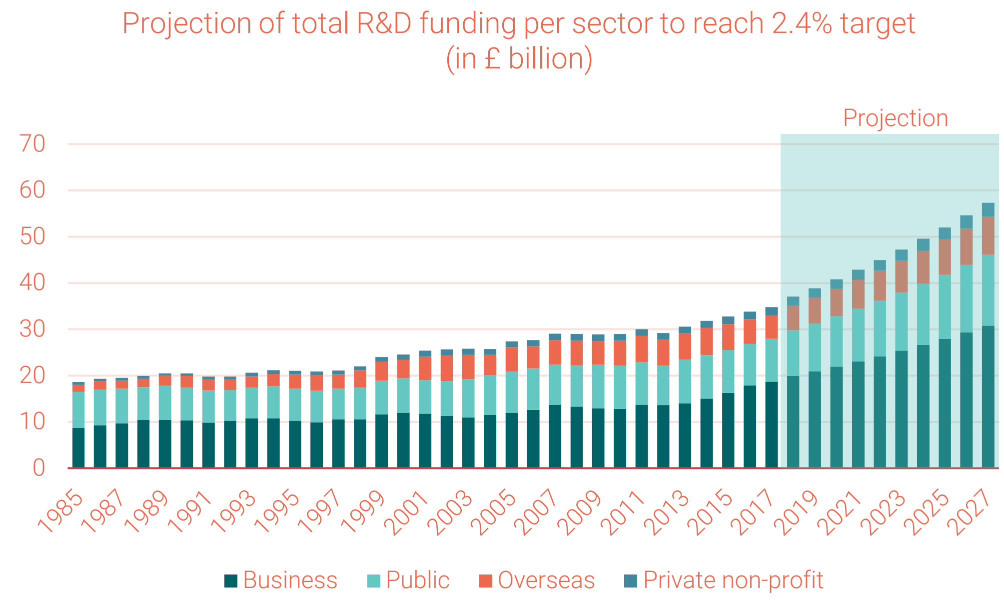


Figure 7: Projection of R&D funding.
Assumes an annual GDP growth of 1.4%. Overseas contains all funding from abroad. Source ONS and projection by authors.

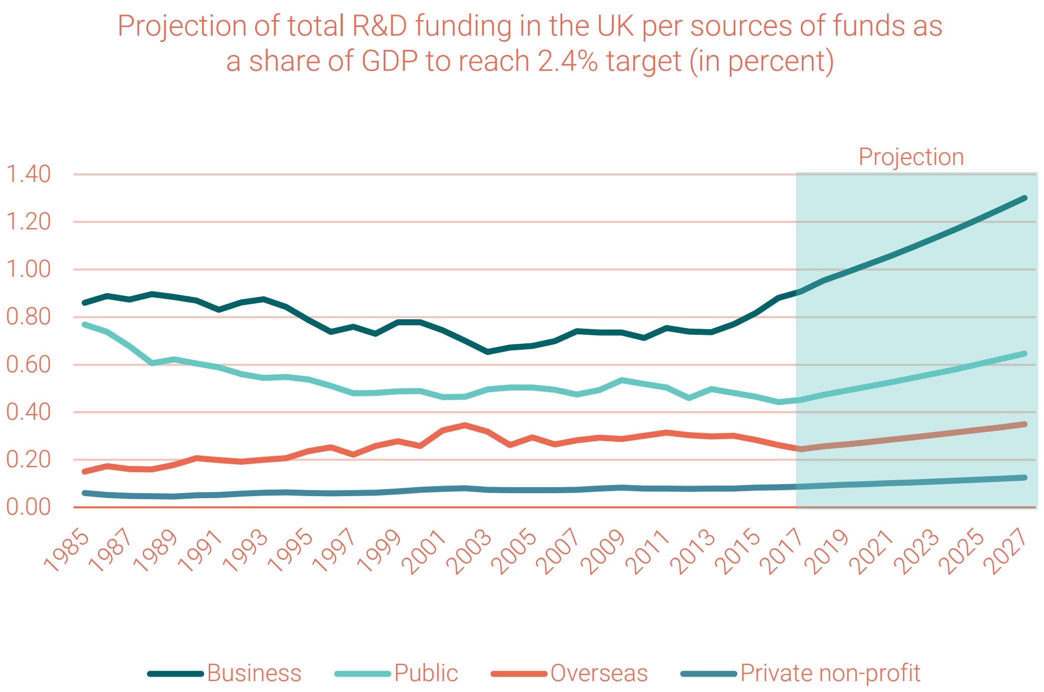


Figure 8: Projection of total R&D funding expressed as a share of GDP.
Assumes an annual GDP growth of 1.4%. Overseas contains all funding from abroad. Source ONS and projection by authors.

In Figure 9, the ratio of private to public R&D investment for a selection of OECD countries is depicted. Those countries that lead the R&D intensity rankings also have the largest ratio of private to public expenditure, leveraging the investment of the business sector to achieve high levels of R&D intensity. For example, in Japan (3.9:1), China (3.9:1), Taipei (3.8:1) and South Korea (3.5:1) the private sector more than triples the investment from the public sector. Here the UK lags behind at 2:1, even with data from 2017 where there is already a widening gap between private and public funding that has occurred since 2011.

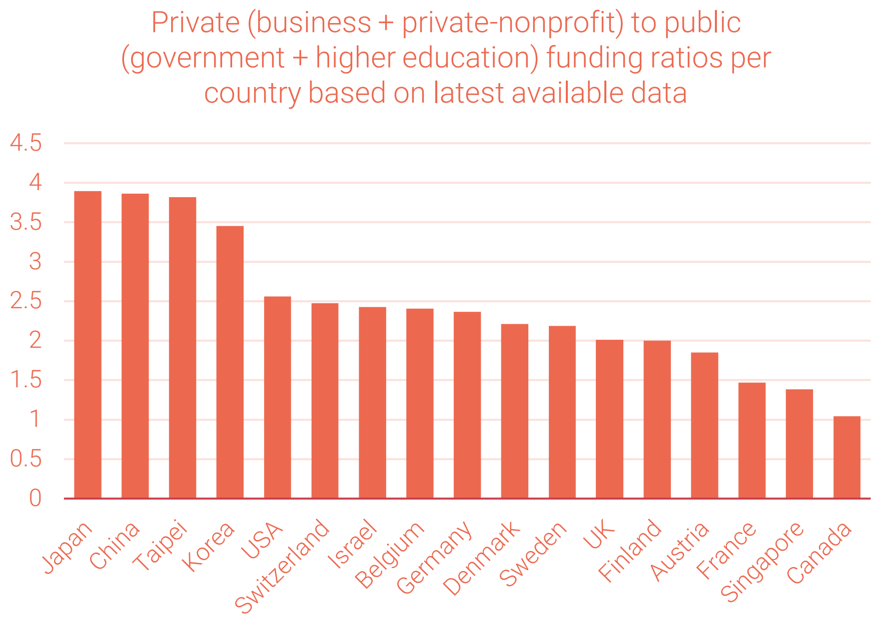


Figure 9: Funding ratios based on latest data from 2017.
Data from Belgium, Finland, Germany and Israel were only available for 2016. Data for Belgium and Switzerland were from 2015 and Singapore from 2014. Data from the UK was based on ONS data. All other countries are based on OECD data.

To meet the 2.4% target, public R&D investment must increase substantially, but leveraging significantly higher levels of private sector investment is fiscally prudent. This is especially important when there are significant opportunity costs in public sector expenditure (e.g. education or health). Based upon the ratios of the leading countries that have successfully delivered sustained high levels of R&D intensity, the UK should aim in the longer term for a private to public R&D investment ratio of between 3 and 4 to 1, and in the short term should set a target of 2.5 to 3 to 1. In the longer term as the Government shifts its focus on to an R&D intensity level of 3% of GDP, leveraging private sector investment will be even more important.

The second part of the report will investigate what policies have been successful in increasing the ratio of private to public sector investment in countries that top the R&D intensity league table.

1.3.2 The public sector should join forces with the private R&D heavyweights

In addition, to understanding how best to spend increased R&D investment, the Government must consider where in the economy to spend it. The UK's industrial structure is dominated by services rather than R&D-intensive sectors such as manufacturing (HM Government, 2017a). As innovative services firms do generally not focus on putting new technologies into the hands of their customers, innovation in the service sector rarely depends on R&D (Abreu et al., 2008). One reason might be that R&D activities in the service sector are not yet adequately captured in the current statistics. Vallance (2019) recently called for the identification of R&D needs in the service sector and how they can contribute to reaching the 2.4% target. Nevertheless, even if R&D in the service sector can be measured more accurately, and even if relevant R&D needs are identified and funded, it is rather unlikely that the service sector will play the leading role in reaching the 2.4% target.

Another potential strategy might focus on underfunded technology fields and companies that need upscaling. Whilst it is important to ensure the competitiveness of highly relevant future technologies (e.g. within the field of Artificial Intelligence) it is questionable whether such a strategy alone would be enough to meet with 2.4% target. The main reason for this is, that irrespective of the type of the industry, the scale of the industry and its firms matters.

There is a significant concentration in R&D investment in the UK. As Haley (2019) states, the largest 15 R&D investors in the UK, mostly large companies, account for more than 30% of total business R&D while the top 50 accounts for over 50% of Business enterprise research and development (BERD). By contrast, SMEs account for approximately 4% of BERD. Therefore, focussing on industries that are small and dominated by SMEs is unlikely to be sufficient to reach the 2.4% target. Hence, an adequate funding strategy must make use of the existing heavyweights in private R&D funding because of their significant impact on total R&D activities.

R&D investment is highly concentrated in a small number of industries in the UK. As shown in Figure 10, pharmaceuticals, automotive, computer and software development, as well as aerospace, represent approximately half of all business expenditure on R&D. Here, pharmaceuticals and the automotive sector stand out, contributing over 30% of total R&D investment.

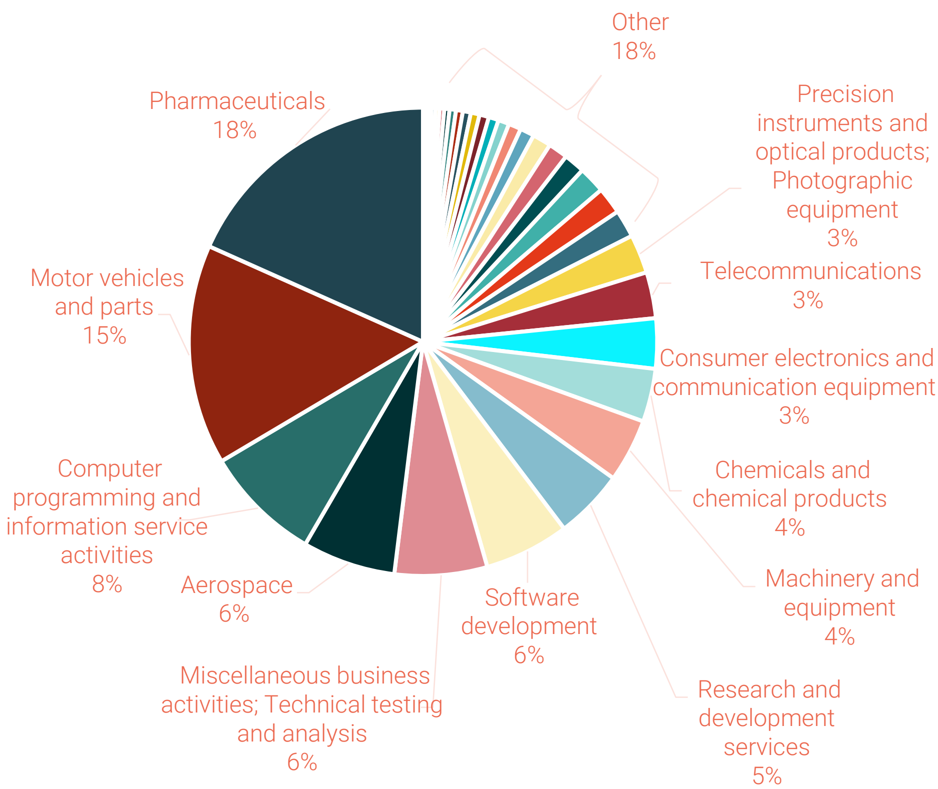


Figure 10: Share of total business expenditure on R&D in £ million by industry group in 2017.
Source ONS.

Further, as can be seen in Figure 11, the pharmaceutical sector has historically always been the largest investor in R&D in the UK spending significantly more in absolute numbers than the next biggest sector in terms of business expenditure on R&D. In comparison, the aerospace industry has been reducing investment in the UK while the recent rise of the automotive sector is a result of partnerships between the government and the industry in the last decade (HM Government, 2018). Additionally, the pharmaceutical sector is the most productive sector in the UK, and with annual turnovers of £41.8 billion, providing 8.2 per cent of UK goods exports and employing more than 113,000 people, directly or in service and supply roles (House of Commons, 2018).

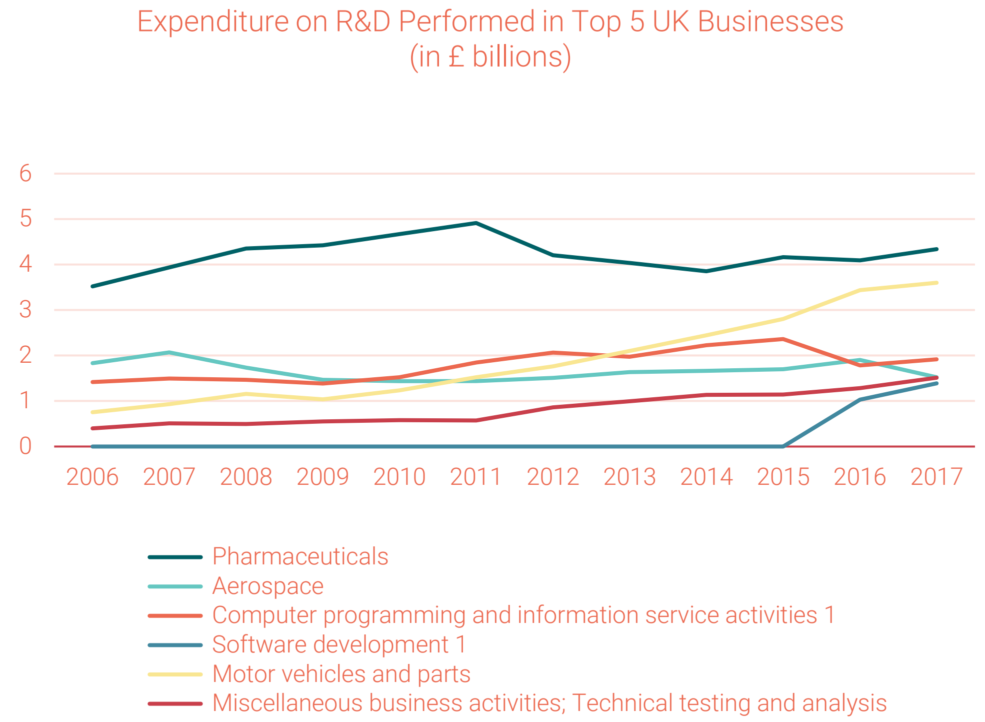


Figure 11: R&D expenditure of Top 5 sectors performing R&D over time[8].
Source: ONS.

The life sciences sector that includes the pharmaceutical sector, has a productivity that is twice as high as the average across the UK economy. Increasing the investment and therefore the size of the UK life sciences industry would result in a disproportionately positive impact on jobs through the multiplier effect (PwC, 2017b).

The UK appears to have a comparative advantage in the pharmaceutical industry and more broadly in the life sciences sector. The deep links of the pharmaceutical industry with academia are demonstrated by over 16,000 co-authored papers between 2006 and 2015 (Clarivate Analytics, 2016). Further, due to its impact on the economy driven by its size and productivity, the pharmaceutical industry can, therefore, be considered as a key partner in achieving the 2.4% target.

The Government recognises the importance of the life sciences sector in delivering their Industrial Strategy as evidenced by the creation of the Life Sciences Council, development of the Life Sciences

[8] *Please note that software development was included in computer programming and information service activities until 2015.*

Industrial Strategy and the two Sector Deals. A deeper understanding of how the pharmaceutical industry can work in partnership with the Government to leverage the UK's comparative advantage and to unlock further R&D investment to deliver the 2.4% target, is therefore crucial.

1.4 Conclusion

R&D investments deliver a range of economic and social benefits, and there is broad consensus across the political spectrum that it is important for the UK to increase R&D intensity – R&D expenditure as a percentage of GDP.

To this end, the Government has made a commitment to the UK investing 2.4% of GDP on R&D by 2027, putting it slightly above the OECD average. This report has demonstrated that given the significant gap between the UK's current levels of R&D investment and the top OECD countries, the goal is ambitious yet generally achievable as other countries like Belgium have successfully demonstrated a similar turnaround.

Countries that have sustained high levels of R&D intensity have exhibited high levels of private sector investment, achieving private to public investment ratios of almost 4:1. These countries generate significant multiplier effects and the UK should emulate these exemplar countries if it wants to achieve the 2.4% target and move beyond to the long term 3% ambition. Therefore, the UK should target a private to public funding ratio in the range of between 3 and 4 to 1 compared to the current 2:1 level.

The UK appears to have a comparative advantage in pharmaceuticals. The industry is one of the most productive industries in the UK, exports significant levels of goods, has deep links with the academic sector and has invented many of the world's leading pharmaceutical products. Historically it has been the largest and most stable R&D investor representing almost a fifth of total business expenditure on R&D.

Understanding what policies would encourage the private sector, and leading R&D investing industries, in particular, to increase their future R&D expenditure is a key part of delivering this ambitious 2.4% target.

2 Part 2 – Policies that drive innovation

2.1 What is innovation?

This part of the report aims to examine how other comparable countries have managed to achieve and sustain this level of R&D intensity and identify which policies could be transferrable to the UK. Two main groups of countries warrant further analysis. First, countries that have managed to continuously outperform the average R&D intensity of OECD countries (e.g. the US) and, second countries that have transitioned from historically low levels of R&D intensity to be above the OECD average (e.g. Austria). Increasing the level of R&D expenditure in the UK to a target of 2.4% of GDP requires a mix of suitable *innovation policy instruments*. In this context, it must be noted that R&D and innovation are not the same.

An innovation is defined as a "new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD and Eurostat, 2018, p.20).

According to the Frascati Manual, R&D can be defined as "comprising of creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge" (OECD, 2015a, p.44). It comprises three types of activity.

- **Basic research** which is experimental or theoretical work undertaken primarily to acquire new knowledge without defining any application.
- **Applied research** which is original investigation undertaken in order to acquire new knowledge but in contrast to basic research primarily directed towards a specific, practical aim or objective.
- **Experimental Development** which is systematic work that draws on knowledge gained from research and practical experience. It produces additional knowledge, which is directed to producing new products or processes or to improving existing products or processes.

An innovation as such has therefore potentially the largest overlap with the R&D activity of Experimental Development (Edquist, 2011).

It should be noted that there are industries, such as the British service industry, that is highly innovative but do not rely much on R&D. R&D is, therefore, a sufficient but not necessary input for innovation processes. R&D expenditure, is also only one of many inputs into the production function of innovation (Potters, 2009), knowingly that it is often used as a proxy for innovation.

The overall relations between the generic terms[9] outlined above, the specific R&D process in the pharmaceutical sector and the share of engagement of stakeholders with non-commercial interests

[9] *It should be noted that Experimental Development is not to be confused with Experimental Medicine, a term that the Medical Research Council defines as the "investigation undertaken in humans, relating where appropriate to model systems, to identify mechanisms of pathophysiology or disease, or to demonstrate proof-of-concept evidence of the validity and importance of new discoveries or treatments" (Medical Research Council, 2019).*

(e.g. academia or public research centres) and commercial interests (e.g. industry) are depicted in Figure 12.

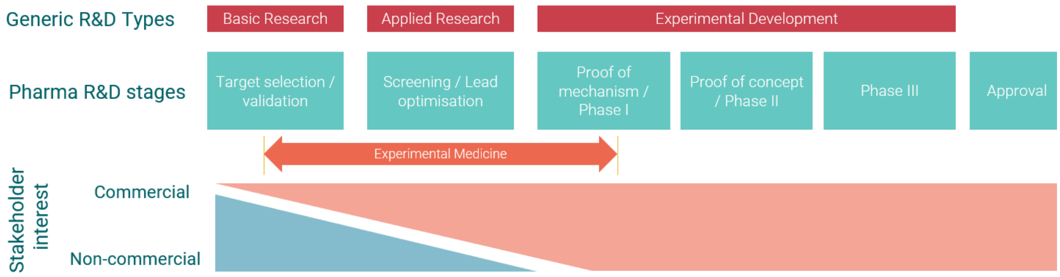


Figure 12: Relation of terminology to classify generic R&D and pharmaceutical sectors terms.
Source: OHE Consulting, based on (OECD, 2015a, p.44), PwC (2012) and Maselbas (2013).

2.1.1 Innovation policies – What they are and why they are needed

High-income countries compete for the title of being the most innovative one – not just for the sake of their own (national) companies. The attraction of foreign firms or industries that build up R&D facilities and thus contribute to the national economy becomes more and more important. That is why many countries recognised their strategic power and leadership role in proactively designing policies that stimulate, coordinate and maintain R&D and innovation.

The concept of policies that enhance the innovative power of a country is not new and what is called innovation policy today has variously been referred to as technology policy, science policy or research policy (Edler and Fagerberg, 2017). Three main justifications for innovation policies include market failure (as knowledge is a public good that can be exploited by anybody), the need to better link the National Innovation System (e.g. in terms of knowledge, skills, financial resources and demand) and the correction of imbalances of variety-creation (e.g. invention/innovation of many competing solutions to a problem) and selection (e.g. promoting the most promising solutions or eliminating the least promising ones)[10].

In general, there are three main types of innovation policy:

- **Mission-oriented policies** aim at providing solutions to specific challenges that are on the political agenda. They have been around for many years especially for defence purposes. More recently there is an increasing call for mission-driven innovation policies (see (Mazzucato, 2017)). This has been partly picked up by the UK Government during the Industrial Strategy which defines four Grand Challenges that need to be solved. These are 'Growing the AI and data-driven economy', 'Clean Growth', 'The future of mobility' and the 'Ageing Society' (see (HM Government, 2017)).

- **Invention-oriented policies** have a narrower focus as they concentrate on the R&D and invention phase and leave the exploitation and diffusion to the market. These policies were highly popular during the post-Second World War and led to the creation of Research Councils for channelling support for research to public and private institutions.

- **System-oriented policies** are more recent in nature and focus on system-level features such as the degree of interaction between different parts of the innovation system. They are related to the

[10] *A more detailed description of the three main justifications for innovation polices is given in Edler and Fagerberg (2017).*

so-called National Innovation System approach that emerged during the late 1980s and early 1990s. This approach was adopted by the OECD in policy advice and evaluation. Its focus is on how the environment can function as a resource (or enabler) for firm-level innovation and how policy can contribute to this.

2.1.2 Challenges in innovation policy design and limitations of the methods used in this report

In order to gain insights into policies that drive innovation, this report discusses in a first step the current literature on innovation policy instruments. In a second step, case studies of countries with a high level of R&D intensity are carried out to identify the specific policy mix that worked in those countries.

Evidence on the impact and effectiveness of different instruments has been collected in the Compendium of Innovation Policy (Manchester Institute of Innovation Research, 2011) but a robust evaluation of the individual policies is difficult (Edler and Fagerberg, 2017). Firstly, different policies that are implemented simultaneously might interfere with each other. Systemic evaluations are rare, and hence the results of evaluations of single instruments must be interpreted carefully. Secondly, identifying the impact of the policy mix on the innovative power of a country is challenging because innovation is hard to measure (Smith, 2006), and there are long lags between policy implementation and the desired outcome.

These factors may hinder a clear conclusion that a single policy that worked successfully in one country might be equally successful in another. Furthermore, there is a risk of mistaking correlation between high R&D intensity in a country and its specific policy mix for causation, meaning that the conclusion if a specific policy mix has caused the increase in R&D spending in a specific country may be misguided. Finally, the non-random selection of the countries itself may introduce a bias to conclusions that are drawn from the individual learnings.

Nevertheless, the review of policy instruments and their application in different country settings is of high value to British policymakers who may want to change the status quo and kick off the journey to reach the 2.4% target. The final recommendations put forward are normative statements that carry a value judgement but are based on best practices observed in different countries. They, therefore, aim for stimulating debate on how to proceed based on best available (but weak) evidence. They should be carefully considered, and their implementation may have to be further tested.

2.2 Which policy instruments stimulate R&D? Evidence review

An *innovation policy* consists of different *policy instruments*. Those policy instruments can either aim at stimulating the demand for, or the supply of innovation, or both. With each policy instrument, policymakers and other stakeholders may want to achieve a particular goal.

Table 1 provides a mapping of a collection of policy instruments according to Edler et al. (2016) to their overall orientation (e.g. demand versus supply side) and goals (e.g. increasing R&D levels). This classification will guide the analyses of countries that have already achieved the UK's ambition of OECD average R&D intensity, and to identify those policies that might be suitable for adoption in the UK.

Given the stated goal of the Government is to increase national R&D intensity, we focus on those policy instruments from Table 1 that contribute to this specific objective.

Table 1: Taxonomy of innovation policy instruments.
Adapted from (Edler et al., 2016).

INNOVATION POLICY INSTRUMENT	OVERALL ORIENTATION: Supply	OVERALL ORIENTATION: Demand	GOALS: Increase R&D	GOALS: Skills	GOALS: Access to expertise	GOALS: Improve Systemic Capability	GOALS: Enhance Demand for Innovation	GOALS: Improve Framework	GOALS: Improve Discourse
Fiscal Incentives for R&D	Major		Major	Minor					
Direct support (for R&D and innovation) to firms	Major		Major						
Policies for training and skills	Major			Major					
Entrepreneurship policy	Major				Major				
Technical services and advice	Major				Major				
Cluster policy	Major					Major			
Policies to support collaboration	Major		Minor		Minor	Major			
Innovation network policies	Major					Major			
Private demand for innovation		Major					Major		
Public procurement policies		Major	Moderate				Major		
Pre-commercial procurement policies	Minor	Major	Moderate				Major		
Innovation inducement prizes	Moderate	Moderate	Moderate				Moderate		
Standards	Moderate	Moderate					Minor	Major	
Regulation	Moderate	Moderate					Minor	Major	
Technology foresight	Moderate	Moderate							Major

Major Relevance · Moderate relevance · Minor relevance

2.2.1 Fiscal Incentives for R&D

Fiscal incentives indirectly lower the cost of R&D by offering a tax offset[11]. The rationale for fiscal (i.e. tax) incentives for R&D draws generally from the market failure that firms cannot appropriate fully their R&D investment as the resulting knowledge is a public good. In recent times, reliance on R&D tax incentives has increased relative to various forms of direct support (OECD, 2015b).

There are four main types of tax incentives. Firstly, there are the *accelerated depreciation schemes* for investments such as machinery equipment, buildings or intangibles. Secondly, *special R&D allowances* allow a firm to deduct more than 100% of their expenditure on eligible R&D activities from their taxable income. In the UK for example, the Small and Medium-Sized Enterprises (SME) R&D relief allows SMEs to "deduct an extra 130% of their qualifying costs from their yearly profit, as well as the normal 100% deduction, to make a total 230% deduction" (HM Revenue & Customs, 2018). If the SME is loss-making, a tax credit up to 14.5% of the surrenderable loss can be claimed. Thirdly, there are *special exemptions of wage and social taxes* for R&D-related employees. The Research and Development Expenditure Credit can be claimed by large companies in the UK and allows for a tax credit of 12% of the eligible R&D costs or an equivalent cash payment in case of a loss-making company (HM Revenue & Customs, 2019).

A further type of financial support to R&D that is closely related to R&D tax incentives is the *Patent Box* which grants lower corporate tax rate on profits generated from patents that are held in a certain country. The UK makes use of such an incentive by lowering the rate of corporation tax to profits earned after 1 April 2013 from its patented inventions to 10% (HM Revenue & Customs, 2017).

The mechanism of fiscal R&D incentives is either based on the volume of R&D investment or the increase in a firm's R&D spending. While a volume-based scheme allows a firm to deduct all eligible R&D expenditure each year, an incremental scheme allows it to deduct only the increase in R&D expenditure during the fiscal year. A definition of eligible operations for tax deductions is required and varies from country to country. Furthermore, the generosity of the tax measure must be defined and is determined by the amount of R&D expenditure that can be deducted and the maximum amount of tax reduction that can be claimed. Last, but not least, it must be agreed on the entities or subjects that are entitled to tax credits, and how and when tax credits are used. In an era of outsourcing, a crucial concern is an extent to which R&D activities performed by a third party can be claimed by the commissioning firm. Most agreements have a limited runtime of a few years (often four to five).

There are certain key advantages associated with fiscal incentives for R&D. Compared to direct support policies (see below), they produce lower allocative distortion as they do not favour certain technology areas or interfere with market mechanisms. As a result, they may lead to production levels that represent actual consumer preferences[12]. Compared to competitive direct grant funding, they are easier to predict for the firm and have lower administrative and compliance costs. On the other hand, fiscal incentives lead to more uncertainty in public budgets and complicate the tax system. Governments also bear the risk that private investments in R&D, that would have been carried out even in the absence of the fiscal incentive, is now carried out at higher fiscal cost due to the loss in taxes. This is termed *crowding out* R&D activities from the private sector and is contrary to what Governments are hoping to achieve.

Most evaluations find short term input additionality, that is the change in private R&D expenditure that can be attributed to public funding (see for example Hægeland and Møen (2007) or Bloom (2002)), although the effect size can vary a lot. R&D tax incentives are an effective tool to "stimulate private R&D and raise the level of business R&D expenditure to a higher level". (Köhler, Laredo and

[11] A full review of the design, impact and effectiveness of fiscal incentives for R&D is given in Köhler, Laredo and Rammer (2012).
[12] It should be noted, that specifically designed tax incentives (e.g. for SMEs) might be counteracting this neutral feature.

Rammer, 2012, p.3). It should be noted that the net welfare effects of tax incentives have not yet been studied extensively.

2.2.2 Direct support to firm R&D and innovation

Compared to fiscal incentives, direct support for firm R&D lowers the direct cost of R&D investment but is made on the same market failure rationale[13]. The design of direct funding programs can be differentiated by three elements. The first element is the programme's *target*. It can be either generic (e.g. project-based funding via the Innovate UK Smart grants) and hence aims to address a variety of industries and firms of different sizes. Or it can be targeted and aims at supporting innovation in strategic sectors, industries or research areas, for example within the Grand Challenges in the UK's Industrial Strategy. Secondly, the *selection mechanism* that decides who gets the funding is of most importance for the overall efficiency of the funding program. For example, it must be decided if the program is set up as a permanent call associated with a professional review or periodic calls with fixed deadlines and selection performed by a programme directorate or committee. Thirdly the *duration* of the program needs to be defined. While most of the programmes that target the support of SMEs have no fixed duration, more targeted programmes e.g. on certain technological or scientific areas are limited in their lifespan (mostly three to five years).

Most countries today make use of generic direct support of R&D and narrow the focus of eligibility for funding to SMEs. The main benefit of direct support measures is that specific areas of interest can be targeted. Where broad policies - for example, to increase R&D activity within a whole country - are concerned, they are less effective and fiscal policies might be the better choice. Overall findings from the evaluations indicate that the target group of potential recipients should be clearly defined and that the measure of direct support is embedded in a portfolio of complementary public interventions as it will enhance the probability of success and a greater, longer-lasting success (Cunningham, Gök and Laredo, 2012).

Due to the reasons outlined above, direct support measures might, therefore, be a valuable instrument to fine-tune R&D intensity within a specific target group of innovators or industry segments. It is however unlikely that direct support measures will be the main driver in boosting broader R&D intensity in the UK.

2.2.3 Policies to support collaboration

Public financial support of collaboration schemes is another form of a direct support measure[14]. It promotes the bridging of gaps between different stakeholders in the national innovation system, amongst others, by allowing the pooling of human and capital resources, bringing different perspectives to the process and by sharing management tasks and risk (O'Kane, 2008). The main rationale, especially for collaboration schemes that involve industry-industry and industry-academia collaborations, is the need to overcome information and co-ordination market failures that hinder the exploitation and transfer of new knowledge.

The design of science and industry collaboration schemes can be diverse; broadly two types can be categorised: The first type is collaborative research centres that are generally located at universities and tend to focus on applied research and specific research areas. The second type is collaborative and knowledge exchange research projects are more limited in time and scope.

Whilst science and industry collaborations are strongly supported by evidence, there is a risk of 'hollow collaborations' where collaborators team up just to follow the financial incentives without providing any significant output additionality (O'Kane, 2008), that is the increase in firms' output as a

[13] *A full review of the design and effectiveness of direct support of R&D has been undertaken by Cunningham, Gök and Laredo (2012).*
[14] *An full overview of the design and evidence on evaluation of schemes that support such collaborations is given in(Cunningham and Gök (2012).*

result of public funding. Cunningham and Gök (2012) point out that generating added value requires policy support for a mixed group of collaborators, e.g. those that are experienced collaborators and those who just starting joint R&D efforts.

Evaluations have found that a long-term, stable commitment from government is a key success factor in designing collaborative funding schemes. It is important that the objective of the scheme is clearly defined and communicated. It must be acknowledged that some stakeholders might participate for other reasons than monetary funding (e.g. knowledge transfer or networking) which should be reflected in the offer and goal of the scheme.

2.2.4 Public procurement policies

Public procurement policies are the only measure that exclusively focusses on the demand side. Interest in public procurement policies increased with increasing evidence pointing out the importance of demand-side factors on innovation. The rationale behind procurement policies is that they can overcome market failure by making or enlarging the market for certain goods and services that in return encourages R&D investment. They can communicate unmet needs to the market and may enable interaction between users and producers.

Governments are large purchasers with significant buying power. The health and defence sectors are good examples where public procurement policies are used to increase the value that the public sector gets for its money. As purchasing commitments from such large public entities can be more credible compared to many smaller private buyers, new models may emerge. The Market-Driven, Value-Based Advanced Commitment (MVAC) model, is an example from the health field, that aims at enabling middle-income countries to incentivise pharmaceutical R&D for areas of high medical need by committing in advance to agreed purchasing levels (Chalkidou et al., 2019).

Public procurement can be adapted to incentive R&D in a variety of ways. On a European level, the Most Economically Advantageous Tender (MEAT) criterion, for example, helps procurers to add additional criteria to public tenders that focus on long-term costs rather than the price (European Commission, 2018a). This stimulates demand for innovation in quality and durability hence may lead to greater sustainability. The UK made use of strategic public procurement policies that link public procurement better to future needs. The public procurement commitment that was introduced in 2006 had the objective to address market failures in the area of environmental innovations. The procurement of zero-waste mattresses by HM Prison Service (HMPS) is a well-documented example (Uyarra et al., 2014) that illustrated how the model can lead to innovations that have long-term benefits. Sweden made use of co-operative and catalytic procurement policies to allow the state to act on behalf of end-users and to coordinate procurement at scale. Here, publicly procured fridges with improved energy efficiency to support the end-user (property developers) in the 1990ies (Edquist and Hommen, 2000).

The UK has been a first mover in promoting innovation through procurement (Uyarra et al., 2014) although reforms, privatisation and austerity led to a varying degree of prominence for this policy tool. The evaluation of the impact of procurement policies is difficult however, due to the diversity of the designs which often merge into each other. Uyarra (2012) suggested that more effort is required in order to better understand the nature of procurement-related interventions and that requires better metrics and methodologies before a rigorous and transparent impact assessment is possible.

2.2.5 Pre-Commercial procurement policies

In contrast to public procurement which results in the purchase of (innovative) goods and services, pre-commercial procurement describes the purchase of research services itself. The results of said services may then benefit the contracting party or another party at a later stage. Pre-commercial procurement addresses both the demand and supply side and is therefore considered to be a hybrid measure.

Rigby (2013) found various rationales for pre-commercial procurement. Amongst others, it may create positive externalities as potential spin-offs and leakages of knowledge may benefit other forms and users in the economy. This might be achieved by setting up additional rules during the pre-commercial procurement phase, e.g. about IP rights. It may also reduce potential market failures of information, for example, by identifying firms that are likely to benefit from investment from venture capital post the pre-commercial procurement phases.

The design of pre-commercial procurement is generally governed through a clear legal framework, with three main approaches (Rigby 2013): Autonomous or bottom-up approaches are based on the legal framework that is used by contracting authorities, which are normally public bodies, to procure pre-commercially themselves. During top-down approaches, contracting authorities normally have help from a government agency. The UK's Small Business Research Initiative (SBRI) scheme would be an example of a top-down approach. The third approach is a mix of the former two, which occurs in cross-border scenarios where for example the EU co-finances pre-commercial programmes, but they are organised as a bottom-up approach.

The evaluation of pre-commercial procurement schemes is limited. Most evidence up to date is related to the Small Business Innovation Research (SBIR) program in the US, however, its impact on innovation, growth, sales and scientific and IP output remains uncertain. Furthermore, it is unclear to what extent the schemes are effective in dealing with the market failures that they are trying to fix.

2.2.6 Innovation inducement prizes in order to increase R&D activities

Another hybrid measure that addresses both the demand and supply sides, is an innovation inducement prize. It is one of the oldest types of an innovation policy measure, with the longitude act that offered money in return for the solution to the problem of finding a ship's precise longitude at sea, being one of its oldest examples. Although its popularity has gradually decreased in the early 20th century, it had a revival lately and have become an important innovation policy in the UK. Today's Longitude Prize, for example, offers an £8 million payout to the winning party that helps to solve the global problem of antibiotic resistance (NESTA, 2014).

There is a variety of rationales for innovation inducement prizes. Firstly, by placing an incentive for the development of a certain technology or technology application, they can overcome market failures. However, Williams (2012) pointed out multiple issues with this rationale: for, example, it is very difficult to get the size of the prize right and avoid inefficiencies from too high prizes or lacking incentives from too low prizes. Or, the targeted technology might not be as socially desirable as one may think in the beginning. A second rationale argues that prizes might not actually only be applicable for the development of new technology but also its demonstration of the application. Finally, technologies could be incentivised that are put in the public domain to attract research at a later stage.

Prizes offer great flexibility in comparison to other innovation policy instruments and hence they come at a large variety (Gök, 2013). They can be either designed as ex-ante inducement prizes or ex-post recognition prizes which depends on whether the prize is given to incentivise future developments in advance or given as an award to the final product. Different archetypes of prizes can have different goals. For example, exemplar prizes pay attention to a certain field or issue, while exposition prizes highlight best practices or ideas within a field. Network prizes can strengthen a community while participation prizes emulate market incentives.

The evidence on the effectiveness and impact of prizes is scarce as only a few relevant evaluations have been carried out. There is a consensus that innovation inducement prizes can only serve as a complementary measure to other innovation policies and not as a standalone substitute. Nevertheless, they may stimulate competition, help their winners to gain prestige and can overcome some of the inherent limitations of other instruments. However, as Gök (2013) points out, it is the design of the prize that one can get wrong easily and that might lead to an ineffective or even harmful effect.

2.3 Global R&D leaders - Learning from others

Where is there room for improvement?

The UK is a global innovation leader. It ranks amongst the most innovative countries, and it belongs to the group of top performers within the European Innovation Scoreboard (EIS) 2018 (European Commission, 2018b) that compares countries based on 27 innovation-related indicators. The UK also does well on a global scale. It ranks 4th in the Global Innovation Index (GII) 2018 which compares 126 countries according to 80 indicators that explore a broad vision of innovation, including political environment, education, infrastructure and business sophistication (Cornell University, INSEAD, and WIPO, 2018).

Nevertheless, the UK lags significantly behind its peers in some key performance indicators. Within the GII it ranks only 21st in terms of the efficiency ratio (how much innovation a country gets for its inputs). Furthermore, while the UK has, according to the GII (2018), several clusters in the top 100 when ranked by the number of scientific publications (London (7th), Oxford (58th), Cambridge (59th) and Manchester (72nd)), each cluster - except Cambridge - drops significantly in its ranking if ranked by patent applications (London (30th), Oxford (75th), Manchester (83rd), Cambridge (48th)).

Within the EIS, the UK underperforms compared to top-performing European counterparts in dimensions such as *innovation-friendly environment*, *firm investments*, *innovator* and *intellectual assets*[15]. In 2017, the UK was underperforming compared to the rest of the EU with respect to broadband penetration, R&D expenditure by the public and the business sector, non-R&D innovation expenditures and private co-funding of public R&D expenditures. Furthermore, it lags other countries with respect to the number of SMEs that innovate in-house, patent, trademark and design applications (European Commission, 2018b).

How do other countries incentivise R&D activities?

The UK lags significantly behind the OECD average in terms of R&D intensity[16]. The UK must substantially increase future R&D investment and incentivise larger amounts of private R&D expenditure to meet the 2.4% target. This chapter will explore countries that meet and exceed the target to understand which policy instruments were successful in encouraging high levels of R&D intensity.

While there is no "one policy mix" as innovation policies must fit the national conditions (European Union, 2013), the following analysis will provide insights into what may work in the UK.

In total six countries have been selected for deeper analyses. The main selection criteria require a country to exhibit either a significant higher R&D intensity than the UK over the last two decades or an increase in R&D intensity from a below OECD-average spending level to a stable spending level above it. As the objective of this report is to explore policies that are suitable to increase business spending in the pharmaceutical sector, the availability of a pharmaceutical or life science sector and

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[15] *A detailed description of all dimensions and all indicators per dimension is given in European Commission (2018).*
[16] *As noted already, R&D is one of the most important inputs to innovation, although not the only one.*

associated academic structures were made second criteria for country selection. Finally, an attempt was made to have a balanced pool of countries in terms of population size, economic strength and geography.

The final selection of countries that matched the criteria was Austria, Belgium, Germany, Japan, South Korea and the US. The latter was selected due to its leading role as an innovator, especially in the pharmaceutical and biotechnology field and the similar environment for R&D fuelled by an excellent academic base. South Korea and Japan were selected as two examples of countries that achieve top ranks in international innovation rankings and exhibit one of the largest private spending on R&D worldwide. Belgium and Austria were selected as two European countries that managed to boost their R&D intensity from a starting point below the OECD average to stable spending levels above it. Finally, Germany was included as continuous top spender on R&D that applies direct, institutional and collaborative funding instruments rather than generic tax incentives.

Each country case study starts with a comparison between the UK and the countries of interest according to their innovativeness, based on their respective performance in the Global Innovation Index 2018 and the European Innovation Scoreboard, respectively. The most important policy instruments of each country are then explored alongside potential learnings for the UK.

2.3.1 Excellence in Experimental Development and an entrepreneurial academic base - The case of the US

Key Takeaways

What is the main difference to the UK?

- A strong internal demand for innovation creates significant pull incentives for firms to invest in R&D, especially in Experimental Development. Over 60% of US R&D is related to the (experimental) development phase, compared with 40% in the UK. US R&D expenditure is therefore invested 'closer to market' making the commercialisation of its output more likely.

What are the highlights of the US' innovation system?

- The entrepreneurial spirit of its academics. Academics profit from excellence in knowledge transfer centres, strong IP ownership rights, access to large amounts of funding from private and public sources, and a lively exchange between academia and industry. This environment led to a culture of entrepreneurship which values trying out new ideas higher than it punishes related potential failures.

Are there noteworthy initiatives or learnings?

- Everything that incentives and supports academics to commercialize their ideas. This includes improved legislation (such as the Bayh-Dole-Act) that improves ownership rights for academics. Creating strong market incentives through credible commitments to purchase the outputs of innovation will generate significant R&D investment.

Table 2 Comparison of key parameters between the US and the UK.
Source: Cornell University, INSEAD, and WIPO (2018).

	US	UK
Population	320 million	66.2 million
GDP per capita (constant USD, 2017)	$59,501	$ 44,118
R&D Intensity (2017)	2.8%	1.7%
OECD Ranking 2017 (for R&D intensity)	9	18
R&D Funding Ratio Private : Public	2.5:1	2:1
Research Ratio Experimental Development : Applied : Basic	3.7 : 1.2 : 1	2.1 : 2.4 : 1

How does the US and the UK compare in terms of economic and innovative power?

The US is a high-income country with a population of over 320 million (UK: 66.2 million) and a GDP per capita (PPP) of $59,501 in 2017 (UK: PPP$ 44,118) (Cornell University, INSEAD, and WIPO, 2018). It is an example of a country with an R&D intensity that has been continuously above the OECD average. In 2017, the US spent roughly 2.7% on R&D as a share of GDP (UK: 1.7%) and it ranks 4th in the overall GII 2018 (UK: 5th rank) (Cornell University, INSEAD, and WIPO, 2018). Figure 13 depicts the performance of the UK and the US in the top indicators used in the GII 2018.

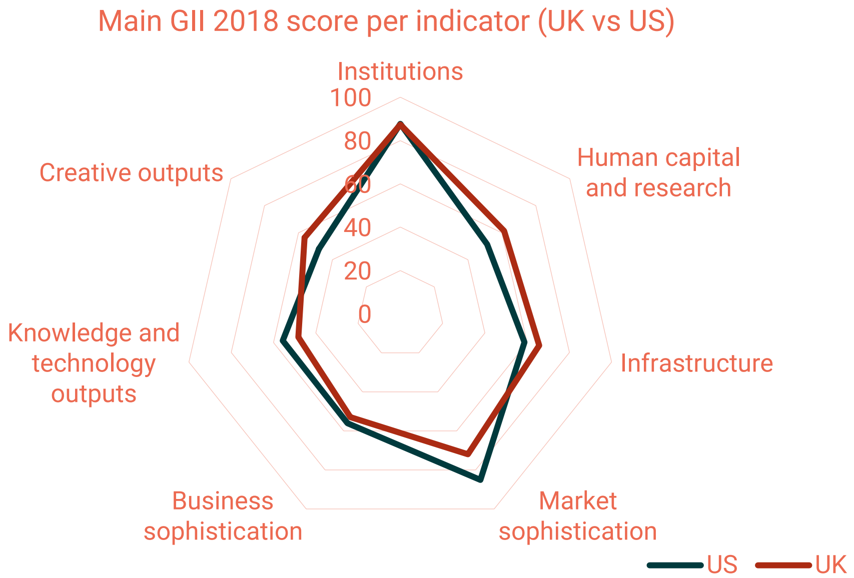

Figure 13: Comparison of main performance indicators of the GII 2018: US and UK.
Source: Cornell University, INSEAD, and WIPO (2018).

Both countries perform equally well with respect to their institutions that define their political, regulatory and business environments. Nevertheless, the US slightly outperforms the UK in three GII indicators. Looking deeper into those categories of the GII 2018, one finds that within the indicator *knowledge and technology outputs* both countries do very well with respect to scientific outputs (e.g.

citable H-index documents[17]) but the US scores higher in all sub-indicators that are related to IP rights. Within the indicator *business sophistication,* the better overall performance of the US is driven in the sub-category of knowledge absorption, where the US is doing significantly better with respect to research talent in business enterprises. The US has also one of the best research linkages between industry and universities and ranks highest in terms of innovation clusters. Finally, in the category of *market sophistication,* the US does very well in terms of ease of getting credit or the number of VC deals. Furthermore, the US profits from its strong and competitive internal market. The UK does better than the US in the main indicator of *infrastructure* and *human capital in research*. Related to the former, the gap between the two countries is mainly driven by underperformance of the US with respect to ecological sustainability. More notably, within the latter category, both countries dominate the global higher education sector and can make use of an excellent academic science base[18].

As in the UK, the Life Sciences and especially the pharmaceutical and biotechnological industry is a key sector for the US as it generates high-paying jobs, conducts a large amount of R&D, and has a strong impact on trade and the countries' competitiveness, although it lost some global market share over the last 20 years (Kennedy, 2018). The life-sciences sector in the US exported almost $90 billion worth of products in 2017, but compared to the medical equipment subsector which exhibits a rough trade balance, pharmaceuticals are experiencing a trade deficit of $56.2 billion (Kennedy, 2018). In comparison, the UK had a positive trade balance in the pharmaceutical sector of roughly €7.8 billion (Eurostat, 2019).

The strong internal demand and the resulting high prices make the US the favourable launch-country for most pharmaceutical companies. The larger profits are often linked to higher R&D in the pharmaceutical sector (Kennedy, 2019).

In summary, the US can be considered as a highly attractive market that creates many commercial opportunities to start, upscale and internationalise a business.

The US' funding mix

Historically federal public funding of R&D in the US is strong. Recent decades, however, have seen a decline in federally funded R&D whilst there has been a significant increase in industry spending (See Figure 14). The first part of this report found similar developments in the UK since the financial crisis. Today's private to public funding ratio in the US is over 2.5 to 1 (compared to 2:1 in the UK).

[17] The H-index is a metric that measures the productivity and impact of a scholar. It is computed based on the most cited papers of the scientist's and the number of citations that they have received.
18 However, the US could to better in terms of the subcategories of (primary & secondary) education and more specifically in the overall PISA rankings and improve the general pupil-teacher ratio.

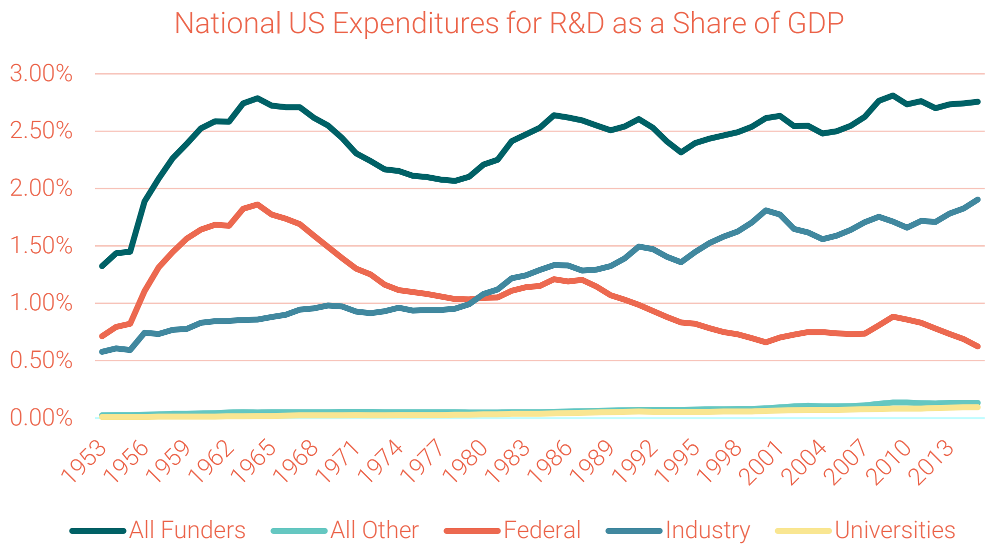

Figure 14: National US Expenditures for R&D as a share of GDP.
Source: American Association for the Advancement of Science (2017).

The innovation system in the US combines a high level of R&D with a strong focus on market application (Shapira and Youtie 2010). Federal agencies fund predominantly basic and applied research, including technology that is too risky for the private sector (Owen, 2017). While compared to other countries, the public funding of basic and applied research is indeed large, it looks comparatively small when compared in absolute terms to the funding of Experimental Development (see Figure 15).

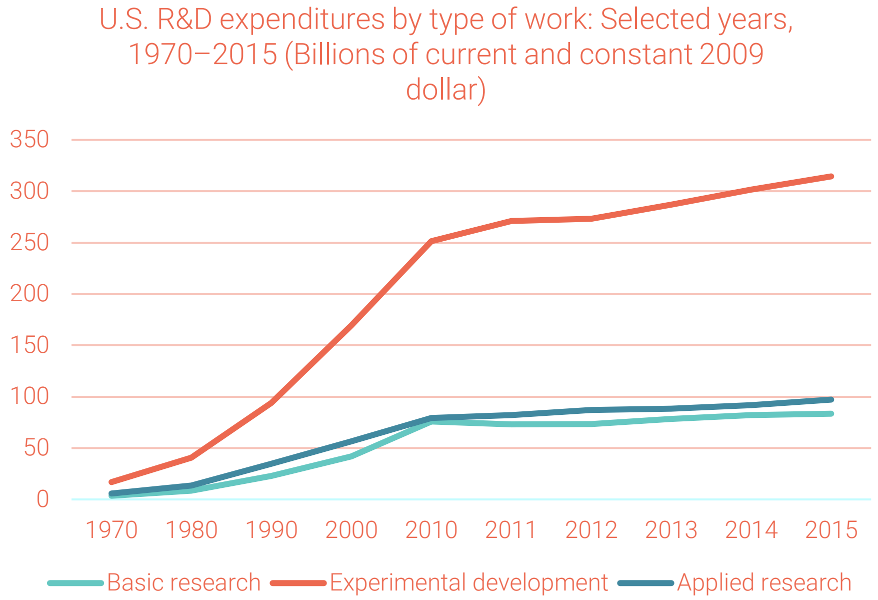

Figure 15: R&D expenditure per type of R&D.
Source: National Science Foundation (2018).

Noteworthy innovation policies in the US

The US exhibits a highly diverse and decentralised innovation system with multiple actors on the federal and state level, or from the public, private or academic sector (Shapira and Youtie, 2010). The White House and the Office of Science and Technology Policy (OSTP) coordinate executive office initiatives, however, many federal agencies have an interest in innovation policy and programs. The Department of Commerce, for example, is responsible for agencies of great importance to the innovation process, such as the US Patent and Trademark office. Other agencies fund research either directly, such as the National Science Foundation or the National Institute of Health. Others, like the Department of Defence (DoD), serve as both funder and purchaser of innovation at the same time.

The total amounts of funding are, due to the size of the US economy, enormous. The National Institute of Health, for example, describes itself as "the largest public funder of biomedical research in the world, investing more than $32 billion a year to enhance life, and reduce illness and disability" (National Institutes of Health (NIH), 2019). To put this in perspective, the NIHR as the largest clinical research in Europe, funds over £1 billion of research each year (Davies et al., 2016).

The US Government indirectly funds and performs research through so-called Federal Research and Development Centres (FFRDCs) that lately have focused more on technology transfer and innovation. These federal institutions are complemented by many public and private universities. The latter act as non-profit organisations that do not only contribute more and more to research funding but furthermore provide an entrepreneurial environment based on linkages to a very successful venture capital scene that enables the fast upscaling of commercially promising ideas.

Innovation policies in the US at the national level are mainly anchored by the philosophy that commercial innovation is driven by the private sector, aided by universities and government laboratories while the government itself has the primary role to facilitate the interaction of all partners[19] (Shapira and Youtie, 2010). According to Owen (2017), an intensely competitive business environment that promotes a variety of approaches to commercialisation might be one reason for many direct funding instruments featuring competition by design. The general policy mix is diverse and features a variety of indirect and direct measures that can be invention-oriented or mission-oriented. Indirect measures in the US that focus on the supply side are mainly R&D tax credits, however, it must be noted that the federal government makes comparatively little use of generic fiscal funding instruments (see Figure 16).

[19] ***Although it must be noted that this can differ on a state level.***

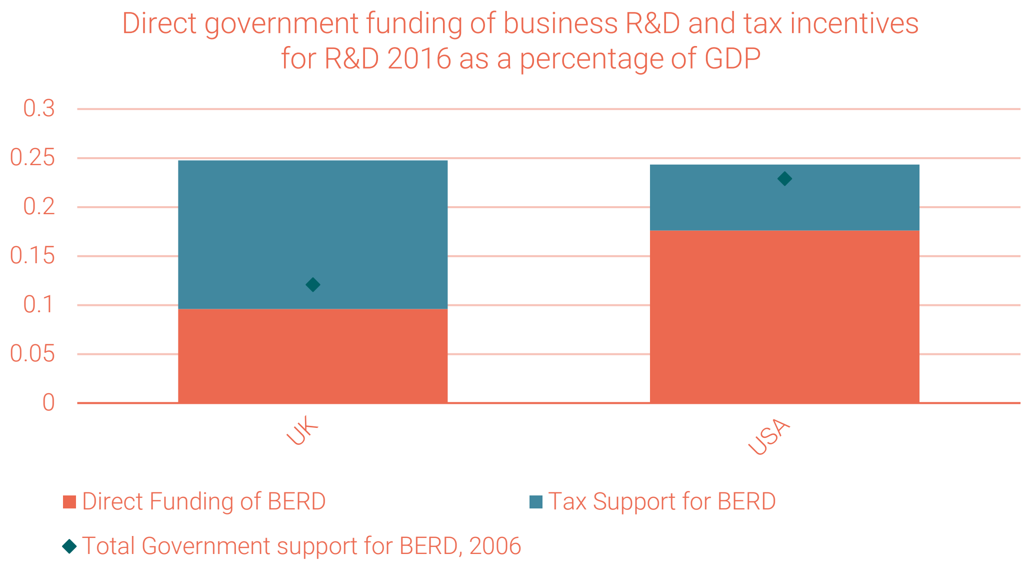

Figure 16: Direct government funding of business R&D and tax incentives for R&D 2016 as a percentage of GDP: the UK and US.
Source: OECD.

Indirect measures with a focus on the demand side are mainly defined through public procurement policies or in a broader sense policy with respect to IP rights. With respect to the latter, the Bayh-Dole act of 1980 was quite significant. The Bayh-Dole act essentially enabled universities, small enterprises and non-profits to own IP rights associated with federally-funded R&D and license them to companies for use (Shapira and Youtie, 2010). Prior to its implementation, the Federal Government retained ownership of all patents granted that arose from research activity using public R&D funding. This new incentive triggered the creation of technology transfer centres that in return provided profits and higher budgets, especially to the academic sector.

There are many direct measures in place in order to stimulate R&D in the industry on a national level. One example is the Small Business Innovation Research (SBIR). Evaluations have found that the SBIR might work either by acting as an alternative for VC in regions where VC is not available or by acting as a complement to VC by providing very early funding streams and a certification mechanism that then attracts private funding in return (Shapira and Youtie, 2010).

Industry-University Cooperative Research Centers (IUCRC) are another example that contributes positively to collaboration capacity building. They aim is to develop long-term partnerships among industry, academia, and government. Initial funding comes from the National Science Foundation and primary support from the Industry. Each centre is established to conduct research that is of interest to both the industry members and the centre faculty (National Science Foundation, 2019).

Data from the OECD (OECD, 2019a) shown in Figure 17 reveals that the US spends 63% of its total GERD on Experimental Development (compared to 38% in the UK). Furthermore, data from the National Science Foundation (NSF, 2019) states that 88% of this type of research is performed by industry. The US spends 17% of the total on basic research and 20% of the total on applied research (compared to 18 and 44% in the UK, respectively). Higher education institutions perform roughly half of the basic research while business performs roughly 58% of the applied research (National Science

Board, 2018)[20]. Therefore, the US represents a positive example of how to progress basic research to later, more commercially exploitable stages of R&D, by attracting more industry spending.

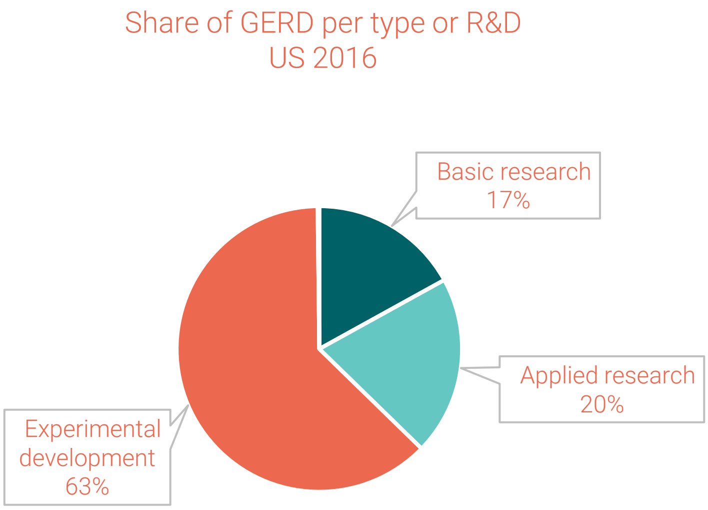

Figure 17: Gross domestic expenditure per type of R&D in 2017: US.
Source: OECD (preliminary numbers).

Potential learnings from the UK's perspective

The US system is larger and more complex than the UK. Innovators generally profit from the strong internal demand and a higher certainty that more innovations can be brought to market at higher profits. One of the most transferable factors is the strong and stable funding of (basic) academic research in combination with a high entrepreneurial spirit. The Government maintains and fuels this environment with several federal and state-wide programs through direct and indirect instruments and large organisations that act as funders and procurers of innovation. These programs yield to a much larger share of Experimental Development compared to the UK.

Additional legislation, such as the Bayh-Dole-Act for example, incentivised universities to perform R&D and profit from the resulting knowledge transfer to parties with a commercial interest which themselves profit from a strong internal market in the US that offers many commercially attractive opportunities.

A strong VC scene complements the public funding programmes of innovative ideas and high-risk projects – and vice versa. Where VC is regionally weaker, governmental programs such as the SBIR may substitute the resulting lack of funding. This constellation has led to dominating positions for the US, e.g. in the biotech sector (Owen, 2017). Here, the UK can learn from a government that kept its funding consistent even in times when VC and stock market funding was weak.

Compared to the countries in the other case studies (see below) the US funds much less through fiscal instruments, but channels funding to a variety of agencies and decentral programs on a state-level. Attempts to implement mission-oriented funding programs in healthcare were so far

[20] **It must be noted that in the mid-1960s and also more recently, the Government's share of research funding has fallen.**

unsuccessful (see for example the NIH's artificial heart program in the 1960s or President Nixon's War on Cancer in 1971) (Owen, 2017). However, because of their successful application in other sectors, (see for example the defence sector or the US space exploration programs), their core idea may be still worth exploring further.

2.3.2 Innovation leader due to long-term investment in STI development – The case of South Korea

Key Takeaways

What is the main difference to the UK?

- South Korea is world-leading, but it took 50 years of Government action to achieve. Today, it is the most R&D-intensive country in the world, supported by significant levels of private-sector R&D investment, which is focused heavily on Experimental Development.

What are the highlights of South Korea's innovation system?

- Innovation policy is put at the heart of the South Korean Government. The system was developed over five decades and started by building up a strong academic science base and then attracting large-scale industrial R&D with a focus on Experimental Development. Industrial R&D is concentrated in the *chaebols*, South Korean's multinationals with strong financial power.

Are there noteworthy initiatives or learnings?

- South Korea took a highly focused approach that favoured a small number of companies and industries, the *chaebols,* which resulted in high shares of Experimental Development and significant levels of private-sector R&D investment.

Table 3: Comparison of key parameters between South Korea and the UK.
Source: Cornell University, INSEAD, and WIPO (2018).

	South Korea	UK
Population	51.0 million	66.2 million
GDP per capita (constant USD, 2017)	$39,433	$ 44,118
R&D Intensity (2017)	4.5%	1.7%
OECD Ranking 2017 (for R&D intensity)	1	18
R&D Funding Ratio Private : Public	3.4:1	2:1
Research Ratio Experimental Development : Applied : Basic	4.4 : 1.5 : 1	2.1 : 2.4 : 1

How does South Korea and the UK compare in terms of economic and innovative power?

South Korea is a high-income country with a population of 51 million (UK: 66.2 million) and a GDP per capita (PPP) of $39,433 (UK: PPP$ 44,118). Overall, it ranks 12th in the GII 2018 and 20th in terms of its efficiency ratio which is only one place ahead of the UK (Cornell University, INSEAD, and WIPO, 2018).

As can be seen in Figure 18, within the GII 2018, South Korea performed slightly better than the UK in the main indicator category of knowledge and technology outputs as well as human capital and research.

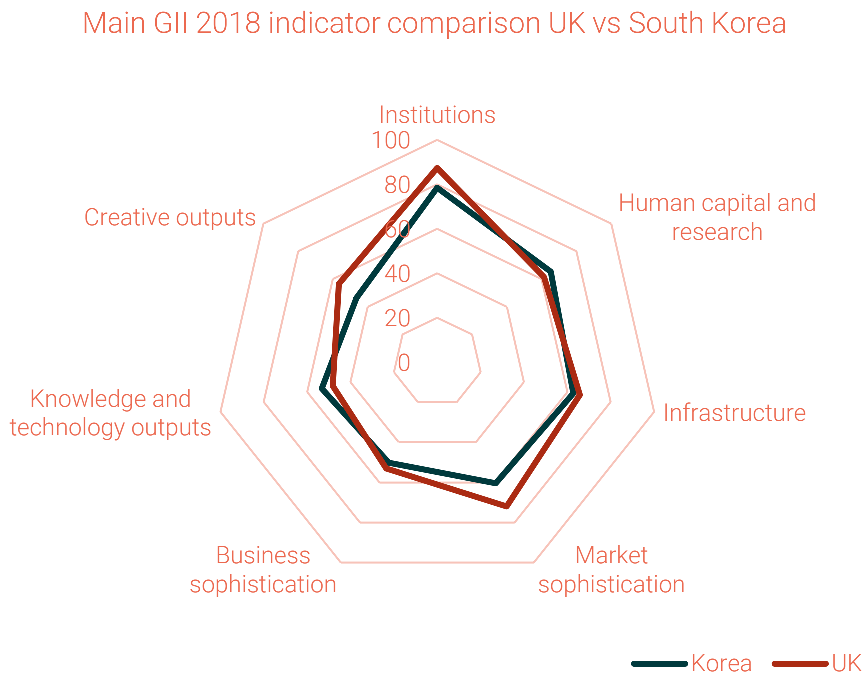

Figure 18: Comparison of main GII 2018 indicators between the UK and South Korea.
Source: Cornell University, INSEAD, and WIPO (2018).

South Korea outperforms the rest of the world in terms of total R&D activities (see Cornell University, INSEAD, and WIPO (2018)). South Korea ranks in the top 5 and the top 10 with respect to the number of available researchers, global R&D companies and university rankings. Relative strengths compared to top-performing countries are ICT infrastructure, the intensity of local competition between market participants, knowledge creation and intangible assets such as the business model creation. This innovation-friendly climate enabled South Korea to come in first in terms of high-tech exports as a share of total trade.

Weaknesses of South Korea in comparison to other top performers are mainly linked to political factors such as political stability, safety, and partly its creative outputs, such as online creativity.

South Korean's funding mix

South Korea is an example of a country which advanced domestic Science, Technology and Innovation (STI) development over the last five decades through implementing policies that led to a rapid expansion of private sector investment in R&D. Figure 19 shows that during the most recent decade, South Korean industry consistently funded over 70% of all intramural R&D resulting in a private to a public funding ratio of 3.5 to 1 in 2017. While in 1964 the government-funded over 90% of R&D, this share dropped to roughly 40% in the early 1980s and eventually to below 30% since 2000 (Joonghae, 2018). In the same period, GERD per GDP rose from below 0.5% to over 4%.

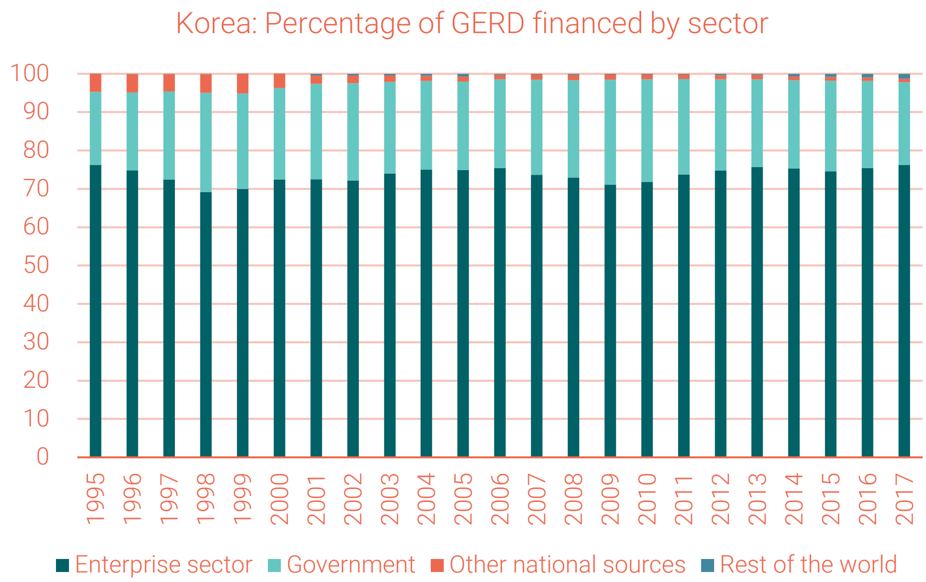

Figure 19: South Korean GERD funded by sector.
Source: OECD.

South Korea's national innovation system consists of three layers: government, intermediaries and research institutions. The President and the Presidential Advisory Council on S&T (PACST) sits on top of this structure, and PACST is responsible for forming the national mid-to-long-term science and technology policies. Therefore, South Korea places innovation and thus science policy at the heart of Government.

Noteworthy innovation policies in South Korea

There were several policies that enabled South Korea to increase private R&D spending, although these came at some costs as they caused a reduction in basic research (Joonghae, 2018): The investment by South Korea in its education system was the most important factor because it is typically the lack of human resources that puts limitations on R&D advancement, not the financial resources. Furthermore, its export-driven development policies ensured that domestic firms were required to compete early on the international stage, and hence were required to innovate in order to gain competitive advantage. Finally, the Government's industrial policies favoured for a long time the so-called *chaebol*, typically large multinational companies, that enjoy greater financial affluence and hence carry out more R&D in comparison to SMEs. While the *chaebol* is considered as one of South Korea's greatest strength in the innovation system, they more recently are considered to be a serious liability and several policies post the Asian financial crisis aim to reduce their influence (Eriksson, 2004).

The Government implemented policies that address the supply side indirectly via tax deduction or tax exemptions, as well as directly via grants or loans to stimulate R&D activities. The direct measures come in the form of the National R&D programmes (NRDPs) that aim to jointly develop industrial technologies with (large) companies who provide matched funds. There is an equivalent of the NRDP that focusses on smaller businesses as well. The Government also offers grants and project-based funding to universities, government-funded research institutes and business enterprises with each respective aim to provide either a highly educated workforce, mission-oriented basic research or the development of market-oriented technology.

Tax incentives have been generally established earlier than direct measures and today South Korea employs a balanced mix of both measures (see Figure 20).

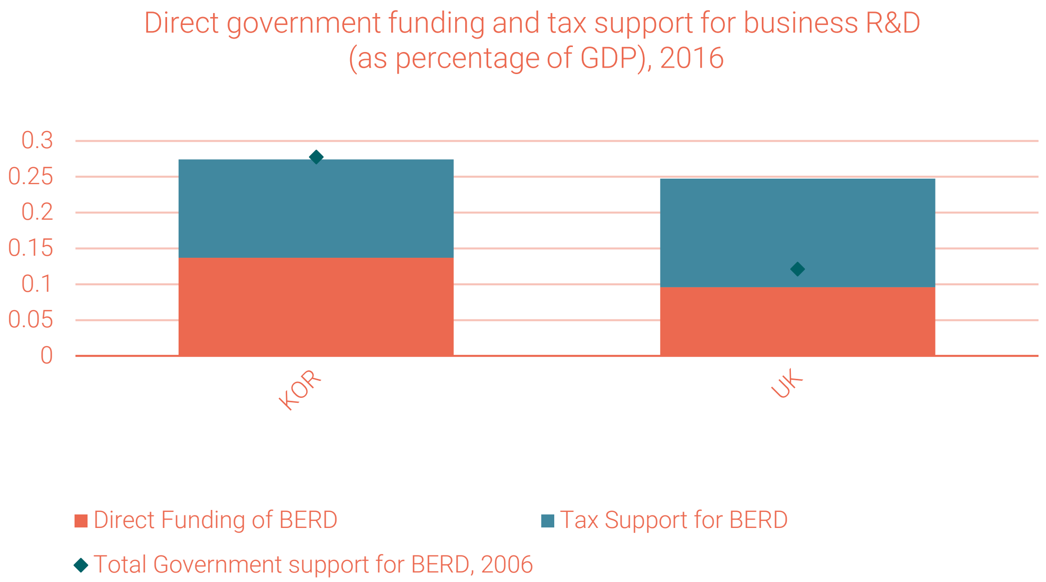

Figure 20: Direct and indirect government support to R&D: South Korea and the UK.
Source OECD.

Policies that support business ventures came later and were used more frequently after the financial crisis as a means to establish the vision of a knowledge-based economy (Suh and Chen, 2007). The direct infusion of equity capital, generous tax incentives, and equity guarantees in combination with the designation of certain small firms as "venture businesses" jumpstarted the South Korean venture capital market in 1992 (OECD, 2003). It grew from a negligible base from the early 1990s to a considerable proportion of GDP (OECD, 2003), and by 2017 South Korea ranked within the top five countries in terms of venture capital as a share of GDP. As the financial sector has been a tool for collusion between the government and the *chaebols* for a long-time (Eriksson, 2004), smaller companies faced difficulties accessing finance. The Government, therefore, uses venture capital also as a tool to directly target technology-oriented SMEs and to reduce the influence of the *chaebols*.

Policies that support collaboration were implemented in order to overcome regional disparity within South Korea, but they receive comparatively small budgets. They focus mostly on university-industry relationships. Some of the demand-side policies include government procurement that targets specifically SMEs, or competition and export promotion policies that fuel innovation more indirectly. Other policies that are part of the innovation policy mix in South Korea include a range of innovation inducement prizes such as awards.

In 2016, the distribution of research in South Korea looked very similar to the US, with Experimental Development making up more than 60% of the total (see Figure 21).

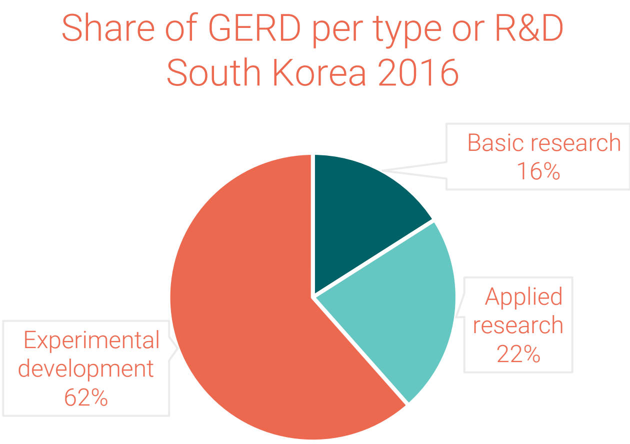

Figure 21: Types of research carried out in South Korea in 2016.
Source OECD.

South Korea advanced its STI capabilities since the 1960s in line with its phases of industrial development (Joonghae, 2018). The role of government changed with each phase. In the 1960s and 1970s, the Government built up scientific institutions and infrastructure. In the 1980s and 1990s its policies aimed for an expansion of technology-intensive industry and the promotion of high-tech innovation. Since the Millennium, policies have helped to support the transition of South Korea into a knowledge-based economy.

Potential learnings from the UK's perspective

Culturally and historically South Korea differs in many ways from the UK. Nevertheless, it is a country which leads industry-funded R&D on a global level.

Firstly, like the US, South Korea funds predominately Experimental Development activities. While this increases the innovative output of the country, this approach bears the risk of losing important public funding sources for basic research – which is becoming problematic in South Korea.

Secondly, the rise in industry-related R&D spending was mainly realised with the help of the *chaebols*, large multinational corporations that can commit to long-term R&D spending. While today South Korea aims to build-up innovation capacities in the SME field, the increase in industry-related R&D would not have happened without these corporations with significant financial resources. This demonstrates the importance of large corporative organisations for overall R&D activity in a country. In the UK, large firms of the automotive, defence and pharmaceutical sector have similar effects.

Nevertheless, South Korea actively supports smaller companies through dedicated funding programs. Interestingly, South Korea managed to fuel the emergence of many SMEs in the life sciences field, that are internationally competitive and that today coexists with the *chaebols*(Wang, Chen and Tsai, 2012). With state-driven programmes, large *chaebols* began to devote resources to developing new medicines. Examples are the LG Life Science and the SK Group or other *chaebols* such as Samsung. Due to the enormous financial input by these *chaebols*, the South Korean biopharmaceutical industry has blossomed while most SMEs conduct advanced R&D and then sell their products to large global pharmaceutical companies (Wang, Chen and Tsai, 2012).

Finally, South Korea built its success and today's large share of Experimental Development by first enabling a strong academic science base. In that way, the supply of new R&D talent could be ensured. Only at later development phases, South Korea focussed on other ingredients to innovation, such as venture business support that led South Korea's Experimental Development-driven R&D mix today.

2.3.3 Large federal fiscal incentives and regional policy autonomy – The case of Belgium

Key Takeaways

What is the main difference to the UK?

- Belgium has achieved what the UK is targeting and has increased its R&D intensity by more than 0.7 percentage points within a decade.

What are the highlights of Belgium's innovation system?

- How federal and local funding instruments act together. Belgium's three highly autonomous regions (Wallonia, Flanders and Brussels-Capital) define individual policy strategies and use direct funding and collaborative funding instruments and entrepreneurship policies to implement them. The federal government provides underlying legislation and - more importantly - a very generous tax incentive that comes without a ceiling.

Are there noteworthy initiatives or learnings?

- The generous tax incentives. More than 70% of Belgium's public support for R&D is generated through it and compared to the UK, no ceilings are in place for all three types of Belgium's fiscal reliefs. In Belgium, this instrument attracted large amounts of funding into R&D from the national and international private sector but may have come at the costs of creating imbalances to the disadvantage of SMEs.

Table 4: Comparison of key parameters between Belgium and the UK.
Source: Cornell University, INSEAD, and WIPO (2018).

	Belgium	UK
Population	11.4 million	66.2 million
GDP per capita (constant USD, 2017)	$ 46,553	$ 44,118
R&D Intensity (2017)	2.7%	1.7%
OECD Ranking 2017 (for R&D intensity)	11	18
R&D Funding Ratio **Private : Public**	2.4:1	2:1
Research Ratio **Experimental Development : Applied : Basic**	2.5 : 2.9 : 1	2.1 : 2.4 : 1

How does Belgium and the UK compare in terms of economic and innovative power?

Belgium is a high-income country and its population of 11.4 million people is significantly smaller than the UK's (UK: 66.2 million) while its GDP per capita (PPP) of $ 46,553 is similar (UK: PPP$ 44,118) (Cornell University, INSEAD, and WIPO, 2018). The EIS 2017 lists Belgium as a strong innovator, although it remains below the group of EU innovation leaders.

Belgium's economy shares some similarities with the UK. The key determinants of Belgium's recent success are the openness and quality of its science base, and its attractiveness to foreign doctoral students (Kelchtermans, and Robledo Böttcher, 2017). Like the UK, its economy is influenced by a strong service-orientation and openness to international trade and foreign direct investment (FDI). Its main research-conducting sectors are the life sciences, chemistry, information and communication technology, and electrical equipment (Kelchtermans, and Robledo Böttcher, 2017).

The country's policies have led to strong growth in R&D intensity within the last decade from 1.9% of GDP in 2007 to 2.6 % of GDP in 2017. Belgium has, therefore, demonstrated that the journey from below OECD-average spending on R&D to above the OECD average is possible.

More R&D investments in Belgium are being made by private business leading to a private to public funding ratio of 2.4 to 1 in 2015[21]. R&D is concentrated in a few large companies notably in the pharmaceutical and chemical sector which receive significant funding, but they were also mainly responsible for the increase in business expenditure on R&D (Kelchtermans, and Robledo Böttcher, 2017). In 2012 for example, UCB, Belgium's biggest pharmaceutical company, received a €200+ million loan from the European Investment Bank for investing in the development of new medicines. In 2014, UCB spent more than €786 million on R&D (Kelchtermans, and Robledo Böttcher, 2017).

Belgium has a very strong science base that does not fully translate into an equally strong innovation performance - a symptom that is partly shared by the UK. Although many efforts aimed at fostering spillovers from science to innovation have been undertaken, there seems to be untapped potential when it comes to the creation and upscaling of innovative firms (Kelchtermans, and Robledo Böttcher, 2017). That picture is reflected in the GII 2018 where Belgium ranks "only" 28th with an efficiency ratio rank of 38 (Cornell University, INSEAD, and WIPO, 2018). As Figure 22 shows, Britain scores higher than Belgium in each of the seven main indicators.

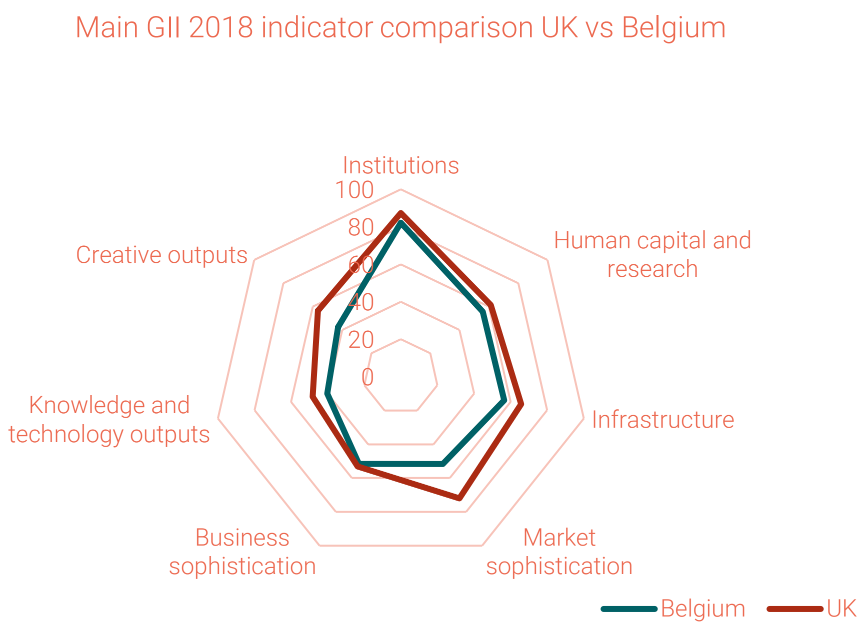

Figure 22: Comparison of main GII 2018 between the UK and Belgium.
Source: Cornell University, INSEAD, and WIPO (2018).

[21] ***2015 is the most recent data point available in the OECD Main Science and Technology Indicator Database for Belgium.***

Belgium's funding mix?

Data availability for Belgium is more limited than for the other countries included in this study. Nevertheless, Figure 23 shows business funds representing almost 60% of total R&D and a significant amount of FDI funding (compared to 51% in the UK).

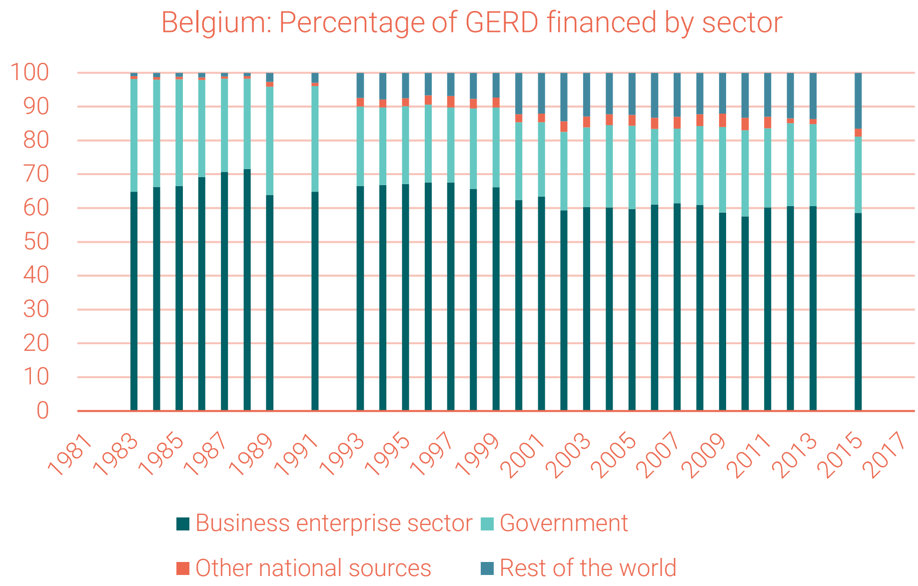

Figure 23: Percentage of GERD per funding source. Belgium.
Source OECD.

Noteworthy innovation policies in Belgium

The Federal State of Belgium is divided into three highly autonomous regions, Wallonia, Flanders and Brussels-Capital, which makes an analysis of its policy mix more complex. The federal government is responsible for the federal scientific research institutes, defines IP, law & standardisation frameworks and runs several federal research programs. Furthermore, within its competence is the R&D tax credit, a major component of the policy mix and one of Europe's largest fiscal incentives for R&D as a share of GDP (see Figure 24).

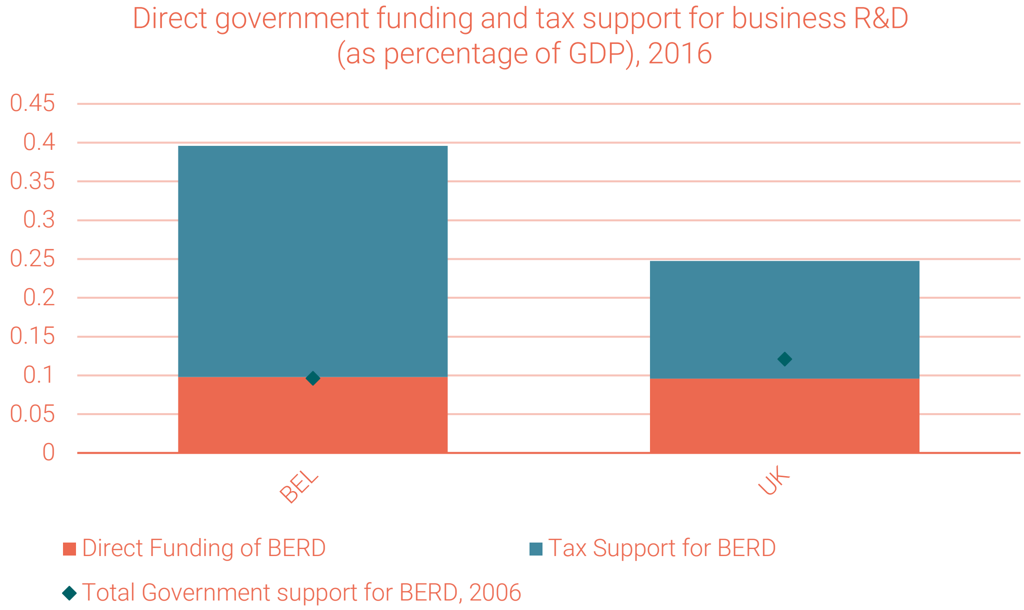

Figure 24: Direct government funding and tax support for business R&D. Belgium vs the UK.
Source: OECD.

Federal fiscal support is complemented by different regional polices as Belgian's regions have the responsibility for research policy for economic development purposes. There are currently two main innovation challenges in Belgium. First, fast-growing enterprises in innovative and less innovative sectors need to be promoted as a long-standing issue is to make innovation more widespread and, hence ensuring a higher economic impact. Second, the shortage and mismatch of human resources for research and innovation is exacerbated by a skill mismatch (Kelchtermans, and Robledo Böttcher, 2017)). These issues are addressed by two main policy responses. Firstly, demand-side policies may lead to feedback from the market that in return translates into products and services that are better in addressing pressing needs. Secondly, policies that make universities more entrepreneurial may fuel better translation from success in science into successful innovation.

Each region deals with the challenges in a slightly different way. With respect to the first challenge, for example, Wallonia's main strategic agenda is given by the Marshall Plan 4.0 which aims at making the region more competitive. It makes, use of policy instruments that aim at building up clusters, enhancing the finance-access for SMEs or making them more entrepreneurial. In contrast, Flanders' Vision 2050 is the overarching strategic policy framework and in that, the noteworthy "SME growth subsidy" aims at creating and up-scaling SMEs. The programme targets companies with growth ambitions through innovation, international expansion or transformation of their business with new activities. The Brussel-Capital region's response is mainly defined by the long-term strategic framework "Strategy 2025". In this, the "Bridge-Program" is an example that was built up to transfer scientific and technological knowledge from the scientific to the business, public and non-profit sector. The program is completed by a diverse set of financial support tools and incubator measures.

The policy mix in Belgium led to a distribution of funding on the three different types of research that is quite similar to that of the UK, with the majority of Gross Expenditure on R&D allocated to applied research (see Figure 25).

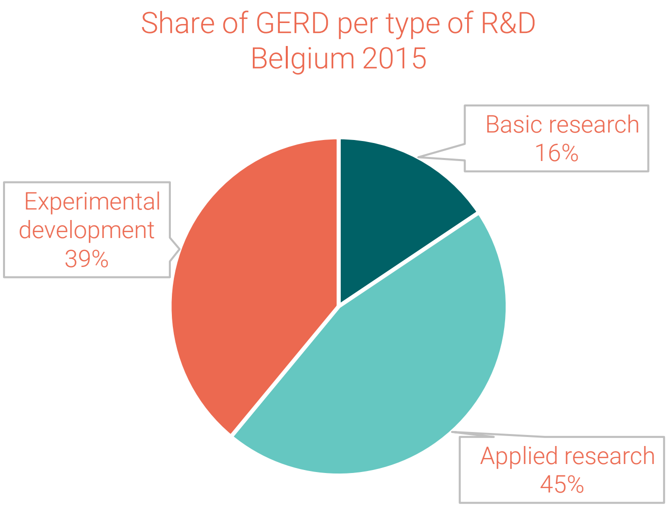

Figure 25: Distribution of type research in Belgium in 2015.
Source OECD.

Potential learnings from the UK's perspective

Belgium's success is mainly driven by continuously increasing Government spending that crowded-in private investment. Flanders, for example, is still reaping the benefits from the socioeconomic action plan titled 'Third Industrial Revolution' launched in 1982 which aimed to renew the economy by investing in new technologies and incentivising knowledge transfer from universities to business (Flanders Investment & Trade, 2018).

The UK could model Belgium's success in attracting a large amount of business and foreign direct investment in R&D by using a strong fiscal incentive (e.g. such as the tax credit). In 2015, Belgium had one of the highest rates of combined public support for business R&D in the entire OECD area, at 0.4% of GDP and more than 70% of this support is accounted for by R&D tax incentives (OECD, 2017a). Compared to that the UK's tax credit stood at 0.15% of GDP in 2015 (OECD, 2019c).

Belgium provides its tax relief through a payroll withholding tax exemption, an R&D tax credit and R&D tax allowance (OECD, 2019b). Eligible expenditures are, depending on the instrument, machinery, equipment, buildings and labour costs. Compared to the UK, no ceilings are in place for all three types of fiscal reliefs. The continuous commitment of the Government to steadily increase public R&D support led to today's large share of private investment into R&D. Such a policy may be fundamental to increase the private to public funding ratio in Britain.

Most of the private R&D investment is concentrated in a few large companies notably in the pharmaceutical and chemical sectors (Kelchtermans, and Robledo Böttcher, 2017). While this may ensure industry commitment, it might create imbalances in supporting innovative fast-growing smaller companies – an issue that Belgium is currently trying to correct. Hence, the UK may be advised to address such risks ex-ante, for example by ensuring through fiscal generic instruments that key industries and companies face large enough incentives to increase their investment in R&D on the one hand, and future sectors and smaller companies are incentivised via dedicated direct or collaborative instruments.

2.3.4 Boosting R&D intensity but struggling to innovate - the case of Austria

Key Takeaways

What is the main difference to the UK?

- Austria's market structure. The UK differs significantly from Austria with respect to its industry and internal market. Austria has a much higher share of manufacturing compared to the UK and cannot profit from a strong internal lead market for its main industries such as the UK.

What are the highlights of Austria's innovation system?

- The built-up in Austria's science base. Austria's increase in resources for Science, Technology and Innovation resulted in an increase of research output by universities and some international research strengths, such as quantum communication.

Are there noteworthy initiatives or learnings?

- R&D should translate (to a large amount) into innovation. Although Austria underwent one of the largest boosts in R&D intensity (from which especially the basic research segment profited), it struggles to capitalise on the commercial exploitation of R&D within the country. It has a lower private to public spending ratio than the UK and a comparable low ratio of experimental and applied research to basic research.

Table 5: Comparison of key parameters between Austria and the UK.
Source: Cornell University, INSEAD, and WIPO (2018).

	Austria	UK
Population	8.7 million	66.2 million
GDP per capita (constant USD, 2017)	$49,868	$ 44,118
R&D Intensity (2017)	3.15%	1.7%
OECD Ranking 2017 (for R&D intensity)	6	18
R&D Funding Ratio **Private : Public**	1.8 : 1	2:1
Research Ratio **Experimental Development : Applied : Basic**	2.6 : 2.0 : 1	2.1 : 2.4 : 1

How does Austria and the UK compare in terms of economic and innovative power?

Austria is a high-income country with the smallest population of the selected countries (8.7 million in Austria vs 66.2 million in the UK) and a GDP per capita (PPP) of $49,868 in 2017 (UK: PPP$ 44,118) (Cornell University, INSEAD, and WIPO, 2018). In the last few years, it achieved an R&D intensity of 3%, well above the OECD average of 2.4%. Like Belgium, it is, therefore, an example of a country that managed to turnaround from below average OECD spending level on R&D. At the same time, however, Austria lags behind highly industrialised countries within international innovation rankings (Leichtfried, 2017) in spite of its high R&D intensity, and its Government's ambition to reach the top.

Within the EIS (European Commission, 2018b), Austria is considered to be a strong innovator but failed to reach the Government's objective to become part of the group of innovation leaders (like the UK). Within the GII, Austria ranked 21st in 2018 (Cornell University, INSEAD, and WIPO, 2018). Figure

26 shows that, similarly to Belgium, Austria does not outperform the UK in any of the GII 2018 main indicators.

Overall, Austria seems to be struggling to transfer its high levels of R&D spending into a successful innovation, and sustainable success for its economy. Schuch and Tesla (2018) found that Austria has relative weaknesses in generating the necessary impact on employment and sales (e.g. in terms of sales of new-to-market/new-to-firm innovations as % of turnover and knowledge-intensive services exports). Furthermore, compared to the UK, Austria exhibits an industrial structure, which makes the emergence or creation of lead markets relatively unlikely, since most innovative companies are highly specialised suppliers and therefore do not have direct access to and impact on the end-user (Schuch and Testa, 2018). These issues are reflected in the GII 2018 by a relatively poor performance in the category of market sophistication for Austria.

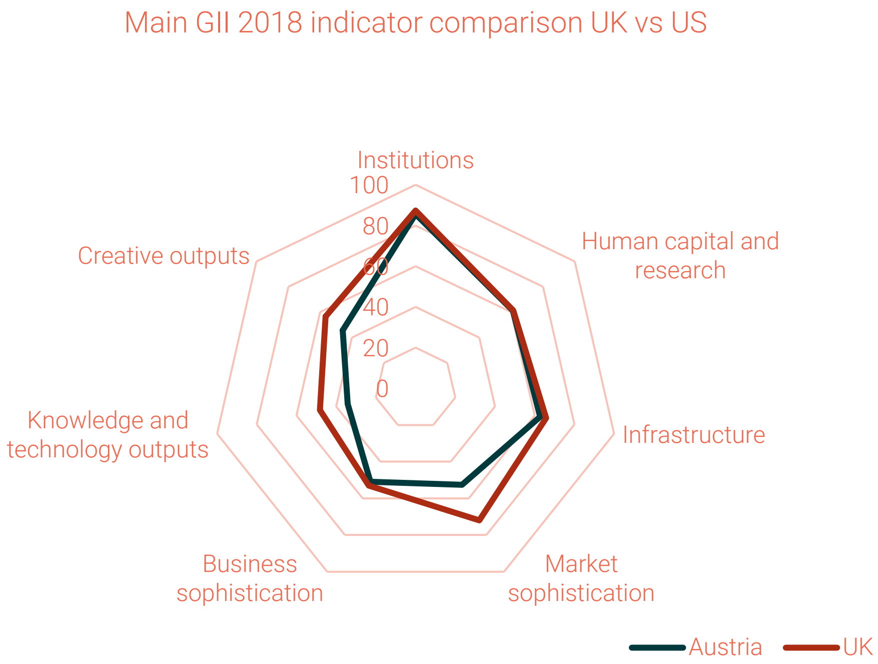

Figure 26: Comparison of GII 2018 main indicators between Austria and the UK.
Source: Cornell University, INSEAD, and WIPO (2018).

Austria's funding mix

Austria's innovation system underwent rapid development over the past two decades. It showed the second-highest increase in R&D intensity of all OECD countries to over 3% of GDP, which was only exceeded by South Korea (OECD, 2018). It is among the top 10 countries in term of gross expenditure on R&D and GERD performed by businesses. Nevertheless, it exhibits a relatively low private (business + private non-profit) to public (government + higher education) funding ratio which was 1.85 to 1 in 2017. Roughly 15% of its R&D is funded by foreign investments (see Figure 27).

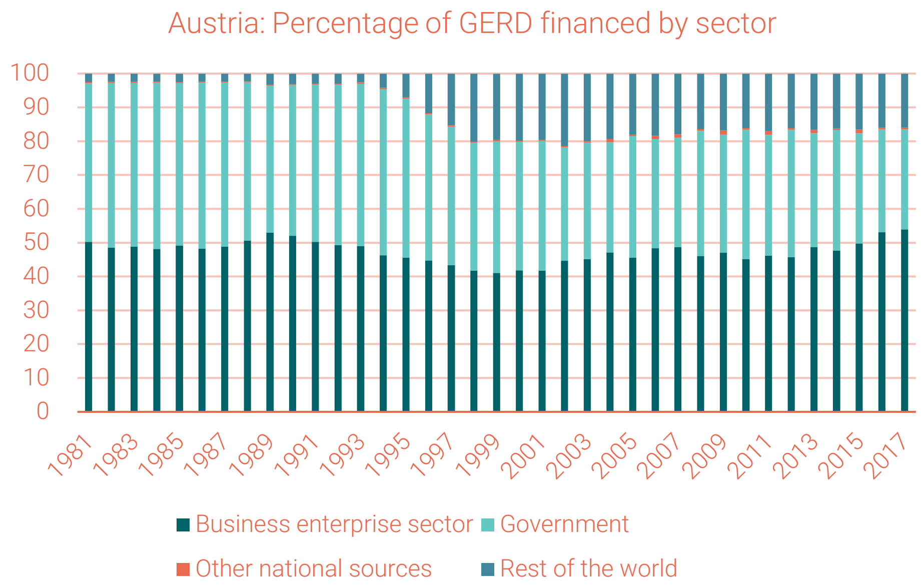

Figure 27: Percentage of Austrian GERD financed by sector.
Source OECD.

Noteworthy innovation policies in Austria

The increase in R&D intensity was mainly driven by focussing on the supply side via generic support for R&D through a tax incentive (the Research Premium). As Figure 28 shows, in 2016 the amount of R&D spending as a share of GDP that was funded through fiscal incentives was similar to the level in the UK. The tax exemption rate was increased to 14% in 2018 and this shift is likely to continue (Schuch and Testa, 2018).

The policy has been well-received especially by R&D-active, domestic firms. Moreover, it has also contributed to improving Austria as a location for R&D as well as to the relocation of R&D activities, particularly of internationally active, research-intensive companies (Ecker et al., 2017).

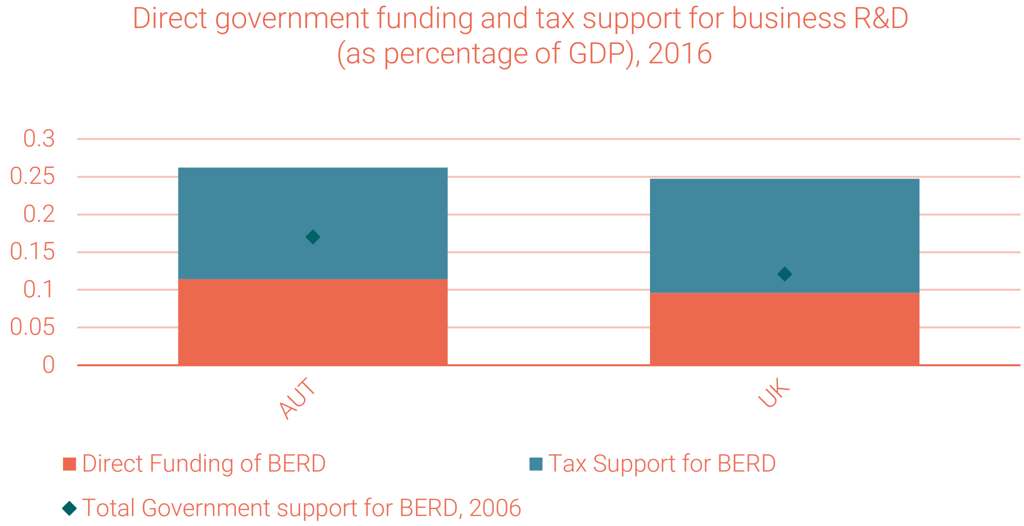

Figure 28: Funding and tax support for business R&D in Austria and the UK.
Source OECD.

Other funding mechanisms are of a more direct nature and are applied by the Austrian Research Promotion Agency (FFG) that promotes R&D by companies. The Austrian Science Fund (FWF) is the country's central body for the promotion of basic research (ABA, 2019). There are also temporary funding vehicles that promote collaboration, such as the COMET initiative (Competence Centers for Excellent Technologies). COMET promotes the cooperation between companies and academia within the context of a jointly defined research program and contributed significantly to industry-science relations. Some evaluations, however, have found that they are often missing higher-risk projects and basic research (OECD, 2018). The Christian Doppler Research Association sets up public sector-financed research units at Austrian universities for a fixed period where scientific researchers work together with corporate partners to find a solution to their research questions.

One of the main challenges for Austria is to increase its research efficiency and hence improve the relationship between innovation inputs and innovation outputs. That might be partially caused by Austria's industrial structure, and many administrative and regulatory barriers. Furthermore, there is little promotion and education about entrepreneurship, and applied R&D programmes are still very engineering-driven but lacking innovation orientation (Schuch and Testa, 2018). As depicted in Figure 29, the latest data available shows that compared to the US for example, Austria funds significantly more applied research and much less Experimental Development.

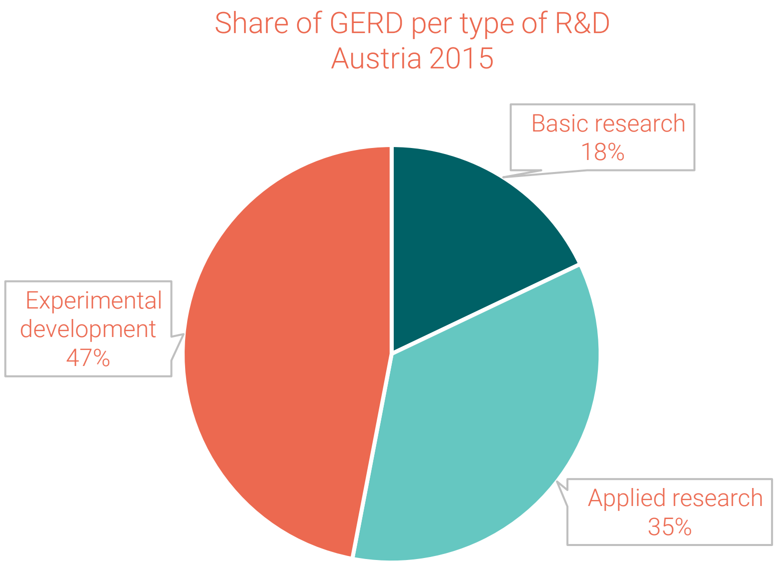

Figure 29: Types of research carried out in Austria in 2015.
Source OECD.

Potential learnings from the UK's perspective

On the one hand, Austria demonstrated how R&D intensity can be boosted by strengthening the fiscal funding instrument continuously over a long period. According to the OECD (2018), the resulting increase in R&D intensity also witnessed an increase in resources for Science, Technology and Innovation and resulted in an increase of research output by universities. Research and innovation through institutions increased (e.g. Institute for Science and Technology Austria) and some international research strengths, such as quantum communication could be built up. Hence, it is this continuity that the UK should adopt in any of its more generic measures as it makes the UK attractive to local and international businesses that perform R&D.

However, despite this positive impact on Austria's academic science base, Austria policies struggle to translate the increase in R&D intensity into sustainable innovation. That is why the OECD recommended that additional funding must shift towards "more effective, impact-oriented funding" (OECD, 2018). In essence, Austria is performing too much research and not enough development. Industry sectors that increase societal welfare through useful products and services, job creation and knowledge gain should, therefore, be the priority.

The UK differs significantly from Austria with respect to its industry and internal market. Austria has a higher share of manufacturing (around 19% of GDP) compared to the UK (10% of GDP) (OECD, 2018). Compared to Austria, almost 50% of R&D funding in the UK comes from three (high-tech) industries (pharmaceuticals, automotive, computer & IT). Those are based on strong internal (lead) markets and produce many innovations. Hence, the UK has a much better starting position than Austria two decades ago, if it sets the right incentives to increase private investment in those industries.

2.3.5 Innovation-driven by SMEs and bridging research organisations – The case of Germany

Key Takeaways

What is the main difference to the UK?

- How innovation is funded. In comparison to the UK, Germany does not rely on any generic, tax-based incentives for its public R&D support. All activities are funded directly, via dedicated institutions or departments, carried by a strong mission-driven mindset and crowding in more private sector funding than the UK.

What are the highlights of Germany's innovation system?

- Its coherent funding strategy and related funding models. The High-Tech Strategy ensures coherence between different funding instruments that aim at futureproofing Germany's competitive advantage (especially in the manufacturing industries). The applied funding instruments incentive significant spending on R&D from small, medium and large enterprises.

Are there noteworthy initiatives?

- The leading-edge cluster competition offered in total €600million in public funds to jumpstart R&D clusters in specific technology areas. In total, 15 clusters have received each €40 million in public funding over five years. The amount of public funding must be matched by private spending of participating companies. After this period, public support may decline but the grown linkages and structures may yield sustainable success of the newly formed clusters.
- A massive amount of public funding is channelled through different research organisations that maintain many individual research institutes with international outreach. Operating on a budget of around €10 billion, those organisations act as bridges between academia and industry and promote a better diffusion of results from basic research to Experimental Development. These organisations seem to attract more private spending on R&D during collaborative projects than similar UKRI structures in the UK.

Table 6: Comparison of key parameters between Germany and the UK.
Source: Cornell University, INSEAD, and WIPO (2018).

	Germany	UK
Population	82.1 million	66.2 million
GDP per capita (constant USD, 2017)	USD 50,425	USD 44,118
R&D Intensity (2017)	3%	1.7%
OECD Ranking 2017 (for R&D intensity)	8	18
R&D Funding Ratio **Private : Public**	2.5 : 1	2 : 1
Research Ratio **Experimental Development : Applied : Basic**	n/a	2.1 : 2.4 : 1

How do Germany and the UK compare in terms of economic and innovative power?

German R&D intensity grew from approximately 2 to 3 per cent in the period 1993 to 2017 and hit the 3% target only recently in 2017. The private to public spending ratio in 2016 was just below 2.5 (the UK is 2:1), and Germany attracts slightly more R&D investment from the pharmaceutical industry than the UK – € 6.2 billion in 2016 compared to € 5.7 billion in the UK, which places Germany first in Europe before Switzerland and the UK (EFPIA, 2018). According to the German industry body VfA, Germany has a competitive advantage in its human capital and a dense network of excellent academic and non-university research organisations (see below). Drawbacks are the lack of any fiscal incentive for R&D (VfA, 2019).

Compared to the UK, Germany is larger (82.1 million vs 66.2 million people) and more prosperous (i.e. GDP per capita in constant USD 50,425.2 versus USD 44,117.7) (Cornell University, INSEAD, and WIPO, 2018). Nevertheless, it ranks similarly on the GII 2018 in terms of innovation. The key differences are that Germany is considered to have lower market sophistication (see Figure 30), which is mainly driven by the UK's high performance in the areas of Governmental e-services and categories related to environmental friendliness and sustainability. In contrast, Germany outperforms the UK in terms of the efficiency ratio where it ranks 9th (UK 21st), which indicates that Germany is better at translating innovation inputs into innovation outputs.

Recently Germany has fallen in the EIS rankings and is now considered a "strong innovator" instead of an "innovation leader". However, the authors note that the difference between Germany and the lowest-scoring country in the innovation leaders' group (Luxemburg) is marginal (European Commission, 2018b). The change in ranking appears to be due to the significant improvement in other countries whilst German performance remained constant.

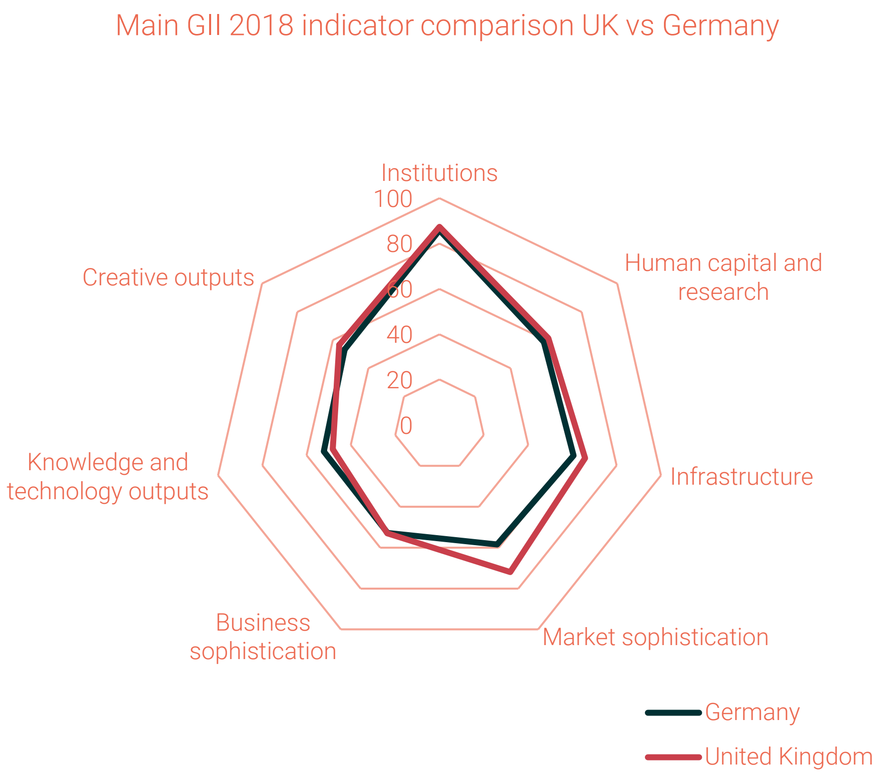

Figure 30: Comparison of main GII 2018 between the UK and Germany.
Source: Cornell University, INSEAD, and WIPO (2018).

Germany is well known for its automotive sector as well as its strengths in mechanical engineering, and certain electrical and chemical-related industries. Examples are brands like Daimler, Siemens or

BASF which are globally recognised brands. The German *Mittelstand* – a collective term for small and medium-sized high-tech industries - is the backbone of the economy excelling at incremental but continuous innovation. Many of them are world leaders in their own small markets (Hommes, Anselm and Triebe, 2011) e.g. Sennheiser Electronics, a headphones company or Pfeiffer Vacuum, a manufacturer of technologies for creating vacuums or detecting leaks.

Interestingly, *Mittelstand* is not only characterised by company size but rather its governance structure and ownership. Many of those companies' leaders are also their owners (BDI, 2019). In comparison to founder-led start-ups in the UK that may follow a model of speedy growth and a profitable exit, German owner-led *Mittelstand* is characterised by "value and long-term orientation and its contributions beyond a purely economic focus on wealth and job creation" (Pahnke and Welter, 2019). This ownership-management structure of the *Mittelstand* is closely linked with social, intergenerational and regional responsibility and hence emotions, passions and belongings play an important role (Pahnke and Welter, 2019).

"Mittelstand" companies contribute significantly to Germany's international competitiveness and extremely high export shares, but they are vulnerable to the significant productivity gains from international competitors who have been faster to adopt digital technologies. In this regard, Germany has been slower to adopt than most other OECD countries (OECD, 2018a). A decline in performance indicators for SMEs (i.e. in-house innovation) that are often part of the *Mittelstand* is also one reason for Germany's decline in the EIS 2018 (European Commission, 2018b).

Germany's funding mix

Similar to the US, a much larger share of R&D in Germany is funded through the private sector (in 2017 65% in Germany vs. 51% in the UK). As can be seen in Figure 31, this share peaked with 68% of total GERD funded by business enterprises in 2007 (before the financial crisis) and dropped slightly to 65% in 2016. The share of GERD funded by the Government has fallen since the 1980s from over 40% in 1981 to 28% in 2017. The government partly stopped this trend at the beginning of the Millenium, however, over the past 20 years, foreign investment grew (although significantly lower than in the UK) which reduced the amount of public spending in relative terms. Reasons for Britain's comparatively better performance the past with respect to FDI were seen in its flexible labour markets, favourable corporate tax rates and relative openness (Driffield et al., 2013).

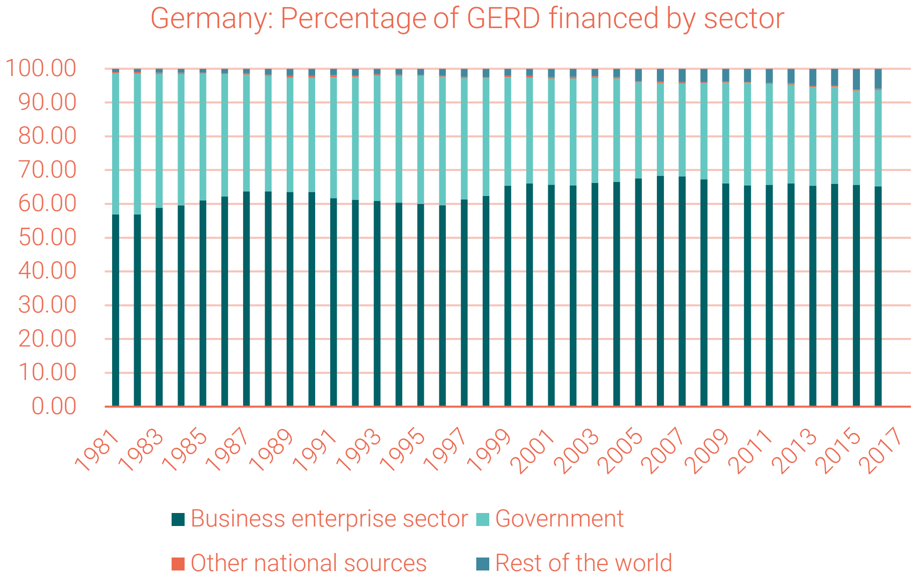

Figure 31: Percentage of GERD per funding source. Germany.
Source OECD.

Noteworthy innovation policies in Germany

Germany's innovation and research system comprise of a variety of different actors with some similarities to the UK. Because of Germany's federal political structure, many of the Federal Government's innovation policies are influenced by the concerns of the local governments of its the Federal States, or Länder (Allen, 2015). The Länder may also complement the national policies with their own policies. The Federal Government and the Länder provide the funding. Intermediaries, i.e. the Deutsche Forschungsgemeinschaft (DFG) which is the equivalent to the research councils within UKRI, are responsible for the allocation of funding. Academic institutions and several research organisations (described below) perform research often in collaborative projects with the industry.

Surprisingly, Germany is a rare example of a high-income country that makes no use of fiscal incentives for R&D[22] (see Figure 32) and therefore it is in unsurprising that as measured as a share of GDP, the German Government offers less support to business R&D than the UK. Instead of fiscal incentives, Germany relies on a set of instruments "which facilitate targeted financing: project funding, institutional funding and the financing of departmental research" (Federal Ministry of Education and Research, 2018a, p.61). In 2016, the Government provided almost 30% of all funding for R&D which amounted to € 27.2 billion (UK: Governmental funding of £ 6.5 billion in 2016) (Federal Ministry of Education and Research, 2018b; ONS, 2018).

[22] Although major media outlets recently reported that the implementation of an annual R&D bonus of up to €500,000 p.a. year may be under consideration (DW, 2019).

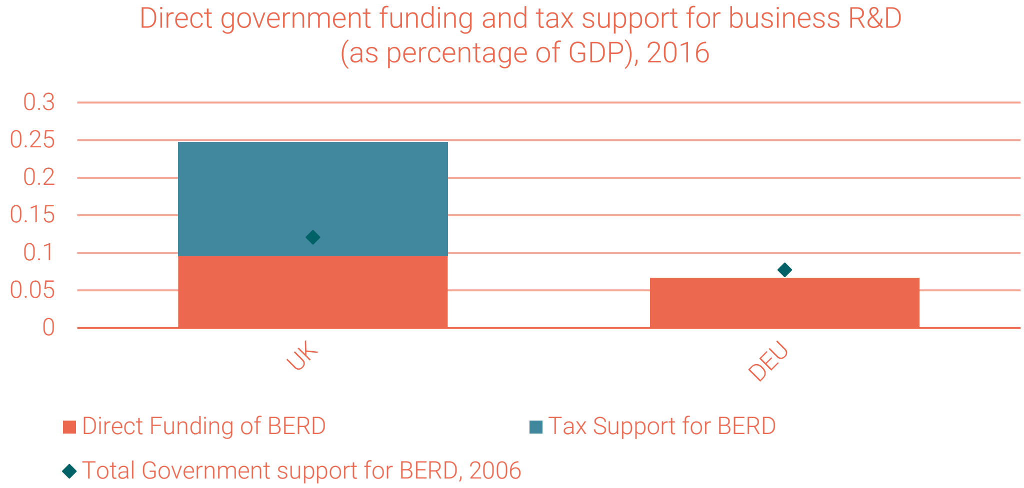

Figure 32: Funding and tax support for business R&D in Germany (DEU) and the UK.
Source OECD.

Germany's funding is based on a similar vehicle to the UK's Industrial strategy with a strong mission-driven mindset. At the beginning of each legislative period (every four years), the so-called High-Tech Strategy (HTS) pools all research and innovation funding activities of different Government departments under one umbrella and allocates a budget of approximately €6 billion (Schmid, 2018). The HTS produces a relatively coherent approach with the goal to translate good ideas quickly into innovative products and services. This concept was introduced in 2006 and extended in 2014. In today's HTS, the definition of what determines an innovation has been expanded to include social innovation (e.g. enhancing active participation by society as a central player during innovation and ensuring that innovation meets societal goals) (Federal Ministry of Education and Research, 2018a). Evaluations found that the HTS increased the public financial spending on R&D while the output in terms of the patent applications is hard to measure (Daimer et al., 2018). Daimer et al. (2018)also conclude that the HTS is likely to have strengthened Germany's capabilities in certain key-technology fields i.e. new materials or electro-mobility.

One nameworthy example that is based on the HTS, is "Industrie 4.0" that relies on a mixed funding model of public and private and financial in-kind contributions offering between a two to one or five to one ratio between private to public investment. The aim of "Industrie 4.0" is to futureproof Germany's strength in manufacturing by driving "digital manufacturing forward by increasing digitisation and the interconnection of products, value chains and business models" (PwC, 2017a). The initiative was budgeted with €200 million from the public side and complemented by financial and in-kind contributions from industry. Its implementation included a dedicated research agenda and an "industry 4.0 platform" which is an online and offline community to build the network foundation for digital transformation in Germany and enhances the knowledge transfer between its stakeholders. It is unique in its rapid transformation from research agenda into mainstream practice and the platform constitutes the largest and most diverse Industry 4.0 network globally.

As stated earlier, Germany does not rely on fiscal incentives for research funding and uses mainly project and institutional funding as its main instruments. Project-based funding in Germany must, as in the UK, adopt the European Union set of funding ratios of, while SMEs are eligible to obtain additional funding in excess of these ratios (The Commission of the European Communities, 2008):

- 100 % of the eligible costs in the case of fundamental research (basic research)

- 50% of the eligible costs in the case of industrial research (mostly applied research) and
- 25% of the eligible costs in the case of Experimental Development.

Institutional funding refers to the operations and investments that are funded by the Federal Governments and "Länder" over a longer period of time and that safeguard the expertise and strategic orientation of the German research landscape in the long run (Federal Ministry of Education and Research, 2018a). Powerful research organisations play an important role in emphasising a specific type of research - or in closing the gap between (basic or applied) research and (experimental) development and are eligible for institutional and competitive grant funding. The most important ones are the Helmholtz society, the Max-Planck Society, the Fraunhofer Society and the Leibniz Association. Each society maintains several research centres or institutes and aggregated details are given below.

- The **Helmholtz Society** is Germany's largest research organisation with an annual budget of €4.7 billion. Two-thirds of this funding comes from public sponsors and the individual Helmholtz Centres are responsible for attracting approximately 30% themselves through contract funding provided by public and private sector sponsors (Helmholtz Association, 2019a). Over 40,000 employees operate in six research fields that are driven by major long-term societal challenges, such as the digital revolution, climate change or the battle against severe diseases. In that sense, they are mission orientated. The organisation is very successful and claims the filing of 400 new patents every year and the generation of approximately 20 new high-tech spin-offs per year (Helmholtz Association, 2019b). One example of a single centre is the German Centre for Environmental Health in Munich that runs on a budget of roughly €300 million in 2018, where €42 million were funded through third party grants. Compared to this, the Crick, UKs flagship biomedical research institute, operates on a budget of £150 million (which is smaller even after adjusting for the exchange in 2018 and population differences (£150 million vs £180 million) and spun out two companies up to date (Crick, 2019).
- The **Max-Planck Society** employs more than 20,000 people with a budget of approximately €1.7 billion per annum, which is complemented by third party contributions from the public and private sector (Max Planck Society, 2019). Many Max Planck Society research centres share the common goal of performing basic research in the interest of the general public. This is often innovative basic research that is not carried out by universities due to a lack of resources and personnel and is also of more interdisciplinary nature (Allen, 2015).
- The **Fraunhofer Society** initially acted as an advisor and administrator to channel public funds to researchers. In 1970 it received its own funding from the Government that had to be matched by private contributions, and hence it started performing research on its own (Allen, 2015). The Fraunhofer society specialises in applied research that is of direct benefit to private and public enterprises and society. Today, it is the largest funder of applied research in Europe and employs more than 26,600 staff, consisting mostly of qualified scientists and engineers. In 2018 it got granted 612 patents and holds a total portfolio of over 3,200 (Fraunhofer Society, 2019b). The society works on a budget of €2.6 billion of which €2.2 billion are generated through contracted research. Here, around 70% is derived from contracts with industry or publicly financed research projects (Fraunhofer Society, 2019a).
- The **Leibniz Association** has a staff of 20,000 people, including 10,000 researchers, and an annual budget of approximately €1.9 billion. Research areas range from "natural, engineering and environmental sciences to economics, spatial and social sciences and the humanities. Leibniz Institutes address issues of social, economic and ecological relevance" (Leibniz Association, 2019). The overall aim is to link basic and applied research, but beyond the research that is

carried out by the association itself, it also provides knowledge and training (e.g. regarding the use of equipment) to the public and private sector (Allen, 2015).

These institutions (especially the Fraunhofer and Leibnitz Association) have a higher ratio of private to public funding than UKRI (which is more comparable to Germany's DFG). The UKRI spent £7.5 bn for the year ending in 2019 while only £1 bn was contributed by project partners (UKRI, 2018). That poses the question, if UKRI's funding model can either be tweaked to attract more private spending or if additional structures and institutions (similar to the research organisations outlined above) would be required.

Since the 1990s Germany's innovation policy instruments have focused more on collaborative research rather than funding individual companies (OECD, 2006). This can either happen by forcing applicants to apply as part of a project-based collaborative network (e.g. between industry and academia) or through dedicated funding programs. An example of the latter is the Leading-Edge Cluster Competition that was launched as part of the High-Tech Strategy in 2007. Clusters are built up by companies, scientific institutions and policymakers. Up to €600 million have been made available from public funds to form up to fifteen leading-edge clusters (€40 million each) in three funding rounds over a period of five years. As the clusters had to match the public support through an equivalent level of private funding, industry and private investors are an important part of these clusters from the beginning.

Unfortunately, Germany does not provide data on funding per type of R&D as defined by the OECD. However, as with the High-Tech Strategy, German funding programs emphasised the exploitation of project results, so strong support of Experimental Development is likely.

Potential learnings from the UK's perspective

Most noteworthy in comparison to the UK is the fact that the German innovation policy mix does not employ any generic tax-based incentive. Instead, Germany's funding approach can be characterised as mission-guided stimulation of the supply-side using project-based funding in a combination that incentivises collaboration between different actors such as industry, academia and research organisations. The combination with the application of a decreasing aid intensity from basic to research to Experimental Development may be one reason for Germany's relatively high share of private investment.

Germany is internationally admired for its economic backbone – namely the *Mittelstand* (Pahnke and Welter, 2019) and profits from powerful research institutes fuelled by a coherent set of collaborative policies. The Max-Planck, Fraunhofer, Leibniz and Helmholtz institutes receive in total over €10 billion and bridge the gap between different types of research (from basic research to Experimental Development). They have an international outreach and bring different actors along the innovation process together. Their institutional funding through the Federal Government and the individual states is complemented through competitive grants for which collaborations between those institutes themselves, academia and industry can apply. Germany realised that to increase the efficiency of each Euro spent on public research funding, a stronger focus on the exploitation of the project results is necessary. Direct project funding conditions, therefore, require today, that at least one applicant has a commercial interest, and that a plan of the potential commercial exploitation of the results is laid out in advance.

In particular, the Fraunhofer Institutes contribute to better translation from basic research into Experimental Development. Others have noted that the "Fraunhofer Institutes were established to ensure that customers are happy and innovative research is client-facing. This means the work is designed with business in mind as without clients the Fraunhofer's would not be successful" (see CaSE (2019b, p.5)). While public funding gives the Institute's long-term stability, contractual research and collaborative projects make up approximately 70% of total funding. This ensures a better link between academic researchers and the ultimate product innovators, industry. This example was also cited during the workshop chaired by Sir John Kingman and co-hosted by the Campaign for Science and Engineering with the note that the UK's Catapult network[23], which aims to mimic the Fraunhofer model, could play a key role in increasing research activities in businesses (CaSE, 2019a).

2.3.6 R&D intensive corporations and the threat of underfunding basic research – The case of Japan

Key Takeaways

What is the main difference to the UK?

- The massive share of R&D financed by business. Since 2005, Japan's industry-funded every year more than 75% of all annual R&D activities.

What are the highlights of Japan's innovation system?

- Japan's 5-year five-year Science and Technology plans. These are successive plans that determine the innovation policy for more than 20 years. However, because R&D and innovation are happening mostly internally at private companies, there is limited evidence on the effectiveness of the different policy instruments applied in each 5-year plan.

Are there noteworthy initiatives or learnings?

- Japan has the oldest population in the world. This allows other countries to take a glimpse into their own future. The current and future 5-year plans, therefore, emphasise the role of society in R&D and innovation. Initiatives such as Society 5.0, show that transformational effort is required to ensure that advanced technology can be integrated sustainably and is better accepted by society.

- Large companies can drive R&D – but may fail to deliver innovations that contribute to the betterment of society. While Japan's R&D activity is dominated by business spending on Experimental Development, the Government sees the risk of missing out on breakthrough innovations that society will profit from. Current political strategies aim at increasing public funding of fundamental research.

[23] While there is no final evidence on the effectiveness of the Catapults available until 2020, early findings show some benefits and that the Catapults are on track to deliver on the promised outputs (Frontier Economics, 2019).

Table 7: Comparison of key parameters between Japan and the UK.
Source: Cornell University, INSEAD, and WIPO (2018).

	Japan	UK
Population	127.5 million	66.2 million
GDP per capita (constant USD, 2017)	42,831	$ 44,118
R&D Intensity (2017)	3.2%	1.7%
OECD Ranking 2017 (for R&D intensity)	5	18
R&D Funding Ratio **Private : Public**	3.9 : 1	2:1
Research Ratio **Experimental Development : Applied : Basic**	4.9 : 1.4 : 1	2.1 : 2.4 : 1

How do Japan and the UK compare in terms of economic and innovative power?

Japan is twice as large (population of 127.5 million vs 66.2 million) and with similar levels of economic prosperity (PPP$ 42,831 PPP$ 44,117) (Cornell University, INSEAD, and WIPO, 2018). It ranks 14th in the overall GII 2018 and performs worse than other countries in terms of its efficiency ratio, where it ranks only 44th. Figure 33 shows that Japan and the UK compare similarly in most of the GII 2018 main indicators with the category of creative outputs being the exception where Japan's performance is significantly weaker.

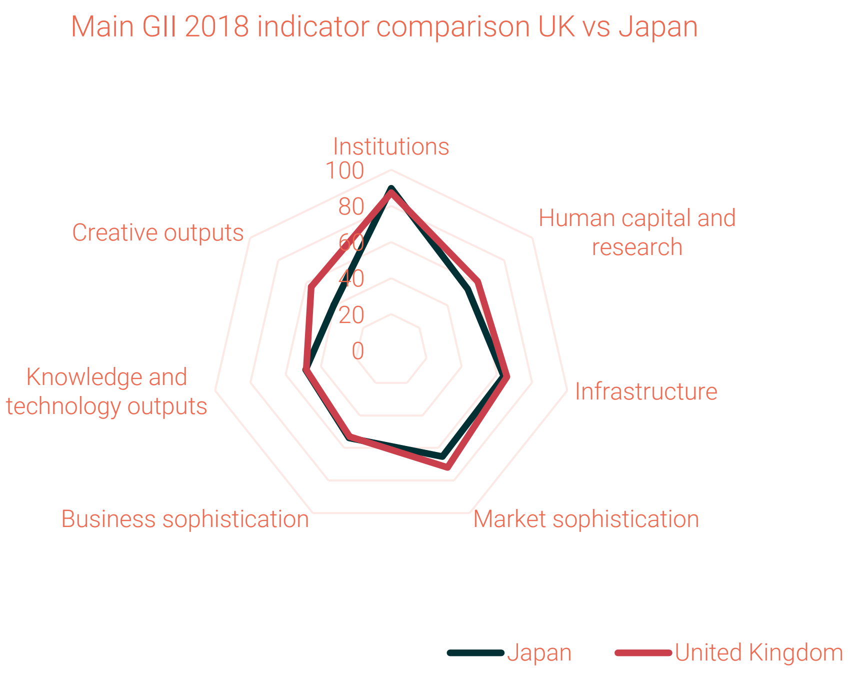

Figure 33: Comparison of main GII 2018 between the UK and Japan.
Source: Cornell University, INSEAD, and WIPO (2018).

Drilling down the GII 2018 categories and focussing on the attribute level, Japan does better than every other country with respect to the cost of redundancy dismissal, ease of resolving insolvency, the intensity of local competition, GERD financed by business, and several attributes related to intellectual property rights.

Culturally, Japan significantly differs from the UK which reflects on its economy. The so-called *nenko* system, for example, ties salary and career progress to the length of employment, which leads to intra-firm collaboration but discourages inter-firm movement. Another example is the lifetime employment practice that leads to good jobs for many until retirement, which, in combination with the *nenko*, may incentivise graduates to join existing firms rather than founding new ones (Palmer et al., 2018).

Japan is also a country of large corporations. Although SMEs exist, their number dropped between 1999 and 2014 by 21% as their ageing owners were unable to find a successor and the entrepreneurial spirit in the country is relatively low (OECD, 2107). Historically, the economy is influenced by the *zaibatsu*, that are conglomerates who owned numerous firms across many industries and had enormous political power. After World War II, the US considered those groups as monopolistic and anti-capitalist and, in an attempt, to change the system, the *keiretsu* were created. Those groups do not directly own many companies but are rather affiliated through stock, banking and production. This leads to a vertically integrated network of firms who support each other (Palmer et al., 2018).

The *keiretsu* system in combination with the *nenko* system are seen as unfavourable conditions for entrepreneurship and about 77% of Japan's R&D is done by large corporations, putting it among the world's largest corporate R&D investors, and 98% of that research is self-financed (OECD, 2012),

The most R&D intensive industries in Japan are the automotive sector, the electronics sector, and the pharmaceutics sector. The pharmaceutical industry profits from both, demand- and supply-side factors. On the demand side, an ageing population in need of higher-quality and lower-cost care is considered to be the main driver of demand. On the supply-side, a relatively fast review process that approves 70% of new products in less than 12 months and a national pricing system that leads to more stable and generally higher medicine prices over the lifetime of the patent compared to other regimes (Palmer et al., 2018) favours the supply of innovative products.

Japan's funding mix

Japan has the highest share of GERD financed by business in the world. Since 1982 this share never fell below 70% which by far exceeds any other country (see Figure 34). In the same period, the share of GERD funded by the government fell from 25% to 15%. The share of GERD funded by the rest of the word (i.e. FDI) is negligibly small.

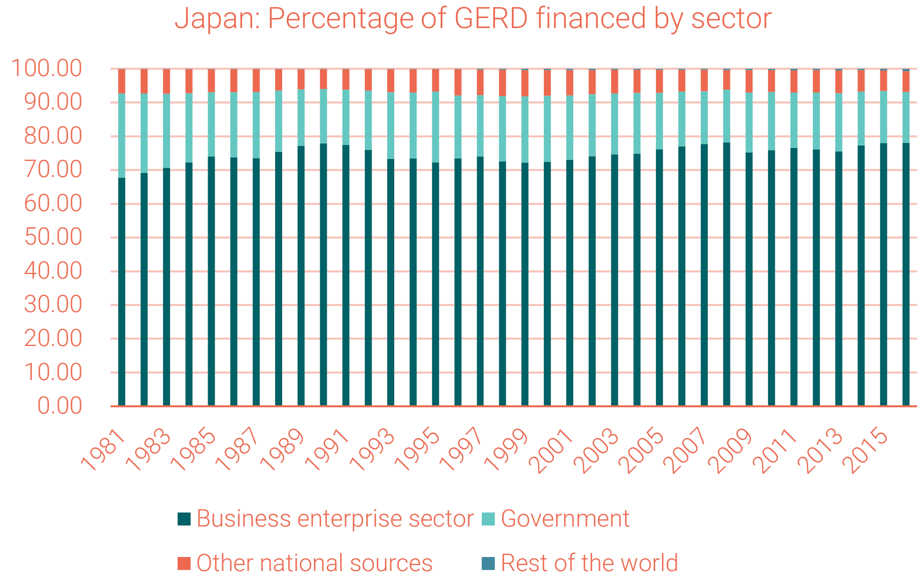

Figure 34: Percentage of GERD per funding source. Japan.
Source OECD.

Due to the high share of business spending on R&D, the Japanese Government's contribution to R&D funding is relatively small and the Government funds relatively little R&D directly. As shown in Figure 35, the Government directly funded only 0.02% of BERD as a percentage of GDP in 2016 (compared to 0.09% in the UK). While tax support for BERD was higher, it was still lower than in the UK (0.11% and 0.15%, respectively).

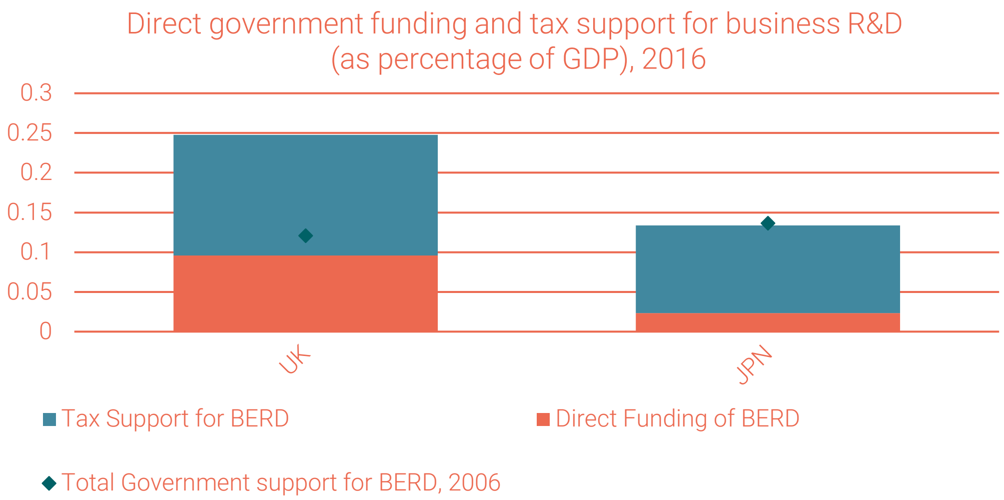

Figure 35: Direct government funding and tax support for business R&D. Japan vs the UK.
Source: OECD.

Noteworthy innovation policies in Japan

In contrast to other high-income countries, large Japanese firms innovate much more internally and are less reliant on international collaboration or contracted public research which limits the amount of evidence with respect to specific policy instruments.

In general, the innovation system and related research policies are coordinated through the cabinet office, while individual ministries are responsible for the distribution of funds. On an administrative and operational level, several independent administrative institutions (IAI) take over. The *Japan Society for the Promotion of Science,* for example, is an IAI that awards grants-in-aid for scientific research, support the scientific cooperation between industry and universities and supports the supply of research talent.

Japan's science and technology policies are aimed at overcoming Japan's social issues (Cabinet Office Japan, 2018) and for that purpose, two strategic instruments, namely the *5th Science and Technology Plan* and a new concept called *Society 5.0* have priority.

The former is grounded in the Science and Technology Basic Law which was enacted in 1995 and which introduced successive five-year Science and Technology plans. Those plans defined priority fields and reflected several important goals including "strengthening Japan's scientific and technological capacity and advancing Japan's industrial competitiveness" (Palmer et al., 2018). Since 2016 the 5th Science and Technology Plan is in place and covers the five-year period between FY2016-FY2021 (MEXT, 2018). The current plan is based on four pillars:

- Acting to create new value for the development of future industry and social transformation
- Addressing economic and social challenges
- Reinforcing the "Fundamentals" for STI (science, technology, and innovation)
- Establishing a systemic virtuous cycle of human resources, knowledge, and capital for innovation.

The content of the 5th plan recognises the fall in public STI budgets and therefore makes larger investments in this area a key priority. Furthermore, it analyses that companies are becoming more risk-averse and therefore R&D, which in Japan is carried out in large amounts by the private sector itself, must deliver a quick return on investments. This is reflected by the large share of Experimental Development in Figure 36 that is closer to its commercial application and hence inherits less risk.

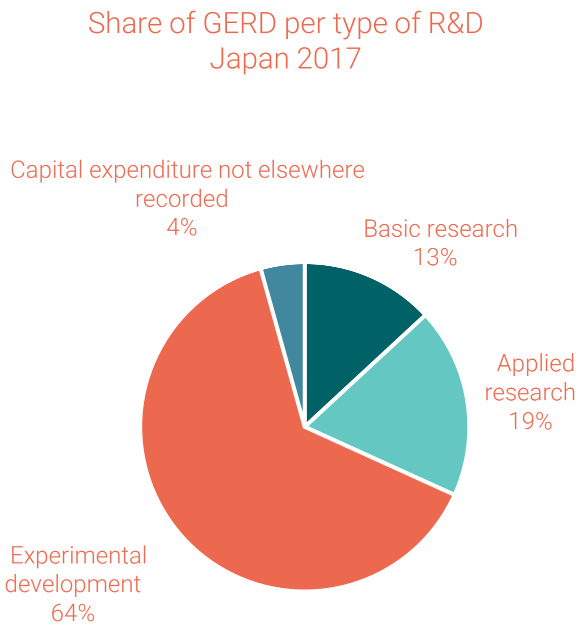

Figure 36: Types of research carried out in Japan in 2017.
Source OECD.

Therefore, the Government concludes that it needs to support "sustainable long-term R&D, including those types that lack immediate commercial potential" (Government of Japan, 2016), which basically implies stronger support for basic and applied research.

The other strategic instrument *Society 5.0* describes the concept of a "human-centred" society that pursues well-being and happiness released from physical restrictions (Cabinet Office Japan, 2018). Society 5.0 aims at resolving various social challenges by incorporating the innovations of the fourth industrial revolution (e.g. Internet of Things big data, AI, robot, and the sharing economy) into every industry and social life. To give an example from the healthcare sector, the concept would offer solutions to Japan's ageing society by connecting and sharing information between medical data users, the implementation of remote medical services or the use of AI and robots to support carers and patients.

Potential learnings from the UK's perspective

The UK and Japan differ significantly in terms of culture and economy. However, Japan has the oldest population in the world which significantly impacts both the economy and society. This allows other countries – such as the UK - to have a glimpse into their own future challenges.

With their future policies and initiatives such as Society 5.0, Japans shows that transformational efforts need to include all of society. Hence special efforts are made to break through a wall of acceptance to ensure that advanced technology can be integrated sustainably. This mirrors other voices calling for better communication of the need for R&D and its benefits for society.

Japan has clearly no problem with its R&D intensity. However, while the UK allocates relatively large amounts of money to basic and applied research via public funds, Japan's R&D activity is dominated by business spending on Experimental Development. Japan's Government,, therefore, sees the risk of missing out on breakthrough innovations for the betterment of society. Thus, current political strategies aim at increasing public funding of fundamental research.

The case of Japan demonstrates how large corporations can carry a large amount of R&D intensity within a country if the potential for national and international economic exploitation of the R&D results is ensured. However, Japan also experienced the downside of this approach. Smaller companies and especially start-ups face difficulties in obtaining money in a system that mostly supports the big players. This may slow down innovation due to the generally lower speed of innovation processes in large corporations.

2.4 A policy mix that unlocks private R&D investments of UK's Pharmaceutical industry

The first part of this report established that reaching the 2.4% target is achievable. As the case studies demonstrate, several countries met or exceeded that target through a wide array of policy instruments and funding mixes related to R&D. In the following, we propose a policy mix that draws from these (positive and negative) learnings but is embedded into the UK-specific context as the UK needs to build upon its relative strengths to increase the amount of R&D that translates into sustainable innovation.

The first part of this report highlighted that the private sector is key to reaching the 2.4% target. In all countries that were included in the case studies, the private sector funded more than half of all R&D activities and all countries, except Austria[24], showed a higher private to public spending ratio than the UK, from over 3.9 to 1 in South Korea to 2.5 to 1 in Belgium (see Figure 37). Hence, to reach the 2.4% target and beyond, the UK will need to alter its private to public funding ratio, requiring policies that attract more business spending.

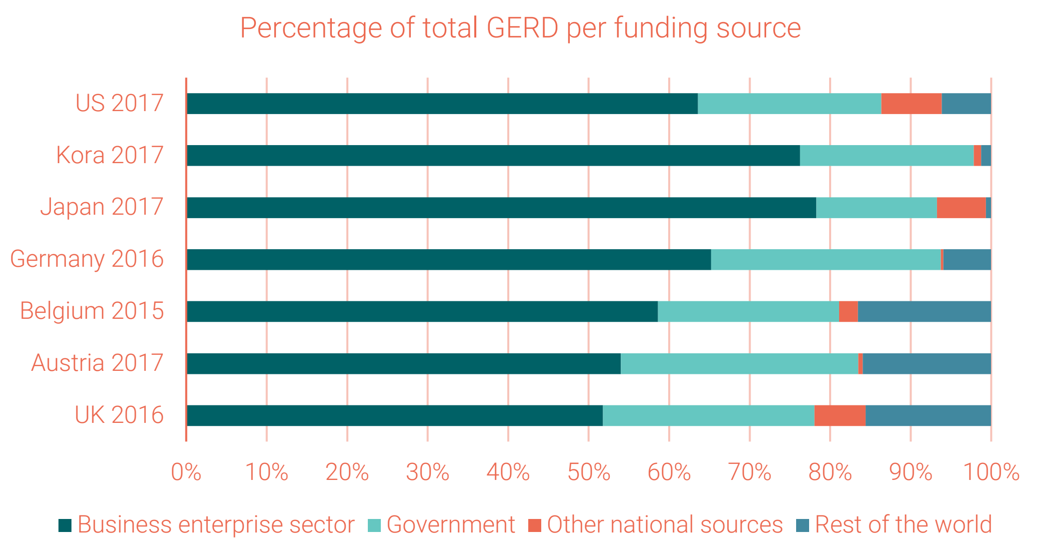

Figure 37: Percentage of total GERD per funding source.
Source OECD.

[24] *However, it should be noted that with over 15% of total GERD, Austria exhibits a relatively high share of FDI.*

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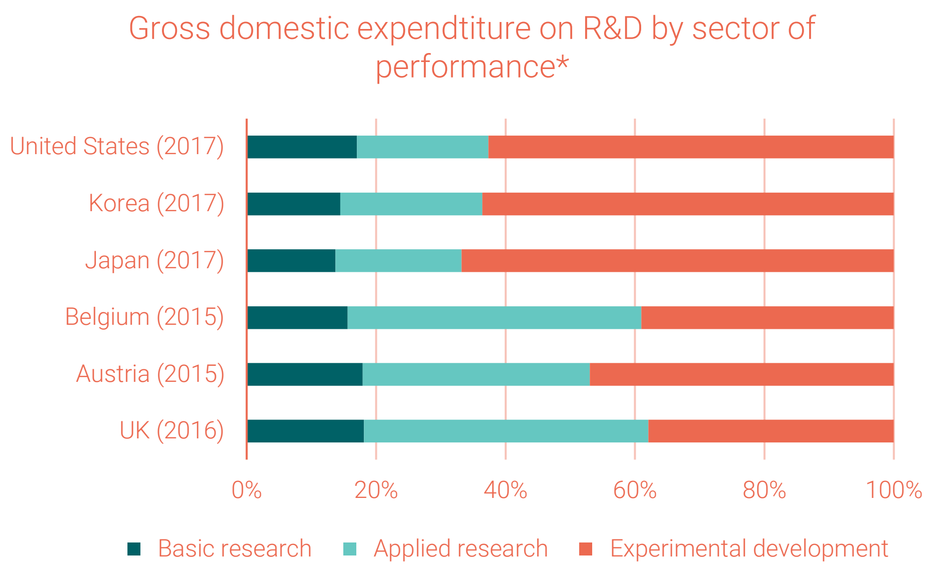
The case studies have shown that multiple policies can crowd-in private sector investment. However, they may differ in their impact on the overall innovativeness of a country. In Austria for example, strong fiscal incentives increased R&D in already R&D-active business and attracted FDI. Due to the industrial structure of Austria however, this has not yet resulted in more innovative power, while similar incentives in Belgium fuelled a successful biopharmaceutical industry that generates a tenth of the country's exports.

The different policies also favour different industries or firm sizes. While Governmental policies in favour of prominent industries and large companies achieved massive amounts in private spending on R&D, nowadays Governments increase efforts to balance their funding programs with SMEs and yield stronger spillover effects to adjacent and upcoming industries.

As can be seen in Figure 38, the Gross Domestic Expenditure on R&D in the UK is allocated currently to 18% to basic research, 44% per cent to applied research and 38% to Experimental Development. This differs significantly from high performing countries like the US, South Korea or Japan.



* Germany does not report its gross domestic expenditure on R&D by sector of performance and is therefore excluded from the graph.

Figure 38: Distribution of type of funded research in comparison.
Data for Germany not available. Source OECD.

While spending on basic and applied research is generally considered to be more effective than supporting activities closer to market and less distortion of healthy competition between actors with commercial interests (European Commission, 2016), Experimental Development generates the most effective lever to enlarge the private to public funding ratio as can be seen in Table 8.

What is required is therefore to firstly enhance translation from basic and applied research to Experimental Developments (e.g. like it is done by Fraunhofer in Germany). Secondly, additional spending in the UK may be used to stimulate the performance of R&D within the Experimental Development phase, as this may enable the UK to reach public to private funding ratios that allow the UK to reach the 2.4% target. It should be noted that in absolute terms, this additional stimulation should not come at the expense of basic or applied research.

Table 8: Private to public funding Ratios in 2015 per type of Research.
Capital expenditures not elsewhere recorded were neglected and Germany was excluded as related data is the relevant data could not be found. Source: OECD.

	Basic research	Applied research	Experimental development
United States (2017)	0.70	1.87	10.29
South Korea (2017)	1.44	2.94	7.28
Japan (2017)	1.10	2.34	15.33
Belgium (2015)	0.62	1.65	13.11
Austria (2015)	0.26	2.33	20.69
UK (2016)	0.67	1.82	7.65

In the UK, the life sciences, as well as the automotive and computer & ICT sectors, should be considered as one of the key partners in reaching the 2.4% target as they are the largest investors R&D and perform comparatively large amounts of Experimental Development. The life-science sector is of particular interest as it a) leads in total R&D spending and b) spends more than half of its budget on Experimental Development as can be seen in Figure 39.

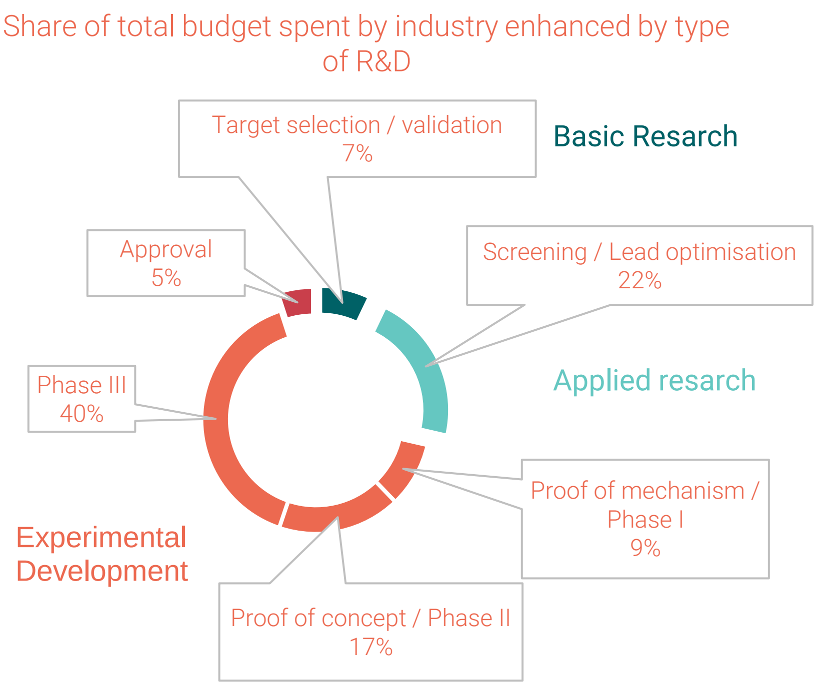


Figure 39: Share of total budget spent by the pharmaceutical industry enhanced by the type of research.
Source: PwC (2012) with adaption based on Maselbas (2013).

There are many good other arguments for why the life-science sector is important in reaching the target. Firstly, it consists of many small, medium and large companies, and thus offers enough heterogeneity in firm size to avoid later dependency on a few large R&D spenders (which are required to maintain a strong baseline of R&D activities). Challenges such as the dependency on large companies as in South Korea and Japan or the need for more innovative SMEs in Belgium can, therefore, be addressed with the right policies from the beginning and may develop over time. Secondly, compared to other sectors, empirical evidence suggests that public funding of the pharmaceutical sector is associated with an increase in private investment, rather than crowding out (Kim, McGuire and Kyle, 2015). Thirdly, as the sector requires funding predominately by investments of a large amount of capital over a long period of time, short-termism may be avoided. Finally, it requires both, specialised and generic infrastructure (Kennedy, 2018) and hence might generate the necessary spillover effects in fields like AI and machine learning that have the potential to enable large productivity gains beyond the life science sector.

Based on our analysis and country comparators, we conclude that four factors can build business conditions and policy options that unlock R&D investments of the pharmaceutical industry while maintaining the UK's strong performance in basic research and promotes its academic excellence.

Maintaining strong generic fiscal incentives to ensure industry expenditure on R&D and FDI

Generic tax incentives work. They result in an increase in private R&D spending (see for example the Belgium & Austrian case) and are one of the most important instruments that should be maintained in the British policy mix. Furthermore, they are of special importance if the goal is to attract FDI in an efficient way. However, they may come with associated costs as their research effectiveness is sometimes lower (see the Austrian case), and an increase in R&D expenditure may not translate into sustainable innovation. Fiscal incentives are therefore a necessary but not sufficient lever for innovation.

Generic incentives do not allow the Government to target specific industries (e.g. pharma or digital technologies), types of R&D (e.g. Experimental Development) or missions (e.g. Ageing Society). Therefore, the UK should at a minimum maintain its competitive fiscal incentives but also consider whether it would like to claim to be the number one in international comparisons. Minor design-modifications however, such as to amend the definitions of eligible activities to include the costs relevant to future data-driven innovation (NEXUS, 2019), might be a useful update to futureproof the instrument.

Grow investment in the development stage of R&D

The evidence suggests that it is recommended to design a specific policy mix of direct measures rather than only enhancing generic instruments. Here, the objective should be to increase the share of Experimental Development carried out within the UK to at least 40% to 50%, as private to public funding ratios are significantly higher in this type of research. This can be aligned with mission orientated R&D investment. The Grand Challenges and other areas identified in the Industrial Strategy would be examples of direct government funding of Experimental Development with specific missions and should be increased. As outlined above, the life-science sector may deliver a significant contribution to R&D spending during such programs as it spends more than 50% of its budget on Experimental Development.

Suitable funding programs need to be designed in accordance with international competition laws. In the UK public procurement and pre-commercial procurement policies may serve as the keystone to increase the demand for innovations. The NHS as a single-payer is in an optimal position to stimulate innovation of value to the society and can act similarly as the Department of Defence in the US as a large funder and purchaser of innovation at the same time. Programmes such as the NHS's pre-commercial procurement program or the Accelerated Access Collaborative (AAC) ensure public money is focused on the areas of greatest impact for the NHS and patients, and are aligned with the work of charities, research organisations and VC funds.

It is furthermore desirable to establish direct funding programs to make the UK the world's leader for clinical trials. It is very likely that such programs trigger large amounts of private investment from national and international firms as the UK offers excellent conditions with respect to patient population and data and clinical infrastructure. Such a program would also serve as an incubator for cross-disciplinary research between adjacent areas such as health informatics, data science and AI or health economics and can exploit the vast amount of data that is collected in the NHS each day. Accompanying research on data security, processing and storage could have lighthouse character.

The National Institute for Health Research (NIHR) already provides successful examples in the field of cancer research. The Experimental Cancer Medicine Centres (ECMCs) contribute to not only increase the volume but also the quality of early phase clinical trials. That reduces the risk and costs associated with failures in later stages and increases the efficiency. As a result, the UK is a highly attractive location for industry-sponsored and collaborative cancer trials.

Experimental Development could also be funded indirectly by providing strategic assets (e.g. patient data platforms like FlatIron) or through institutional funding similar to the German Fraunhofer model. The UK could seize the opportunity for a world-leading public-private collaboration around clinical trials. It would provide significant societal value whilst generating significant spillover effects (e.g. through the development of data science capabilities).

Strengthen the entrepreneurial role of the academic sector

The UK has a world-leading university sector and the government should continue to increase investment in universities and basic scientific research. However, encouraging academics to focus more on applied research and Experimental Development will produce more commercial research and would crowd-in additional private sector investment.

Cultural, legal and financial factors mean that academic entrepreneurship is significantly higher in the US. Specific legislation such as the Bayh-Dole act creates incentives for academic researchers to transfer knowledge to parties with commercial interest. Access to VC and corporate VC or the SBIR program ensure that new ideas profit from stable funding. Last but not least, benefits the US from a higher rate of exchange of individuals between the private sector and academia.

The UK should, therefore, consider to adopt legislation that creates stronger incentives for the individual academic and their corresponding institutions to commercialise their research, maintains and enhance useful programs that promote the relationship-building between industry and academia, and improves access to VC within the UK or bridge periods of poor funding with similar programs to the SBIR in the US.

Ensure the supply of world-class talent

The US and South Korea have grounded their success on the adequate supply of R&D talent by national universities. For many companies, the UK's outstanding position in access to top-level researchers is a significant reason to invest in R&D in the UK[25]. It is therefore paramount for the UK to maintain and increase the supply of national and international top-talent to universities and the life sciences workforce. Education and Innovation policies must work together to define the right targets and policy mixes.

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[25] As Sir Patrick Vallance (Government Chief Scientific Adviser and Head of the Government Science and Engineering profession) puts it: "One thing is certain, though – and I say this from my experience as Head of R&D at GSK – there is nothing that trumps the ability to attract key talent from top universities and the research sector. The ability to interact with world-class research is still the biggest lever we have for attracting increased investment from business." (Vallance, 2019).

The challenge is to maintain world-leading academic clusters while growing structures outside the "golden triangle" of Cambridge, Oxford and London as it requires a more balanced way of funding. Especially the South Korean case demonstrated how building up the science base can lead to commercial opportunities in the long-run and how a too-narrow focus on a few regions bears the threat of creating regional socio-economic imbalances that are hard to fix at a later stage.

Ensuring the supply of R&D talent through universities does not only require budget increases but also requires the removal of red tape within universities to enable academic staff to deliver a high-quality teaching experience and research output at the same time. Dedicating programs to increase the amount of student-led research in cooperation with companies (e.g. during MSc thesis), could be used to bridge the gap between academia and industry and guide students better to future employers. It must also be ensured that the UK and its universities continue to attract international top-talent and offer opportunities and the right to work in the UK after graduation. With respect to the life-sciences, training schemes must deliver the skill requirements in emerging capability gaps to stay ahead of international competition.

2.5 Conclusion

R&D is the most important input for innovation. Innovation itself is crucial for ensuring the UK growths sustainably and solves the grand challenges of our time. While the UK is a highly innovative country, its R&D intensity lags those of other innovative countries - this creates a long-term risk. To reach the Government's 2.4% target there needs to be both, a significant increase in public R&D funding, and adoption of policies and incentives to attract significantly more private-sector R&D investment. Countries that have achieved the UK's stated aim have done so by crowding in substantially more private sector investment, with private to public investment ratios of more than 3:1 in comparison to the UK's 2:1.

This second part of the OHE report, therefore, analysed the policy instruments that may be suitable to stimulate R&D spending either via increasing the demand for or supply of, innovation. Several countries that exhibit a high level of R&D intensity make successful use of these policies, but these policies must be analysed within their cultural, economic and political contexts.

Each country case study provided valuable learnings from a UK perspective. The US is distinctive in terms of the relationship between a strong market pull and its impact on R&D and innovation. It also provides very favourable conditions for innovation including an active VC culture and academics with an entrepreneurial spirit. Germany demonstrated how translational research can be fueled through institutions that rely on large amounts of matched funding from private and public actors. Austria showed that with dedication and a clear mission, R&D intensity can be increased but it is important that this also translates into innovation and the societal benefits are captured locally. Belgium's strong fiscal incentives without a ceiling encouraged companies to make large investments into R&D. And South Korea and Japan showed that a balanced ecosystem of large and small innovators is important for long-term R&D investments. However, once the system is out of balance, it requires dedicated efforts to find the right equilibrium again.

The policies that are most likely to work in a UK context, were put forward as recommendations. A special emphasis has been placed on the pharmaceutical industry as it is the largest single investor in R&D in the UK. This does not mean that the pharmaceutical industry is the only industry sector that should receive funding nor that it is the only sector that will need to increase its expenditure on R&D. Nevertheless, due to its heterogeneity in firm size, interdisciplinary links with other sectors and the impact its innovative products and services have, it is the most important target for such policies.

The recommended policies - and related instruments – aim to increase the attractiveness of the UK as an R&D location for national and international investors. If private spending on R&D is to be increased, policies need to aim for enlarging the share of Experimental Development in the UK. The pharmaceutical industry allocates over 50% of its research budget to this research phase during clinical trials. The industry provides, therefore, an excellent lever for policies that aim to increase the share of Experimental Development. First steps for cross-sector collaboration have been made recently by the NHS Confederation (2019) and should be continued.

Nevertheless, companies choose their R&D location not only according to the biggest financial incentives but due to multiple location factors. Other countries have demonstrated how excellence in academia and the entrepreneurial behaviour of academics leads to increased private spending in R&D. The Government should, therefore, ensure that the supply of world-class R&D talent continues and that the academic sector gets stronger incentives to aim for the commercialisation of their research.

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