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Private Sector R&D Investment Policies

A review of policies in OECD countries for boosting private sector R&D investment

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Executive Summary

Policies aiming to boost private sector R&D investment need to help businesses overcome four key barriers: low appropriability, scale, radicalness, and uncertain payoffs.

- **Low appropriability**: knowledge created as a result of a firm's investment can easily be imitated or adopted by other firms.
- **Scale**: proving reliability at scale for commercialisation can require large investments in demonstration projects.
- **Radicalness**: incremental improvements to existing technologies are more likely to attract financial investment than radical innovations.
- **Uncertain payoffs**: this weakens the incentive to invest.

R&D support requires both direct and indirect incentives. Policies for directly incentivising R&D efforts (‘demand pull’ policies) aim to increase the size of markets, e.g. R&D subsidies, tax credits, and public procurement. Policies for indirectly incentivising R&D efforts (‘technology push’ policies) increase the availability of new knowledge, e.g. funding public colleges and universities and supporting knowledge networks.

- **Technology push and demand-pull policies are both necessary**, given the substantial variation among technologies and between industries.
- **Technology push policies are important in the early stages of the R&D process and lead to radical innovations.**
- **Demand pull policies are important in the later stages of the R&D process and lead to incremental innovations.**

Publicly funded R&D promotes private R&D investment. Overall, public R&D compliments private R&D, although it may also crowd out some private R&D (through a substitution effect). There are different levels of benefits felt across different sectors and firm sizes.

- **In the UK, each £1 of public R&D stimulates between £0.41 and £0.74 of private R&D within the same year, and between £1.96 and £2.34 of private R&D over time** (Oxford-Economics 2020).
- **R&D incentives tend to be most effective in countries with certain features,** namely strong protection for intellectual property and property rights, access to the latest technologies, and ready access to finance.

- **R&D policies need to be integrated with policies for other sectors**, including industrial, economic, health, environment, defence and security, not just with closely connected areas such as HE and innovation.

R&D support policies are becoming more systemic in their approach.

- **The design of policy instruments is shifting to focus on developing new or stronger links between actors, rather than targeting individual R&D actors**, leading to more cooperative, multi-actor and often 'place-based' approaches.
- **A placed-based approach to policy development allows experimentation** around more integrated and coordinated support for private sector R&D investment and the development of regional innovation ecosystems.

The UK can support improved private sector R&D investment by learning from and adapting successful R&D policies developed in other countries. 15 exemplars of good practice covering a range of policy types are identified from five OECD members: United States, Germany, France, Switzerland, and Japan. These policies are mostly sector non-specific. The key findings were as follows:

- **The most reliable, generic policy interventions are policies to support collaboration, cluster policy, and direct support to firm R&D and innovation.** The growing importance of cluster policy reflects the shift from linear to systemic thinking about R&D and innovation.
- **Fiscal incentives and direct support to firm R&D and innovation are the most common policies.** R&D tax incentives accounted for around 50% of total government support for business R&D in the OECD area in 2017. **Direct grants support longer-term, high-risk research and often target specific areas** that either generate public goods (e.g. health and defence) or have particularly high potential for spillovers. R&D grants are instrumental in promoting experimental research while tax measures are more likely to promote experimental development.
- **Policies involving science and technology institutes and public funded research can boost private R&D investment** by increasing the stock of knowledge, training graduates, creating new technologies, creating networks, and creating new firms. Many national governments have implemented policies to promote the formation of university spin-off companies in response to their contribution to economic growth, whilst the establishment of science parks encourages and facilitates university–industry R&D collaboration.
- **Public-private partnerships (PPPs) can accelerate infrastructure investment and generate value through co-production.** PPPs help to encourage private financing by increasing funding sources and reducing financial risk.

- **Government procurement can enable ground-breaking innovations** that require large markets to be viable and patient capital.
- **Most policies are developed and implemented on an individual basis and therefore the effect of combining policies cannot be easily evaluated.** This is despite the importance of using a mix of policy instruments and highlights a gap in our understanding of how policy instruments interact.
- **Some policy instruments have been extensively studied** (e.g. clusters and fiscal incentives for R&D), whilst **other policies have not** (e.g. innovation procurement).
- **Contextual factors influence the transferability of a policy**, such as the industry, region, national, and supranational (e.g. the EU) context.

Table A: Exemplar policies

Policy Type	Policies	Key Evaluations
(A) Fiscal incentives for R&D	**France:** R&D tax credit reform (2014) **Japan:** R&D tax credit reform (2003)	**Japan:** increased R&D expenditure: each 1% increase in effective tax credit was estimated to increase R&D expenditure by 2.3%.
(B) Direct support to firm R&D and innovation	**Germany (2):** Zentrales Innovationsprogramm Mittelstand (Central Innovation Programme for SMEs) *(also G)*; KMU Innovativ (Innovative SME) **USA (2):** R&D loan program in the state of Michigan; Small Business Innovation Research (SBIR) **France:** R&D Defence Subsidies	**Germany:** increased R&D activity, R&D intensity (expenditure/turnover), new products being brought to market, and R&D jobs created. However, some crowding out of private R&D investment. **USA:** increased survival rates and follow-on venture capital (VC) investments in surviving companies. **France:** 10% increase in government-financed R&D generates a 5% to 6% additional increase in privately funded R&D.
(C) Policies for training and skills	**Switzerland (2):** Universities of Applied Sciences; Commission for Technology and Innovation (CTI) Start-Up Coaching *(also D)*	Increased number of regional patent filings and patent quality. 91% of supported start-ups had an active R&D collaboration with either a university or another business.
(D) Entrepreneurship policy	**Switzerland:** Commission for Technology and Innovation (CTI) Start-Up Coaching *(also C)*	*See (C) Policies for training and skills.*
(E) Technical services and advice	**Germany:** Bavaria High-Tech Offensive *(also G)* **Japan:** Kosetsushi – local technology centres	**Germany:** increased likelihood of firms making an innovation in a given year by around 5%. **Japan:** successful in attracting non-innovative SMEs to invest in innovation for the first time.

		Technologically more advanced SMEs were more likely to collaborate with local technology centres than with universities.
(F) Cluster policy	**Germany:** Spitzencluster-Wettbewerb (Leading-edge Cluster Competition) **France:** Pôles de Compétitivité *(also G)* **Japan:** Industrial Cluster Project (METI) and Knowledge Cluster Project (MEXT) *(also G)*	**Germany:** for each euro in funding received, SMEs increased their own innovation expenditure by an additional EUR 0.36. **France:** increased business R&D spend by EUR 1.875 for every euro received in public R&D subsidies. Effected SMEs more and took about 4 years to materialise. **Japan:** R&D productivity (based on patent applications) increased only in participating firms who collaborated with the core universities in the cluster area.
(G) Policies to support collaboration	**Germany:** Bavaria High-Tech Offensive *(also E)*; Zentrales Innovationsprogramm Mittelstand (Central Innovation Programme for SMEs) **USA:** Early Detection Research Network (EDRN) *(also H)* **France:** Pôles de Compétitivité *(also F)* **Japan:** Industrial Cluster Project (METI) and Knowledge Cluster Project (MEXT) *(also F)*	**Germany:** increased collaboration with public research institutes, and improved access to suitable R&D personnel. Decreased R&D expenditure, likely due to the provision of free resources. **USA:** initiated over 60 network collaborative projects, and over 30 collaborations have been formed between EDRN laboratories and biotechnology or diagnostic companies. **France:** *see (F) Cluster policy*. **Japan:** *see (F) Cluster policy*.
(H) Innovation network policies	**USA:** Early Detection Research Network (EDRN) *(also G)*	**USA:** *see (G) Policies to support collaboration*.
(I) Procurement	*None identified*	-
(J) Regulation	*None identified*	-

Contents

1. Introduction

1.1 Scope of the Review

This report summarises a rapid review of recent evidence on effective policies developed in selected OECD member economies for boosting private sector investment in research and development (R&D). The purpose of the review was to provide examples of good practices and policy lessons that can help the government to achieve its ambition to increase total R&D investment. The review included a systematic search of academic literature and targeted web searches to identify relevant policy evaluations and government papers. The review focused on five countries including the United States, Germany, France, Switzerland, and Japan.

This report presents a summary of key (recent) evidence on 'what works' with policies developed to boost private sector investment in R&D. For the most part it draws on a desk-based review of R&D policy instruments from the academic and grey literature. Given the wide range of material on the subjects covered it is by no means comprehensive; rather it seeks to highlight findings on where there is precise evidence that policies have boosted private sector R&D.

1.2 Methodology

This evidence combined both systematic searches of the relevant academic literature (see Appendix B) and identification of organisations with a remit of strengthening private sector R&D investment in the United States, Germany, Japan, France, and Switzerland. Our approach involved targeted searches of relevant government and business organisations websites for listed initiatives within each of these countries to identify relevant policy papers (e.g. White Papers, Green Papers, and Enterprise or Innovation Strategies) and relevant international bodies such as the OECD that undertake policy case studies. We limited our search period to 2010 onwards when the OECD Innovation Strategy was published.

Systematic searches were conducted using Clarivate Web of Science and EBSCO ECONLIT bibliographic databases using search terms set out in Appendix B and stored and managed in Endnote database. The searches resulted in 2,883 potential articles that were screened to identify 77 potentially relevant papers which were obtained and considered for inclusion in this review. These searches were also supplemented by commissioning IDOX Knowledge Exchange to identify relevant grey literature, targeted searches of relevant websites of relevant organisations in the five selected countries and citation searches.

Our searches of academic literature mainly yielded non-country specific articles that described factors that affected private sector investment in R&D. We first provide a summary of these factors before presenting our five country-based case studies. Then we summarise the main papers reviewed in detail for this report. Information on each potential policy good practice was collected through the use of a data extraction template.

1.3 Structure of Report

Following this introduction, the findings of this review are presented in three chapters:

- **General Findings:** provides a short overview of: (i) the importance of R&D to the economy and policies to stimulate private investment in R&D; (ii) the 'state of play' in the level of understanding of the impact of public policies on boosting private sector investment; (iii) the global factors that facilitate or hinder the increase in private sector investment in R&D.
- **Examples of Good Practice:** summarises what policy lessons the UK can learn from, and what policies the UK could pursue to boost private sector R&D, factoring current economic conditions and the UK's economic structure.
- **Conclusion:** summarises the key points identified in this review, gaps in the evidence and future policy priorities.

2. General Findings

2.1 Introduction

"R&D policy" is an overarching term which includes research[1] and science and technology[2] policies, and overlaps considerably with "innovation policy"[3] (Doern and Stoney 2009). However, innovation policy is much broader than R&D policy, since it also includes commercialisation and various demand-side policies (Georghiou, Edler et al. 2014). In the case of the broader field of innovation policy, the NESTA project entitled "Compendium of Evidence on the Effectiveness of Innovation Policy Intervention Project" have produced 18 reports that set out a typology of innovation policy instruments, distinguishing supply-side from demand side instruments, and classifying instruments on the basis of seven innovation goals. There is comparatively less literature focussing directly on R&D policy instruments, or at least using that particular term, perhaps reflecting a lack of awareness of the established body of work on this in the area of policy design (Martin 2016). Similarly, there was found to be little on the economic theory of R&D policy instruments and the economics of specific R&D policies.

The aim of our review is to bring together the related streams of literature (on innovation, research, science and technology) to present a summary of key (recent) evidence on 'what works' with policies developed to boost private sector investment in R&D. The purpose of this section is to set the context for this, by providing a short overview of: (i) the importance of R&D to the economy and policies to stimulate private investment in R&D; (ii) the 'state of play' in the level of understanding of the impact of public policies on boosting private sector investment; (iii) the global factors that facilitate or hinder the increase in private sector investment in R&D.

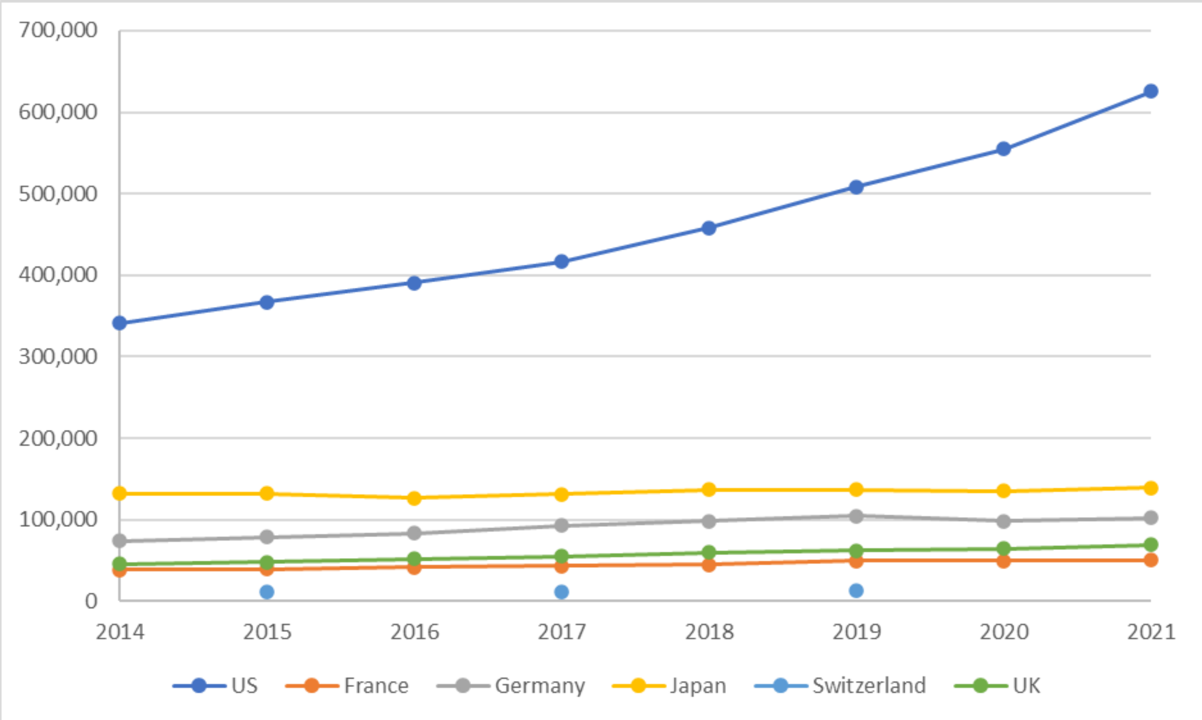
2.2 The Importance of Policies to Boost Private Investment in R&D

Research and development (R&D) is an important driver of innovation (OECD 2010) and underpins economic growth in two ways (Bloom, Schankerman et al. 2013, Aldieri, Bruno et al. 2020). First, it boosts economic growth directly (Bilbao-Osorio

[1] "Research policy refers to policies aimed at the funding, conduct and dissemination of basic and applied research in the natural, health and social sciences" (Doern and Stoney 2009:9)
[2] "S&T policy promotes and governs the use of scientific and technical knowledge in public policy and regulation ('science in policy') (Doern and Stoney 2009:9)
[3] "Innovation policies refer to government policies aimed at fostering the use of the best S&T to produce new and competitive 'first-to-market' products and new production processes, and the innovative organizational approaches and management practices to support these activities" (Doern and Stoney 2009)

and Rodríguez-Pose 2004, Hasan and Tucci 2010) and second, it generates positive externalities in the form of knowledge creation (Rehman, Hysa et al. 2020). R&D performed by businesses or 'Business Enterprise R&D' (BERD)[4] accounts for a significant proportion of gross domestic spend on R&D and thus, policies to boost private investment in R&D is a priority for different national governments. The total spend of BERD varies between different countries, as shown in Figure 1, which compares the amount of BERD (2014-2021) for our five case study countries.

Figure 1: Business Enterprise R&D



Source: OECD.[5] Unit: millions of current international dollars.

There are four key barriers to private sector R&D investment, which policies focus on helping businesses to overcome.

Barriers to private sector R&D investment

Appropriability: Low appropriability is the most widely accepted explanation for why firms will be unwilling to fully fund their own demonstration projects (Teece 1986, Cohen and Noll 2002, Hall, Mairesse et al. 2009). Appropriability is low when knowledge created as a result of a firm's investment can easily be imitated or adopted by other firms.

[4] BERD refers to R&D performed by business, but funded from any source. Business is the largest funder, but government funds a non-trivial part (at least in the UK, other countries may differ).
[5] Data extracted from stats.oecd.org on 27/06/2023. To clarify, the UK data is consistent with the UK's Office for National Statistics revisions published in November 2022.

Scale: The challenge of proving reliability at scale, particularly for radical innovations can be daunting for businesses who may need to invest in large demonstration projects to commercialize their R&D (Wilson 2012, Funk 2013).

Radicalness: Incremental improvements to existing technologies are more likely to attract financial investment than radical innovations.

Payoffs are uncertain: Incentives to invest in demonstrations may also be weak because expectations about the payoffs are uncertain. This issue is especially problematic for innovations that depend highly on government actions for their payoffs, for example environmental technologies.

(Nemet, Zipperer et al. 2018)

These barriers are even more significant given the recent economic uncertainty relating to the COVID-19 pandemic and the Russian war against Ukraine (Annunziata and Bourgeois 2018, Barbier 2020). Therefore, a policy toolkit is needed to help businesses overcome these barriers and improve overall investment in R&D by the private and public sector (OECD 2021). These policies help channel resources to firms in order to incentivise or reward innovation efforts (Bruce and de Figueiredo 2020). They include:

- **Direct R&D support:** subsidies on R&D projects (i.e., sharing the cost of R&D); provide finance in the form of grants or providing guarantees to others; public procurement (buying or promising to buy goods or services that result from business innovations); and tax credits (Guellec and van Pottelsberghe de la Potterie 2003). These are otherwise referred to as **'downstream market incentives' or 'demand pull'** and aim to increase the size of markets (Nemet, Zipperer et al. 2018)
- **Indirect R&D support:** the funding of the operation of public colleges and universities; paying third parties to provide services that firms require to innovate (such as government labs); transfer of technology sponsored or held by governments, or preferential access to data such as health or mobility records; supporting knowledge networks. These **'technology push'** policies increase the availability of new knowledge.

A 2022 report published by the Centre for Economic Performance (CEP) suggests that a mix of research and development subsidies (including tax credits, grants and incentives), reinvigorated competition and improvements in the quantity and quality of education and training is needed to increase research and innovation in the EU (Teichgraeber and Van Reenen 2022). Technology push and demand-pull policies are both necessary, given the substantial variation among technologies and between industries (Barbier 2020). For instance, technology push is important in early stages and demand pull in later stages of the R&D process; meanwhile incremental innovations depend on demand pull while radical innovations require technology push. In addition to a mix of policy instruments, there is also a need for R&D policies to be integrated not just with closely connected areas such as HE policy and innovation policy but also with policies for other sectors, including industrial and economic policy, health policy, environment policy, and defence or security policy (Martin 2016).

2.3 Understanding the Impact of Public Policies on Private Sector R&D Investment

As aforementioned, there is relatively little literature focussing directly on R&D policy (Martin 2016). Therefore, knowledge of ”what works” in boosting private sector investment is somewhat limited by a lack of critical data and evidence of valid counterfactuals. As a result, our understanding of the impact of public policies on private sector R&D investment is largely based on broader and less specific areas of the literature (Bruce and de Figueiredo 2020). For example, the role of government funds targeted to the private and non-profit sectors in enhancing the direction, productivity, and efficiency of R&D (Azoulay et al, 2019). Similarly, the role of government policy, such as intellectual property rules, tax credits, and infrastructure investments, in supporting private-sector innovation (Bloom, Van Reenen et al. 2019). These studies focus on different proxy measures of innovation, including the net growth of high-tech jobs (Leicht and Jenkins 2017). For example, a 2018 report from Eurofound highlights the employment-related effects of innovation support measures, such as the German initiative ‘Enterprise value: People’[6]. Other proxy measures of private-sector innovation include: Gross foreign direct investment (value and percentage of gross domestic product); Private-sector spending on R&D (value and percentage of GDP); Patent applications made and granted (total and as a population ratio) and Royalty and license fees payments (value and as a population ratio).

Empirical studies that do focus directly on R&D policy report both positive and negative links between public and private R&D. First, there exists a complementary relationship (positive) between public R&D (government funded) and private R&D (Rehman, Hysa et al. 2020). Second, the public R&D may crowd out (negative) private R&D, which is called substitution effect (Kim and Nguyen 2020). There are also different levels of benefits felt across different sectors and firm sizes.

Meanwhile, there are two main measures of ‘additionality’ of public policies on private sector R&D in the grey literature (Economic-Insight 2015):

[6] This is part of a wider ‘New Quality in Work Initiative’, which aims to promote a new work culture and personnel policy across the German economy, placing an emphasis on work quality as the basis for innovation and competitiveness.

- The £ increase in private investment arising from a £1 increase in public investment.
- The coefficient of additionality which measures the percentage increase in private investment arising from a 1% increase in public investment.

A study commissioned by BEIS found that each £1 of public R&D stimulates between £0.41 and £0.74 of private R&D within the same year. Furthermore, public R&D continues to influence levels of private spending in subsequent years. The Oxford Economic (2020) analysis suggests that the long-run impact of public R&D on private R&D is more than three times the short-run impact. The long-run leverage rate is estimated to be between 1.01 and 1.32, suggesting that each £1 of public R&D eventually stimulates between £1.96 and £2.34 of private R&D (Oxford-Economics 2020).

2.4 Factors that Affect the Increase in Private Sector Investment in R&D

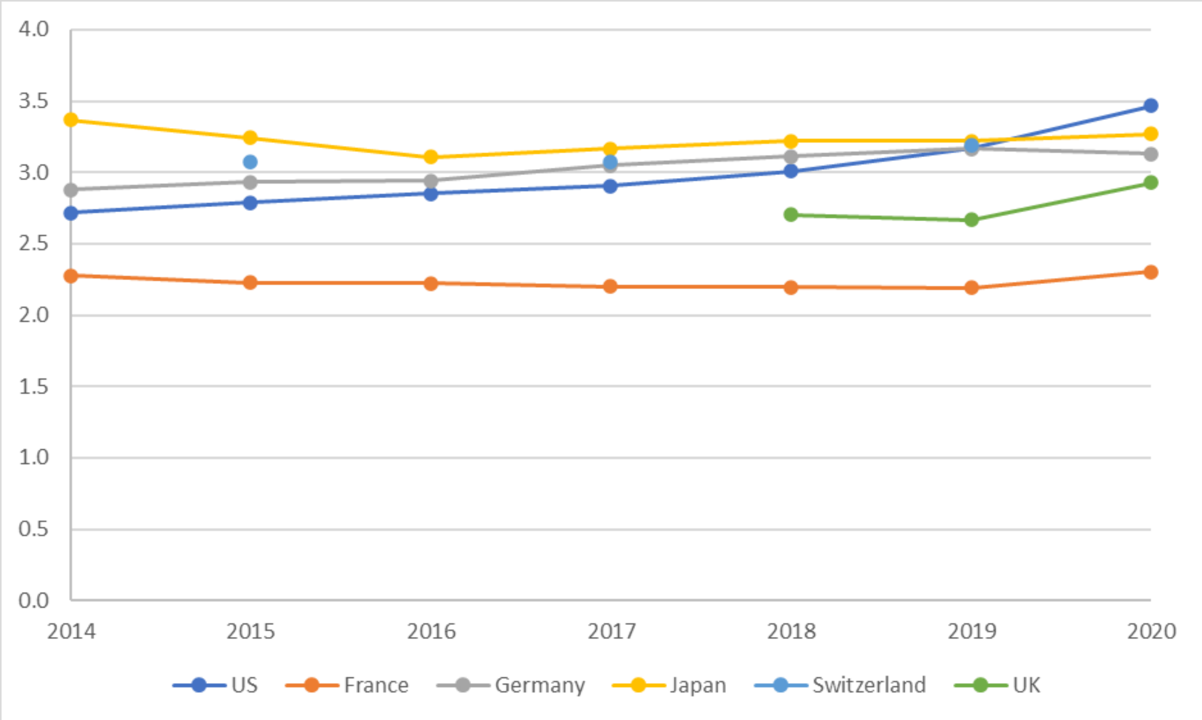
Governments can learn from each other to improve the design and administration of innovation support (OECD, 2021). However, facilitating mutual learning between governments is challenged by the multiplicity of policy objectives, and the contextual factors that determine the overall effectiveness of support policies in specific settings (Aujirapongpan, Songkajorn et al. 2020). The multiplicity of policy objectives can determine varying gross domestic spending on R&D. This variation is evident in Figure 2, which compares the Gross domestic spend[7] on R&D of our five case study countries.

The overall effectiveness of support policies, specifically R&D incentives to increase private R&D investment, varies by place and is influenced by a wide range of factors captured in the ’national systems of innovation’ and ‘varieties of capitalism’ literatures (Hall and Soskice 2001). For instance, (Danzman and Slaski 2022) reveal that R&D incentives generally increase private R&D, but to a varying extent depending on incentive types, countries' income levels, industry and firm characteristics, and the design and implementation of the incentives. Similarly, innovation in the Japanese pharmaceutical sector is “completely different from that of American and European ones” (Aldieri, Bruno et al. 2020, Danzman and Slaski 2022), due to the differing effect of socio-economic drivers or its ‘system of innovation’[8] as these are referred to in the literature (Roberts and Schmid 2022) (Kokko, Tingvall et al. 2015).

[7] This is the gross domestic spend on R&D as a percentage of GDP.

[8] The character of the national innovation system determines factors such as, “the quality of higher education, the efficiency of the labor market, incentives and attitudes toward entrepreneurship,

Figure 2: Gross domestic spending on public and private R&D



Source: OECD.[9] Unit: Total as a percentage of GDP.

Consequently, there is a wide variation in the impacts of public R&D on private R&D across countries. For example, in the Oxford Economics (2020) study of the UK and nine other OECD countries the greatest impact was found for Japan, where £1 of public support is estimated to stimulate £3.16 of private investment in the long term. In contrast, the same £1 of public support in Spain would encourage just £1.21 of private investment. Similarly, the Oxford Economics (2020) study observed that countries with strong protection for intellectual property and property rights, access to the latest technologies, and ready access to finance tend to have higher leverage rates. The variation in the impacts of public R&D on private R&D across countries has important implications for (1) data and metrics of relative performance, including additionality created by public sector R&D investments, and (2) the transferability of better practices (or 'good practice') and lessons between country contexts. (Oxford-Economics 2020).

The funding, organisation and implementation of R&D policy is not always at the national level, but can be 'sub-national' (at the state or regional level) or 'supra-national' (e.g. EU). This again varies depending on the national context and has baring on the transferability of better practices (or 'good practice') and lessons

openness to trade and foreign direct investment, the availability of venture capital, the quality of market institutions, and the availability of infrastructure" (Kokko, Tingvall et al. 2015)

[9] Data extracted from stats.oecd.org on 27/06/2023. Switzerland only has available data for 2015, 2017 and 2019. The average gross domestic spending across these years for Switzerland is 3.12. The UK data is only plotted from 2018-2020 to be consistent with the UK's Office for National Statistics revisions published in November 2022, which reported national statistics for this period only.

between countries. For example, in the UK, France and Japan policy structures are centralised at a national level. In contrast, in the United States and Germany, subnational governments have greater autonomy to develop and control their own policy areas with varied interactions between federal and regional actors (Okamuro, Nishimura et al. 2018). Furthermore, the character of the innovation system and specifically the effectiveness and approach of implementers can vary between regions. For example, a comparison the industrial policies in Pittsburgh and Cleveland and found a primary difference to be who led the implementation: universities in Pittsburgh, the business community in Cleveland (Armstrong, Shieh et al. 2019). Furthermore, different factors influence the innovation activities of different industries (Prokop and Stejskal 2016) for example different sector-specific challenges in the machinery and equipment, chemical, pharmaceutical and metal industry in Germany (Barbier 2020). Consequently, the easiest types of policies to justify are those that increase the amount of innovative activity in a way that is as sector neutral as possible (Weyant 2011).

Appendix A: R&D policy overviews for selected countries

Table below and tables A1-A5 (Appendix A) provide a summary of the approach to R&D policies for each country considered in this investigation, highlighting their contextual differences. In response to impact of these contextual factors (industry, region and national context), R&D support policies are increasingly "shifting away from top-down and centralised approaches towards policies that favour cooperative, multi-actor and often more 'place-based' approaches" (Okamuro, Nishimura et al. 2018).

Table 1: Overview of countries investigated

Country	Overview
France	According to OECD data, the ratio of total R&D spending to GDP is 2.19% in 2019 and 2.30% in 2020. This is below the OECD average of 2.74% (2020). The French government centrally funds R&D in form of R&D contracts signed with dedicated state research institutions, as well as support measures provided by the state, whether direct via the French National Research Agency (ANR) (subsidies, calls for proposals and contracts supporting programmes) or indirect (different tax incentives).
Germany	According to OECD data, the ratio of total R&D spending to gross domestic product (GDP) is 3.17% in 2019 and 3.13 in 2020. This is only superseded by Sweden in the EU with a R&D spending ratio of 3.39% in 2019 and 3.49% in 2020. Germany's government aims to achieve 3.5% by 2025.
Japan	Japan is amongst the world's largest investors in R&D. In the OECD area, it is the sixth highest spender in 2020. Japan's total expenditure on R&D during 2020 was ¥19.24 trillion (£128bn) with an increase in 2021 to ¥19.74 trillion nearly

Country	Overview
	3.6% of GDP. Innovation in Japan is an interaction between private companies (who are the central actors in the process), the government, universities, and public research institutions in Japan. The Japanese government identifies three strategic areas for R&D: • Artificial Intelligence (¥174.4 billion); • Biotechnology (¥248.2 billion); • Quantum technology (¥116.8 billion). Artificial Intelligence and Biotechnology R&D is mostly funded by businesses, whereas Quantum Technology by non-profit institutions and public organisations.
United States	The United States of America spend the most amount of funding on R&D globally. Together with China, they account for half of global R&D spending. In 2019, USA covers 27% ($656 billion) of global R&D and China 22% ($526 billion). For 2020, it is estimated that the USA spends approximately $708 billion in total. R&D spending is 3.17% of GDP in 2019 and 3.47% in 2020 which makes it the 6th and 4th top as a share of GDP in those years in the OECD area. As with most top R&D-performing countries, funding for R&D is mainly done by the business sector. Federal, state, and local governments, higher education institutions, and non-academic non-profit organizations also perform and fund domestic R&D.
Switzerland	In the OECD area, Switzerland is the 5th top spender on research and development in 2019 with 3.19% R&D expenditure of GDP. Switzerland invests over CHF 23 billion in research and development (R&D) annually. Basic research is conducted mainly at federal institutes of technology and universities. Applied research and development and the transfer of knowledge into marketable innovations, however, is primarily performed by the private sector and universities of applied sciences. Innovation focuses on five areas: • health and life sciences; • mobility and transportation; • energy, the environment and natural resources; • manufacturing and production; and • computer and computational science.

3. Examples of Good Practice

3.1 Overview

Despite there being comparatively less literature focussing directly on R&D policy instruments, we identified a potential 15 exemplars of good practice (4 from Germany, 2 from Switzerland, 3 from the United States, 3 from France, 3 from Japan) that the United Kingdom might learn from and adapt to support improved private sector investment in R&D.

We have chosen the term good practice[10] over best practice as we are interested in practices that might be transferred and adapted to new contexts. Examples of good practice are ideally based on evaluation evidence and identified as a good practice by experts, the OECD, or the European Commission. However, we found few evaluation reports and where we found papers that had reviewed R&D policies, it often lacked precise evidence on whether the policies had boosted private sector R&D. The exemplars of good practice identified are the exceptions, where precise evidence could be found, although this was still somewhat limited.

Each policy was plotted according to its sectoral coverage. Most policies identified can be described as 'sectorally blind' in that they are sector non-specific and provide knowledge mobilisation support across several sectors. Most studies focus on a specific country or region, with Germany and the United States being most represented out of our five selected countries. Despite the importance of using a mix of policy instruments, the review found that the R&D policies evaluated have mostly tended to be developed and implemented on an individual basis. Therefore, there remains a gap in our understanding of how different R&D policy instruments interact when combined (Martin 2016). One exception is analyse the R&D policy mix in France and identify duplication and even negative spillovers of different policies when the regional context is taken into account (Montmartin, Herrera et al. 2018).

The type of policies chosen as exemplars are listed in Table 2 and their frequency reflects the literature findings, whereby some policy instruments have been extensively studied (e.g. clusters and fiscal incentives for R&D), whilst other policies have not been subject to rigorous study (e.g. innovation procurement). An

[10] The United Nations definition of good practice is: "a good practice is not only a practice that is good, but a practice that has been proven to work well and produce good results, and is therefore recommended as a model. It is a successful experience, which has been tested and validated, in the broad sense, which has been repeated and deserves to be shared so that a greater number of people can adopt it".

introduction to the key policy types identified in the literature review are provided in the next section.

Table 1 : Policy Type

Policy Type	Frequency (Country)
Fiscal incentives for R&D	1 (France), 1 (Japan)
Direct support to firm R&D and innovation	2 (Germany), 2 (United States), 1 (France)
Policies for training and skills	2 (Switzerland),
Entrepreneurship policy	1 (Switzerland), 1 (Japan)
Technical services and advice	1 (Germany), (1) Japan
Cluster policy	2 (Germany), 1 (France), 1 (Japan)
Policies to support collaboration	1 (Germany), 1 (United States), 1 (France), 1 (Japan)
Innovation network policies	1 (United States)
Procurement	0
Regulation	0

3.2 Policies Chosen as Exemplars and their Impact

Cluster policy

There is no shortage of evidence on the benefits of clusters[11] and tech clusters[12] (DLUHC 2023). Studies show that the co-location of businesses and institutions generates 'knowledge spillovers' and other positive agglomeration effects. These benefits are generated by the shared pool of expertise, finance, skilled workers, access to component suppliers and channels for spreading information and innovation. The benefits are not just confined to people and firms within the immediate geography of the cluster, as the impacts often spills over into the wider region. However, this can also spread knowledge to market rivals throughout the economy, so needs to be carefully managed to ensure private firms don't respond to 'market rivalry spillovers' by underinvesting. The importance of clusters reflects the shift from linear to systemic thinking about R&D and innovation and moving away

[11] Clusters are defined as: "…geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g., universities, standards agencies, trade associations)" (Porter 2000:15),
[12] Kerr, W. R. and F. Robert-Nicoud (2020). "Tech Clusters." Journal of Economic Perspectives **34**(3): 50-76. define "tech" clusters to be locations where new products and production processes are created that affect multiple parts of the economy.

from policy instruments that focus on individual R&D actors to those attempting to develop new or stronger links between actors (Martin 2016).

The barriers to the growth of emerging clusters of activity look different between sectors and across different national and regional contexts. This means there is no one size fits all model, as each area will require different interventions depending on what is already in place and the drivers of growth for specific clusters (DLUHC 2023). This is reflected by the different approaches to cluster policies, across the five countries investigated, as shown in Table 4 below.

Public funded research and Science and technology institutes.

Public-funded research can boost private investment in R&D in numerous ways, such as increasing the stock of knowledge (which may drive product or process innovation), training graduates, creating new technologies, creating networks, and creating new firms (Azoulay, Graff Zivin et al. 2019). The importance of public-funded research varies between industries and even within sub-sectors: for example, differences in the importance of university research to biofuel and wind technologies, with wind technologies to be more applied and reliant on knowledge from downstream businesses, whereas biofuels are newer, patentable technologies and more reliant on university research (Popp 2017). Academic patenting and licensing have become increasingly common in recent decades, encouraged by the 1980 Bayh-Dole Act and other policies. This has led to an extensive set of studies focusing on the positive impacts of IP and academic entrepreneurship on R&D (Henderson, Jaffe et al. 1998, Mowery, Nelson et al. 2004, Azoulay, Ding et al. 2009, Okamuro and Nishimura 2012, Hausman 2022). Similarly, many national governments have implemented policies to promote the formation of university spin-off companies in response to their contribution to economic growth (Mustar, Wright et al. 2008, Hayter 2013, Iacobucci and Micozzi 2015). A study found a cohort of university spin-off to have a ‘performance premium’ of 3.4 % points higher employment growth than a comparative group of industry start-ups (Czarnitzki, Rammer et al. 2014). Another policy instrument aimed to encourage and facilitate university–industry R&D collaboration is the establishment of science parks. A comparison of Finnish firms located within science parks and those outside, showed that the former exhibit relatively better performance in terms of innovative output, at least as reflected in patenting (Squicciarini 2008).

Infrastructure Investment and Public-Private Partnerships

The estimated effect of infrastructure investment and public-private partnerships boosting private investment in R&D varies depending on the type of infrastructure. Investing in infrastructure is often seen as an important part of economic policy, at the regional, national as well as international level (Holmgren and Merkel 2017). For example, road investments have the highest impact on production in the construction and manufacturing industries. Accelerating infrastructure investment is often achieved by Public private partnerships (PPPs), since it helps to increase the potential sources of funding. PPPs help address societal problems, overcome market failures, and generate value through co-production (Button 2016). Public private partnerships enable private firms to participate in the financing of an infrastructure project, without taking on either part or all of the business risks. Projects in which the public sector takes more of the business risk incentivises private investment (Resor and Tuszynski 2012).

Fiscal Incentives and Direct support to firm R&D and innovation

Fiscal incentives and direct grants support firm R&D and innovation in different ways (OECD 2021). These impacts have been studied in the OECD microBeRD project, which "investigates the structure, distribution and concentration of business R&D and R&D funding and models the incidence and impact of public support for business R&D" (Appelt, Bajgar et al. 2016). The key findings from the microBeRD analysis show that R&D tax incentives not only increase expenditures but also the level of human resources that firms report to dedicate to R&D. Furthermore, "R&D tax incentives encourage additional business R&D both because existing R&D performers increase their R&D expenditure (intensive margin) and because additional firms start performing R&D (extensive margin)". Consequently, expenditure-based R&D tax incentives are a primary business innovation support policy tool across most OECD countries and partner economies (Appelt, Bajgar et al. 2016). In 2017, R&D tax incentives accounted for around 50% of total government support for business R&D in the OECD area, up from 30% in 2000 (Appelt, Bajgar et al. 2016). A study by Centre for Business Research (2021, Cambridge Judge Business School) calculated that the R&D tax credit and Patent Box schemes together now cost the Treasury around £8.4 billion a year. As Table 3 (below) shows, this is an order of magnitude more than the combined total of all other government programmes to fund innovation in UK companies (Connell 2021).

Table 2: Government Policies that help fund Business R&D

Policy	Key Features	Estimated Annual Cost to Treasury	Source
R&D Tax Credits	Subsidy of 13% to 33%	£7.3 billion	HMRC
Patent Box	Subsidy	£1.1 billion	HMRC
Innovate UK Grants to Businesses	Subsidy of 25% to 70% of project costs. Most grants involve collaboration between organisations including universities	£530 million	ONS GERD data and discussions with Innovate UK

Policy	Key Features	Estimated Annual Cost to Treasury	Source
SBRI Contracts	100% funded public sector innovation contracts promoted by Innovate UK	£100 million est.	Discussions with Innovate UK
EIS and SEIS	Subsidy on private investment	£540 million	H.M. Treasury
VCTs	Subsidy on private investment in funds	£70 million	H.M. Treasury
British Business Bank	Equity and loans, directly and through partners	Designed to be profitable overall. It provided £1.1 billion of commitments in 2019.	British Business Bank Annual Accounts 2019
Advanced Research and Innovation Agency	DARPA/ARPA based agency to fund theme programme manager-initiated projects. Not yet established.	£200 million per annum (£800 million over 4 years)	UK Government announcement

Source: Connell 2021

The microBeRD analysis also found that “input additionality of R&D tax incentives” is larger for small and medium-sized firms vis-à-vis large companies. This reflects the fact that smaller firms perform, on average, less R&D than larger firms. Similarly, little input additionality is found for firms in highly R&D intensive industries (Pharmaceuticals, Computer manufacturing, Scientific R&D) (Appelt, Bajgar et al. 2016).

Meanwhile, direct grants support longer-term, high-risk research and often target specific areas that either generate public goods (e.g. health and defence) or have particularly high potential for spillovers. (Howell 2017) argues that the ‘Small Business Innovation Research (SBIR) programme’ in the US supports firms by facilitating technology prototyping and demonstration of a technology, which helps to attract additional private VC funding. The microBeRD analysis highlighted that direct grant support measures are more conducive towards promoting research whereas tax support is principally associated with heightened levels of experimental development (Appelt, Bajgar et al. 2016). Therefore, a mix of R&D tax incentives and direct grants are optimal. However, the average effects found in the microBeRD analysis vary across countries. This is in part related to differences in the uptake and distribution of indirect and direct support measures across different types of firms, as well as differences in the national systems of innovation.

Innovation-framing regulation and Innovation Procurement

To support R&D activities “policy design should simplify the business support landscape and reduce uncertainty” (OECD 2021). This relates to the regulatory and budgetary burden imposed by the regulatory system and the need for ‘innovation-framing regulation’ (Straughter and Carley 2021). The literature on innovation-framing regulation argues that public regulators should work “hard to avoid stifling innovation, particularly in a competitive international environment” and “generate ‘simply better’ regulation that imposes no real costs on anyone and requires no difficult trade-offs” (Ford 2013). Similarly, regulation should be “outcome-oriented, pragmatic, and data-driven”. Ford (2013) argues that there is no such thing as value-neutral, objective, purely technocratic regulation. These institutional barriers apply to public procurement. Therefore, procurement innovation is needed in order to successfully leverage procurement as a tool for increasing the uptake of private R&D investment (Wang, Morabito et al. 2020). Recent research focuses renewed attention on the importance of government procurement, in particular with regards to ground-breaking innovations that require large markets to be viable and patient capital to take off the ground (Mazzucato 2011, Mazzucato 2018).

Examples of Good Practice by Case Study Country

Table 3: Overview of good practice polices

Country	Policy Name and description	Contextual factors	Policy Type	Innovation Orientation	Evidence to support identification of best practice
Germany	**Spitzencluster-Wettbewerb (Leading-edge Cluster Competition)** Leverage existing clusters by formalising cluster management, strengthening networks, including between SMEs, large businesses and research organisations. Funded organisations are either purposely created vehicles or existing local business organisations. Total funding of EUR 600 million over 3 rounds, 100% match-funded by industry.	Academic literature showing the positive impact of clustering on knowledge spillovers, innovation and growth. Programme is funded by the federal ministry for economy and climate. Funding period 2007-2017.	**(F)** Cluster Policy	● Supply side ● Open to all sectors	Evaluation finds significant leverage effect of funding, especially on SMEs: For each euro in funding received, SMEs increased their own innovation expenditure by an additional EUR 0.36. Peer groups didn't increase investment in innovation in the same magnitude, therefore it is unlikely that public funding is displacing private investment. However, there are some negative spillovers in terms of operating income on unsupported industries in supported regions. (Audretsch, Lehmann et al. 2019, Engel, Eckl et al. 2019, Töpfer, Cantner et al. 2019, Wolf, Cantner et al. 2019)
Germany	**Bavaria High-Tech Offensive** Funding for innovation infrastructure such as research facilities and science parks (incl. free office space), and cluster management, but no direct funding to businesses.	Bavaria is one of the most innovative states in Germany hosting many innovative MNEs as well as SMEs, so innovation policy focuses on consolidating this position as well as supporting emerging technologies. The programme is funded by the state government. Funding period 1999-2001.	**(G)** Policies to support collaboration, **(E)** Technical services and advice	● Supply side ● Open to all sectors	Evaluation finds an increase in innovativeness (likelihood of making an innovation in a given year) of around 5% by firms in the targeted sector, increase in collaboration with public research institutes, and improved access to suitable R&D personnel, but decrease in R&D expenditure. However, R&D expenditure decreased by 19.4%, likely due to the provision of free resources.(Falck, Heblich et al. 2010)
Germany	**Zentrales Innovationsprogramm Mittelstand (Central Innovation Programme for SMEs)** The programme combines three strands: individual projects, cooperative projects and networks. These complement each other in that funding for specific R&D projects is combined with structural measures that improves the innovation environment. Application processes are streamlined and funded projects are smaller than in other programmes to be more attractive to SMEs. The programme is open to any technology and industry to identify emerging trends.	Created by consolidation of several smaller support measures for SMEs. The programme is funded by the federal ministry for economy and climate and has been running since 2008.	**(B)** Direct support to firm R&D and innovation, **(G)** Policies to support collaboration	● Supply side ● Promote cross-sector innovation ● Open to all sectors	The preliminary evaluation reports finds supported businesses doubling their R&D intensity (R&D expenditure/ turnover), increase in collaborations and improved networks. Most funded businesses increase R&D activity, 3% of funded businesses innovate for the first time. 15% of rejected funding proposals are still completed using private funds, indicating some crowding out.(Kaufmann, Bittschi et al. 2019, Berger, Biela et al. 2020, Bocek and Vollborth 2022)
Germany	**KMU Innovativ (Innovative SME)** The targeted technologies are ICT, biotech, production technology, energy efficiency (since inception), optical technologies, nanotech, civil	The programme was started in 2007 as part of the federal government's High-Tech Strategy. It is run by the federal ministry for education and research. The ministry runs research support programmes for different technology fields. This	**(B)** Direct support to firm R&D and innovation	● Supply side ● Sector specific	50% of projects resulted in a new products brought to market, contributing 12% of turnover in the year of market introduction. Early outcomes also show 500 additional R&D jobs created, with more being safe guarded.(Crass, Rammer et al. 2019)

Country	Policy Name and description	Contextual factors	Policy Type	Innovation Orientation	Evidence to support identification of best practice
	security, medical technology (since 2011). To target SMEs, the application process is structured in two stages, with the total process aimed to take around 7 months. Application support and a signposting service are also available as part of the programme. In contrast to the Zentrales Innovationsprogramm Mittelstand, the target is more research-intensive, early-stage rather than applied innovation.	programme pulls several of them together and tweaks the normal funding mechanisms to make it more attractive for SMEs.		● Promote cross-sector innovation	
Switzerland	**Universities of Applied Sciences** UASs have 3-fold mandate: research and teaching focused on applied research, methods and knowledge, research in collaboration with firms, collaborate with other research institutions. Most students have completed an apprenticeship before enrolling at UAS.	Universities of Applied Sciences (UAS) were established in Switzerland during 1990s. In contrast to traditional universities, their focus is on applied rather than basic research.	**(C)** Policies for training and skills	● Supply side ● Demand led ● Open to all sectors	6.8% increase in number of regional patent filings, and 9.7% increase in patent quality measured by patent family size, number of claims and citations per patent compared to regions without UAS. These impacts can be causally attributed to the policy based on differences-in-differences estimation.(Pfister, Koomen et al. 2021)
Switzerland	**Commission for Technology and Innovation (CTI) Start-Up Coaching** The coaching journey contains several support measures, including individual coaching to develop a business plan and strategy, IP, finance and team development; workshops e.g. on IP, finance, legal issues, regulation, marketing. Finally there's an opportunity to present to the "CTI Start-up Label Certification Board" and receive the start-up label if successful. Further support after gaining the label, e.g. market entry camp, further coaching	The policy supports science-based star-ups through coaching by industry experts. This is in conjunction with entrepreneurship education at universities as well as a label for "high-potential" start-ups that graduated from the programme.	**(D)** Entrepreneur ship policy, **(C)** Policies for training and skills	● Supply side ● Open to all sectors	Of start-ups coached between 2005 and 2017, around 80% were still in operation at the end of 2017, this increased to 85% those that received the "high-potential" label. 91% of supported start-ups have an active R&D collaboration with either a university or another business. Majority of businesses invested in R&D in the last financial year. (Kaiser, Odermatt et al. 2019)
United States	**R&D loan program in the state of Michigan** Through a series of competitions administered during the decade of the 2000s, the state provided credit access and support services to entrepreneurial firms with advanced research and technology commercialization projects. As reported below, the program was competitive, with only 21% of applicant-startups winning funding. The average loan size was quite large, at $1.2 million, and the typical awardee was a four-year-old life science.	Firms derive added benefits from "certification" effects long-studied in the program evaluation literature or from the bundle of support services and training provided through the program. Findings add credence to the view that public R&D programs are particularly beneficial for smaller and younger firms.	**(B)** Direct support to firm R&D and innovation	● Supply side ● Open to all sectors	Evaluation provides evidence based on 241 startups that compete for advanced research and technology commercialization loans between 2002 and 2008 through a Michigan-based program. Among applicants with project scores near the threshold required for funding, found that award recipients are 20%–30% more likely to remain in business four years after the competition relative to similar companies that seek but fail to receive funding. The evaluation found that award receipt stimulates follow-on venture capital (VC) investments in surviving companies. (Zhao and Ziedonis 2020)

Country	Policy Name and description	Contextual factors	Policy Type	Innovation Orientation	Evidence to support identification of best practice
United States	**Early Detection Research Network (EDRN)** Aims to identify, develop, and validate biomarkers to improve the detection of early-stage cancers and risk assessment. This consortium of more than 300 investigators at academic institutions and in the private sector is working collaboratively to bring biomarkers and imaging methods to clinical fruition.	The EDRN (established in 2000 in Rockville, MD) has implemented measures to improve biomarker discovery and validation, such as data sharing, use of common data elements, generating multidisciplinary and multi-institutional collaborations within a cohesive and productive team environment, and putting emphasis on quality control and data replication for all candidate biomarkers for reaching a “go” or “no go” decision.	**(G)** Policies to support collaboration, **(H)** Innovation network policies	● Demand led ● Sector specific	A measure of the success of the EDRN is the number of biomarkers tests or devices approved by the FDA to which EDRN investigators have made significant contributions and the number of biomarkers tests developed by EDRN investigators that are available in Clinical Laboratory Improvement Amendments laboratories. EDRN investigators have published more than 2,500 peer-reviewed articles; more than 20% are in high-impact journals (IF > 10). EDRN investigators currently have more than 64 patents and more than 12 licenses, which is indicative of the practical applications sought within the Network. The EDRN initiated over 60 network collaborative projects, and over 30 collaborations have been formed between EDRN laboratories and biotechnology or diagnostic companies. More than 1,000 biomarkers have been discovered, developed, or evaluated by EDRN investigators and approximately 300 of these were found to have sufficient accuracy to be moved forward for consideration in prevalidation studies. Equally important is that hundreds of these biomarkers have been discarded using the biomarker triage system developed by the EDRN. (Srivastava and Wagner 2020)
United States	**Small Business Innovation Research (SBIR)** Program funds small businesses that are developing and commercializing innovative new technology.	It is commonly regarded as a “government venture fund.” As a matter of public policy, it needs to be clearly understood that the SBIR program is not a government venture fund, does not compete with VCs, and has objectives of national economic and societal importance that do not conflict with those of private-sector investors.	**(B)** Direct support to firm R&D and innovation	● Demand led ● Promote cross-sector innovation ● Open to all sectors	The evaluation begins by comparing the number and size of SBIR and VC seed-stage investments in the U.S. Then it contrasts their very different objectives, company selection criteria, staging of investments, obligations imposed on recipient companies, and metrics used to measure success. The findings show that most of the new technology ideas funded by the SBIR are either too high-risk or too limited in commercial potential to be attractive to VCs. However, some of the most successful SBIRfunded companies later become backed by venture funds. Far more often, they remain small but consistent generators of innovation and are an essential part of the national R&D industrial base. In short, the SBIR program and VC industry are highly complementary components of the nation’s innovation ecosystem. (Swearingen, Gaster et al. 2021)
France	**R&D Defence Subsidies** This includes not only defense related R&D subsidies spent by businesses, but also spend by sectors including e.g., universities (called “government budget appropriations or outlays on R&D” or GBAORD by the OECD).	Defence R&D is the single most important component of government-funded R&D in the UK and France as well, and a major component of government-sponsored R&D in many other developed economies. Defense R&D is usually motivated by geopolitical, not economic, considerations (Mowery, 2010), raising the possibility of using actual R&D defense subsidies as the instrument for government funded R&D.	**(B)** Direct support to firm R&D and innovation	● Demand led ● Sector specific	The evaluation is interested in whether government-funded R&D in a given country and industry (or to a given firm) displaces or fosters private R&D in the same country and industry (or firm). On average, a 10% increase in government-financed R&D generates a 5% to 6% additional increase in privately funded R&D. Additionally, governments may allocate R&D defence subsidies not based on purely military considerations but also as a way to foster employment and investment in specific sectors or firms (Moretti, Steinwender et al. 2019)

Country	Policy Name and description	Contextual factors	Policy Type	Innovation Orientation	Evidence to support identification of best practice
France	**Pôles de Compétitivité** Cluster policy – Clusters apply to receive an official "cluster" label. There are around 70 clusters, although only 17 are considered "world-class" and received the majority of funding. Consortia within the clusters then apply for collaborative R&D funding. Total funding available was EUR 3 billion over two phases (2005-2008 and 2009-2012), with bi-annual selection rounds of projects.	French clusters are often organised around associations, which have professional management and represent their members interests, which include businesses, research laboratories and universities. The cluster policy aimed to support the most successful clusters through an official designation and dedicated funding for collaborative R&D projects.	**(F)** Cluster policy, **(G)** Policies to support collaboration	● Supply side ● Promote cross-sector innovation ● Open to all sectors	Increase in business R&D spend by EUR 1.875 for every euro received in public R&D subsidies. Effect is largest for SMEs and takes about 4 years to materialise after the start of the policy.
France	**R&D tax credit** Until 2004, the French tax credit was an incremental tax credit scheme set at the 50% rate and defined as follows: [0.5 * (R&Dt − R&Dt−1)]. In 2004 this policy tool has been re-defined as a combination of level and incremental tax credit: [0.65 * (R&Dt) + 0.45*(R&Dt-1-R&Dt-2), with a ceiling on overall expenditure. In 2008, the ceiling was dropped, and the benefit was defined only in terms of total R&D volume.	France has one of the most generous R&D tax credit regimes in the OECD, in particular after a reform in 2014.	**(A)** Fiscal incentives for R&D	● Demand led	Impact assessments are mixed. Some find additionality for the tax credit before the reform, with R&D expenditure increasing by slightly more than the tax credit expenditure (Duguet 2012). Whereas others find no positive effects, and some crowding out of private by public investment, which became more sever after the reform (Marino, Lhuillery et al. 2016) or a small positive impact after the 2008 reform on both the extensive (number of firms conducting R&D) and intensive margin (overall R&D expenditure above and beyond what would have been expected in the absence of the tax credit). (Bozio, Irac et al. 2014).
Japan	**Kosetsushi – local technology centres** "Tiered" services starting from services with a low information gap that are more accessible to non-innovating SMEs and solve immediate needs, progressing to more cutting edge R&D. Such services help build innovation capacity and unlock future R&D investment. Centres operate "library of equipment" model, which lowers the high up-front costs to conduct R&D for SMEs, by allowing them to e.g. use testing facilities.	SMEs are often far behind the technological frontier – innovation policy needs to help them to catch up and invest in technologies new to the firm, but uptake of such programmes tends to be weak.	**(E)** Technical services and advice	● Supply side	Majority of users in two case study centres had no employees with science or engineering degree, never contacted a consulting firm, never collaborated with other businesses other than suppliers or customers, never collaborated with universities or national research institutes. Successful in attracting non-innovative SMEs to invest in innovation for the first time. Patent data indicate that technologically more advanced SMEs are more likely to collaborate with kosetsushi than with universities.(Izushi 2005, Fukugawa 2016, Fukugawa and Goto 2016).
Japan	**R&D tax credit (2003 reform)** While many innovation policies target non-innovating firms, this policy supports businesses that already conduct R&D, but face financial constraints.	In 2003, Japan switched from a system of incremental R&D tax credit, where tax credits were only applied to R&D expenditure beyond the base level of expenditure from the past 5 years, to a total tax credit system, where tax credit is available on the total amount spent on R&D.	**(A)** Fiscal incentives for R&D	● Demand led	The effect of the change in tax credit system depends on previous R&D expenditure with benefits largest for firms with R&D expenditure that was already high before. An elasticity of 2.3 was found, implying that a 1% increase in effective tax credit leads to 2.3% increase in R&D expenditure. (Kasahara, Shimotsu et al. 2013).

Country	Policy Name and description	Contextual factors	Policy Type	Innovation Orientation	Evidence to support identification of best practice
Japan	**Industrial Cluster Project (METI) and Knowledge Cluster Project (MEXT)** The cluster policy initiatives in Japan under the Ministry of Economy, Trade and Industry (METI) (2001-2010) and the Ministry of Education, Culture, Sport, Science and Technology (MEXT) (2002-2009) both aimed to create R&D consortia by facilitating collaboration between small and medium enterprises (SMEs), large firms, public research institutes, and universities, and by promoting the interactions between university–industry–government at the subnational level.	Network support is more effective than subsidy among the support measures.	**(F)** Cluster policy **(G)** Policies to support collaboration	● Demand led ● Open to all sectors	"Industrial Cluster Project" has no effect on participant firms in terms of the productivity of R&D measured by the number of patent applications; if the participating firms collaborate with the core universities in the cluster area, its productivity of R&D increases. Commitment to the joint R&D project is higher for the participant firms of the METI program than for those of the MEXT programmes(Nishimura and Okamuro 2011, Okamuro and Nishimura 2018).

Conclusion

Compared to the literature on innovation policy (much broader than R&D policy), the review found there to be comparatively less literature focussing directly on R&D policy instruments (Martin, 2016). Similarly, there was found to be little on the economic theory of R&D policy instruments and the economics of specific R&D policies. Nevertheless, we have brought together related streams of literature (on innovation, research, science and technology) to present a summary of key (recent) evidence on 'what works' with policies developed to boost private sector investment in R&D.

There are four key barriers to private sector R&D investment, which policies focus on helping businesses to overcome: (1) Appropriability; (2) Scale; (3) Radicalness; and (4) Uncertainty of payoffs. A policy toolkit is needed to help businesses overcome these barriers and improve overall investment in R&D by the private and public sector (OECD 2021). These policies help channel resources to firms in order to incentivise or reward innovation efforts (Bruce and de Figueiredo 2020). They include direct and indirect R&D support, and both are necessary, given the substantial variation among technologies and between industries.

Prior studies show a marked difference in public policies for stimulating private R&D investments across different countries (Heblich et al., 2010; Koomen et al., 2021; Hassine and Mathieu, 2020; and Shimotsu et al., 2013). Evaluations of additionality (The £ increase in private investment arising from a £1 increase in public investment) and the coefficient of additionality (the percentage increase in private investment arising from a 1% increase in public investment) also vary, but still provide broad averages across very different micro-level contexts.

The overall effectiveness of support policies, specifically R&D incentives to increase private R&D investment, varies by place and is influenced by a wide range of factors captured in the 'national systems of innovation' and 'varieties of capitalism' literatures (Hall and Soskice, 2001). Consequently, there is a wide variation in the impacts of public R&D on private R&D across countries. The variation in the impacts of public R&D on private R&D across countries has important implications for (1) data and metrics of relative performance, including additionality created by public sector R&D investments, and (2) the transferability of better practices (or 'good practice') and lessons between country contexts. (Oxford-Economics 2020).

Overall, the effectiveness of R&D investments depends on the following factors:

- different measures of R&D and innovation – inputs, outputs and outcomes;
- the trade-off between positive and negative (substitution) effects;

- different spatial geographies;
- country contexts vary (varieties of capitalism) – finance and capital markets, regulation, business practices, supply chain relationships etc;
- industry structures and business models vary;
- innovation appropriability varies ('the ability of different stakeholders to retain for themselves the financial benefits that arise through the exploitation of an innovation');
- the importance of public-funded research varies between industries and even within sub-sectors.

The literature review found a limited number of evaluation reports and papers that had reviewed R&D policies often lacked precise evidence on whether the policies had boosted private sector R&D. The exemplars of good practice identified are the exceptions, where precise evidence could be found, although this was still somewhat limited. Despite there being comparatively less literature focussing directly on R&D policy instruments, we identified a potential 15 exemplars of good practice (4 from Germany, 2 from Switzerland, 3 from the United States, 3 from France, 3 from Japan) that the United Kingdom might learn from and adapt to support improved private sector investment in R&D.

The type of policies chosen reflects the literature findings, whereby some policy instruments have been extensively studied (e.g. clusters and fiscal incentives for R&D), whilst other policies have not been subject to rigorous study (e.g. innovation procurement). The evidence across multiple country contexts, suggests that the most reliable, generic policy interventions are ‘policies to support collaboration’, ‘cluster policy’ and ‘direct support to firm R&D and innovation’. The importance of clusters reflects the shift from linear to systemic thinking about R&D and innovation and moving away from policy instruments that focus on individual R&D actors to those attempting to develop new or stronger links between actors (Martin 2016). Similarly, the key findings from the microBeRD analysis show that R&D tax incentives not only increase expenditures but also the level of human resources that firms report to dedicate to R&D (OECD, 2021). Consequently, expenditure-based R&D tax incentives are a primary business innovation support policy tool across most OECD countries and partner economies (Appelt, Bajgar et al. 2016).

Reference List

Aldieri, L., B. Bruno, L. Senatore and C. P. Vinci (2020). "The future of pharmaceuticals industry within the triad: The role of knowledge spillovers in innovation process." Futures 122: 9.

Annunziata, M. and H. Bourgeois (2018). "The future of work: how G20 countries can leverage digital-industrial innovations into stronger high-quality jobs growth." Economics-the Open Access Open-Assessment E-Journal 12: 23.

Appelt, S., M. Bajgar, C. Criscuolo and F. Galindo-Rueda (2016). "R&D Tax Incentives: Evidence on design, incidence and impacts."

Armstrong, C., J. Shieh and P. Zielinski (2019). "Increasing the return on investment from federally-funded research and development." Theoretical Issues in Ergonomics Science 20(1): 4-7.

Audretsch, D. B., E. E. Lehmann, M. Menter and N. Seitz (2019). "Public cluster policy and firm performance: evaluating spillover effects across industries." Entrepreneurship & Regional Development 31(1-2): 150-165.

Aujirapongpan, S., Y. Songkajorn, S. Ritkaew and S. Deelers (2020). "Japan's Digital Advance Policy Towards Performance in Multilateral ASEAN's Innovation Businesss." Entrepreneurship and Sustainability Issues 8(1): 1081-1094.

Azoulay, P., W. Ding and T. Stuart (2009). "The Effect of Academic Patenting on the Rate, Quality, and Direction of (Public) Research Output." Journal of Industrial Economics 57: 637–676.

Azoulay, P., J. S. Graff Zivin, D. Li and B. N. Sampat (2019). "Public R&D Investments and Private-Sector Patenting: Evidence from NIH Funding Rules." Review of Economic Studies 86(1): 117-152.

Barbier, E. B. (2020). "Greening the Post-pandemic Recovery in the G20." Environmental & Resource Economics 76(4): 685-703.

Barbier, E. B. (2020). "Is green rural transformation possible in developing countries?" World Development 131: 12.

Berger, F., J. Biela, F. Merkl, J. Kahl, B. Klement and F. Dornbusch (2020). Begleitende Evaluation des Modellvorhabens “ZIM-Kooperationsnetzwerk International” sowie Untersung der Förderung von internationaler Zusammenarbeit bei Forschung und Entwicklung (FuE) im Zentralen Innovationsprogramm Mittelstand (ZIM). Frankfurt, DE: Technopolis Group.

Bilbao-Osorio, B. and A. Rodríguez-Pose (2004). "From R&D to Innovation and Economic Growth in the EU." Growth and Change 35: 434-455.

Bloom, N., M. Schankerman and J. Van Reenen (2013). "Identifying technology product market rivalry." Econometrica(81): 1347–1393.

Bloom, N., J. Van Reenen and H. Williams (2019). "A Toolkit of Policies to Promote Innovation." Journal of Economic Perspectives 33(3): 163–184.

Bocek, F. and T. Vollborth (2022). Wirksamkeit der geförderten FuE-Projekte und Kooperationsnetzwerke des Zentral Innovationsprogramms Mittelstand (ZIM). Eschborn, DE: RKW Kompetenzzentrum.

Bozio, A., D. Irac and L. Py (2014). Impact of Research Tax Credit on R&D and Innovation: Evidence from the 2008 French Reform (December 1, 2014). Banque de France Working Paper No. 532.

Bruce, J. R. and J. M. de Figueiredo (2020). Innovation in the U.S. Government, National Bureau of Economic Research, Inc, NBER Working Papers: 27181.

Button, K. (2016). "Public-private partnerships: a review of economic considerations with particular reference to transportation projects." Transportation Planning and Technology 39(2): 136-161.

Cohen, L. R. and R. G. Noll (2002). The technology pork barrel, Brookings Institution Press.

Connell, D. (2021). Is the UK's fagship industrial policy a costly failure? An Independent Reappraisal of the Objectives, Theory, Practice and Impact of the UK's £7.3 Billion a Year R&D Tax Credits and £1.1 Billion a Year Patent Box Schemes. Cambridge, Centre for Business Research.

Crass, D., C. Rammer and B. Aschhoff (2019). "Geographical clustering and the effectiveness of public innovation programs." The Journal of Technology Transfer 44(6): 1784-1815.

Czarnitzki, D., C. Rammer and A. A. Toole (2014). "University spin-offs and the "performance premium"." Small Business Economics 43(2): 309-326.

Danzman, S. B. and A. Slaski (2022). "Explaining deference: why and when do policymakers think FDI needs tax incentives?" Review of International Political Economy 29(4): 1085-1111.

DLUHC (2023). Investment Zones: Policy Offer. HM Treasury and H. a. C. Department for Levelling Up.

Doern, G. B. and C. Stoney (2009). "Federal research and innovation policies and Canadian universities: A framework for analysis." Research and Innovation Policy: Changing Federal Government-University Relations: 3-34.

Duguet, E. (2012). "The effect of the incremental R&D tax credit on the private funding of R&D an econometric evaluation on french firm level data." Revue d'économie politique 122(3): 405-435.

Economic-Insight (2015). What is the relationship between public and private investment in science, research and innovation. A report commissioned by the Department for Buisness, Innovation and Skills.

Engel, D., V. Eckl and M. Rothgang (2019). "R&D funding and private R&D: empirical evidence on the impact of the leading-edge cluster competition." The Journal of Technology Transfer 44(6): 1720-1743.

Falck, O., S. Heblich and S. Kipar (2010). "Industrial innovation: Direct evidence from a cluster-oriented policy." Regional Science and Urban Economics 40(6): 574-582.

Ford, C. (2013). "Innovation-Framing Regulation." Annals of the American Academy of Political and Social Science 649: 76-97.

Fukugawa, N. (2016). "Knowledge creation and dissemination by Kosetsushi in sectoral innovation systems: insights from patent data." Scientometrics 109(3): 2303-2327.

Fukugawa, N. and A. Goto (2016). Problem Solving and Intermediation by Local Public Technology Centers in Regional Innovation Systems: The first report on a branch-level survey on technical consultation, Research Institute of Economy, Trade and Industry (RIETI).

Funk, J. L. (2013). "What Drives Exponential Improvements?" California Management Review 55(3): 134-152.

Georghiou, L., J. Edler, E. Uyarra and J. Yeow (2014). "Policy instruments for public procurement of innovation: Choice, design and assessment." Technological Forecasting and Social Change 86: 1-12.

Guellec, D. and B. van Pottelsberghe de la Potterie (2003). "The impact of public R&D expenditure on business R&D." Economics of Innovation and New Technology 12(3): 225-243.

Hall, B. H., J. Mairesse and P. Mohnen (2009). Measuring the Returns to R&D. National Bureau of Economic Research Working Paper Series, No. 15622.

Hall, P. and D. Soskice (2001). Varieties of Capitalism: The Institutional Foundations of Comparative Advantage, Oxford University Press.

Hasan, I. and C. Tucci (2010). "The innovation–economic growth nexus: Global evidence." Research Policy 39: 1264–1276.

Hausman, N. (2022). "University innovation and local economic growth. ." The Review of Economics and Statistics 10(4): 718-735.

Hayter, C. S. (2013). "Harnessing University Entrepreneurship for Economic Growth:Factors of Success Among University Spin-offs." Economic Development Quarterly 27(1): 18-28.

Henderson, R., A. Jaffe and M. Trajtenberg (1998). "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting 1965–1988." Review of Economics and Statistic 80: 119–127.
Holmgren, J. and A. Merkel (2017). "Much ado about nothing? - A meta-analysis of the relationship between infrastructure and economic growth." Research in Transportation Economics 63: 13-26.
Howell, S. T. (2017). "Financing Innovation: Evidence from R&D Grants." American Economic Review 107(4): 1136-1164.
Iacobucci, D. and A. Micozzi (2015). "How to evaluate the impact of academic spin-offs on local development: an empirical analysis of the Italian case." The Journal of Technology Transfer 40: 434-452.
Izushi, H. (2005). "Creation of relational assets through the ‘library of equipment’ model: an industrial modernization approach of Japan's local technology centres." Entrepreneurship & Regional Development 17(3): 183-204.
Kaiser, N., B. Odermatt, S. Bade, B. Haering and P. Koch (2019). Wirkungsanalyse CTI Strt-up Coaching. Bern, CH, Innosuisse.
Kasahara, H., K. Shimotsu and M. Suzuki (2013). Tax Credit Affect R&D Expenditure? The Japanese R&D Tax Credit Reform in 2003 (October 31, 2013). CESifo Working Paper Series No. 4451.
Kaufmann, P., B. Bittschi, H. Depner, I. Fischl, J. Kaufmann, E. Nindl, S. Ruhland, R. Sellner, V. Struss, T. Vollborth and J. Wolff von der Sahl (2019). Evaluation des Zentralen Innovationsprogramms Mittelstand (ZIM): Richtline 2015 Endbericht. Wien, AT: KMU Forschung Austria.
Kerr, W. R. and F. Robert-Nicoud (2020). "Tech Clusters." Journal of Economic Perspectives 34(3): 50-76.
Kim, T. and Q. H. Nguyen (2020). "The Effect of Public Spending on Private Investment." Review of Finance 24(2): 415-451.
Kokko, A., P. G. Tingvall and J. Videnord (2015). "The Growth Effects of R&D Spending in the EU: A Meta-analysis." Economics: The Open-Access, Open-Assessment E-Journal 9: 1-26.
Leicht, K. T. and J. C. Jenkins (2017). "State investments in high-technology job growth." Social Science Research 65: 30-46.
Marino, M., S. Lhuillery, P. Parrotta and D. Sala (2016). "Additionality or crowding-out? An overall evaluation of public R&D subsidy on private R&D expenditure." Research Policy 45(9): 1715-1730.
Martin, B. R. (2016). "R&D policy instruments – a critical review of what we do and don’t know." Industry and Innovation 23(2): 157-176.
Mazzucato, M. (2011). "The entrepreneurial state" Soundings 49(49): 132-142.
Mazzucato, M. (2018). " Mission-oriented innovation policies: challenges and opportunities. " Industrial and corporate change 27(5): 803-815.
Montmartin, B., H, M. Herrera and N. Massard (2018). "The impact of the French policy mix on business R&D: How geography matters." Research Policy 47(10): 2010-2027.
Moretti, E., C. Steinwender and J. Van Reenen (2019). The Intellectual Spoils of War? Defense R&D, Productivity and International Spillovers, National Bureau of Economic Research, Inc, NBER Working Papers: 26483.
Mowery, D. C., R. R. Nelson and B. N. Sampat (2004). Ivory Tower and Industrial Innovation. University-Industry Technology Transfer Before and After the Bayh-Dole Act. Palo Alto, CA, Stanford University Press.
Mustar, P., M. Wright and B. Clarysse (2008). "University spin-off firms: lessons from ten years of experience in Europe." Science and Public Policy 32(2): 67-80.
Nemet, G. F., V. Zipperer and M. Kraus (2018). "The valley of death, the technology pork barrel, and public support for large demonstration projects." Energy Policy 119: 154-167.

Nishimura, J. and H. Okamuro (2011). "Subsidy and networking: The effects of direct and indirect support programs of the cluster policy." Research Policy 40: 714-727.

OECD (2010). The OECD Innovation Strategy.

OECD (2021). OECD Science, Technology and Innovation Outlook 2021.

OECD (2023). Framework for the Evaluation of SME and Entrepreneurship Policies and Programmes 2023.

Okamuro, H. and J. Nishimura (2012). "Impact of university intellectual property policy on the performance of university-industry research collaboration." The Journal of Technology Transfer 38: 273 - 301.

Okamuro, H. and J. Nishimura (2018). "Whose business is your project? A comparative study of different subsidy policy schemes for collaborative R&D." Technological Forecasting and Social Change e 127, 85-96.

Okamuro, H., J. Nishimura and F. Kitagawa (2018). "Multilevel policy governance and territorial adaptability: evidence from Japanese SME innovation programmes." Regional Studies 53: 803 - 814.

Oxford-Economics (2020). The relationship between public and private R&D funding. E. a. I. S. Department for Business. London.

Pfister, C., M. Koomen, D. Harhoff and U. Backes-Gellner (2021). "Regional innovation effects of applied research institutions." Research Policy 50(4): 104197.

Popp, D. (2017). "From science to technology: The value of knowledge from different energy research institutions." Research Policy 46(9): 1580-1594.

Prokop, V. and J. Stejskal (2016). The Drivers of Company Innovation Activities in German Industries. 11th European Conference on Innovation and Entrepreneurship (ECIE), JAMK Univ Appl Sci, Jyvaskyla, FINLAND, Acad Conferences Ltd.

Rehman, N. U., E. Hysa and X. Mao (2020). "Does public R&D complement or crowd-out private R&D in pre and post economic crisis of 2008?" Journal of Applied Economics 23(1): 349-371.

Resor, R. R. and N. Tuszynski (2012). "Public-Private Partnerships When Are They Appropriate for Transportation Infrastructure?" Transportation Research Record(2288): 40-47.

Roberts, P. S. and J. Schmid (2022). "Government-led innovation acceleration: Case studies of US federal government innovation and technology acceleration organizations." Review of Policy Research 39(3): 353-378.

Squicciarini, M. (2008). "Science Parks' tenants versus out-of-Park firms: who innovates more? A duration model." Journal of Technology Transfer 33: 45-71.

Srivastava, S. and P. D. Wagner (2020). "The Early Detection Research Network: A National Infrastructure to Support the Discovery, Development, and Validation of Cancer Biomarkers." Cancer Epidemiology Biomarkers & Prevention 29(12): 2401-2410.

Straughter, J. and K. Carley (2021). "Towards a network theory of regulatory burden." Applied Network Science 6(1): 1-12.

Swearingen, W., R. Gaster, M. Wallner, J. Peterson and R. Friesenhahn (2021). "IS SBIR A GOVERNMENT VENTURE FUND?" Technology and Innovation 22(1): 13-27.

Teece, D. J. (1986). "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy." Research Policy 15(6): 285-305.

Teichgraeber, A. and J. Van Reenen (2022). A policy toolkit to increase research and innovation in the European Union. London, Centre for Economic Performance.

Töpfer, S., U. Cantner and H. Graf (2019). "Structural dynamics of innovation networks in German Leading-Edge Clusters." The Journal of Technology Transfer 44(6): 1816-1839.

Wang, L., M. Morabito, C. T. Payne and G. Robinson (2020). "Identifying Institutional Barriers and Policy Implications for Sustainable Energy Technology Adoption among Large Organizations in California." Energy Policy 146.

Weyant, J. P. (2011). "Accelerating the development and diffusion of new energy technologies: Beyond the "valley of death"." Energy Economics 33(4): 674-682.

Wilson, C. (2012). "Up-scaling, formative phases, and learning in the historical diffusion of energy technologies." Energy Policy 50: 81-94.

Wolf, T., U. Cantner, H. Graf and M. Rothgang (2019). "Cluster ambidexterity towards exploration and exploitation: strategies and cluster management." The Journal of Technology Transfer 44(6): 1840-1866.

Zhao, B. and R. Ziedonis (2020). "State governments as financiers of technology startups: evidence from Michigan's R&D loan program." Bo Zhao, Rosemarie Ziedonis.

Appendix A: R&D policy overviews for selected countries

Table A1: Overview of R&D policies for France

Private R&D spending	Public R&D spending	Examples of National Government Strategies
Businesses provide the majority (60%) of funding for gross national expenditure on R&D in 2017. This level of funding by the private sector is much lower than that recorded in Japan, Germany and the United States. Business expenditures on R&D are primarily concentrated in the largest companies with more than 2,000 employees.	Within the OECD countries, France provides one of the largest level of total government support to business R&D as a percentage of GDP in 2019, nearly twice as much as the equivalent for the entire OECD area. Whereas the OECD average of government support increased by 5% between 2006 to 2019, France increased by 16%. As a consequence, business R&D intensity increased from 1.29%to 1.44%. Funding priority areas are: • 'manufacture of air and spacecraft and related machinery' (28%); • 'manufacture of communication equipment' (10%); • 'manufacture of fabricated metal products, except machinery and equipment' (9%); and	Multiannual research programming legislation Introduced in 2021, the legislation provides strategic support for 10-15 years. In addition, the French government stated three main objectives for this legislation: • to reinforce the funding capacity for research projects, programmes and laboratories; • to increase the appeal of scientific careers and attract skilled researchers nationally and internationally; • to improve France's industrial competitiveness by strengthening collaboration between public and private research. Future Investments Programme (PIA in French) Launched in 2010 to stimulate employment, boost productivity and increase the competitiveness of French businesses by encouraging investment and

Private R&D spending	Public R&D spending	Examples of National Government Strategies
	• 'manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks' (9%). These received almost half of government funding. Due to the importance of military R&D programmes, 48% of government funding for R&D contracts signed with businesses came from the French Ministry of Defence.	innovation in priority sectors to drive growth. In four phases a total of €77 billion is invested in higher education, research and innovation with. In its fourth phase (2021-2025), €20 billion are allocated for strategic sectors of the future and national strategies, e.g., hydrogen, cybersecurity, quantum, digital education and possibly, digital health, bio-production, digitalisation of mobility, future telecoms networks. Launched in 2017, the Crédit d'impôt Recherche (CIR) is a key tax incentive designed to encourage French company investment in growth and innovation. This could be the development of new products, services or processes for example, or by substantially improving something that already exists. According to latest OECD statistics, SMEs in France are particularly benefitting from the relief, accounting for 86% of all R&D tax relief recipients in 2019.

Table A2: Overview of R&D policies for Germany

Private R&D spending	Public R&D spending	Examples of National Government Strategies
Private sector R&D accounts for around two thirds of overall R&D spending. The private sector spent EUR 75.6 billion on internal R&D activities and awarded research contracts with a value of EUR 21.6 billion to third party service providers and institutes. According to the 2021 EU R&D Investment Scoreboard, eleven of the top twenty most active European R&D companies were situated in Germany (incl. Volkswagen, Daimler, BMW, Robert Bosch). The automotive sector has traditionally accounted for the lion's share of research spending – equivalent to around one third of total industry R&D spending. Particularly strong increases in the pharmaceuticals, IT and measurement technology sectors can be observed in 2020. Although large companies contribute most to domestic spending in R&D (2019: 75.8bn Euro), German SMEs spent about 9% of investments made by the private sector. Due to the pandemic, companies spent 6.3% less (71bn Euro) on R&D in 2020 than in the previous year	The R&D of Germany is shaped by the country's federal nature. There are two ministries responsible on federal level: The Federal Ministry for Education and Research (BMBF) is responsible for education and research policy (including the European Framework Programmes), and the Federal Ministry for Economic Affairs and Climate Actions (BMWK) for innovation and technology policy (incl. research policy on aeronautics, space, transport and energy). Each individual German state (Länder) has its own regional development agency and specific incentives for tech transfer and start-ups. It is the states that provide the core funding of universities, while the federal level finances specific research programmes and co-funds (together with the states) non-university research organisations. • Pact for Research and Innovation: To boost excellence in research and improve the competitiveness, German government invested more than €7.5bn institutional research funding in 2022. • Excellence Strategy: Awarded eleven universities with the title "University of	Industrial Strategy 2030 This national strategy provides an overall policy frame focussing on the importance of innovation for sustainably maintaining and developing a high level of private and public prosperity. It identifies three central pillars: • Improving the overall conditions for entrepreneurial activities • Strengthening new technologies – mobilising private capital • Maintaining technological sovereignty High-Tech Strategy 2025 (HTS 2025 - Germany's equivalent to the UK's Industrial Strategy) A government-wide innovation strategy to address global challenges and to encourage cooperation with R&D stakeholder focusing on knowledge transfer. The priority areas identified for their potential for economic growth are: • Digital economy and society; • Sustainable economy and energy; • Innovative working environment; • Healthy living;

Private R&D spending	Public R&D spending	Examples of National Government Strategies
	Excellence" with a total funding of €148m annually and approved 57 Clusters of Excellence based at 34 universities. • Economic stimulus package: To boost health research, artificial intelligence, and green hydrogen technologies in the aftermath of COVID19, the German government provides billions in economic aid and funding to research and development activities within the country. • National Hydrogen Strategy: To achieve a carbon-neutral future €9bn are invested in developing this technology. Germany also plays a leading role in international R&D programmes, such as Horizon2020 and the ERC.	• Intelligent mobility; • Civil security.

Table A3: Overview of R&D policies for Japan

Private R&D spending	Public R&D spending	Examples of National Government Strategies
The private sector is a major contributor to R&D in Japan with approximately 70% of Japan's total R&D expenditure. Businesses investment in R&D in 2020 is ¥13.86 trillion (£92.4bn).	In 2020, Universities accounted for 19.1%, investing ¥3.68 trillion (£24.5bn). Non-profit organisations and public agencies accounted for 8.8%, investing in ¥1.70 trillion (£11.1bn). The majority of government support for R&D in Japan is done with tax incentives. In 2019, R&D tax incentives accounted for 83% of total government support for business enterprise R&D (BERD). Main beneficiaries are the manufacturing sector (64% of R&D tax relieve) and the service sector (30% of R&D tax relieve). Four funding agencies are responsible for allocating the majority of Japan's competitive public R&D funds: • Japan Society for the Promotion of Science (JSPS): has the largest budget and provides bottom-up funding through grants-in-aid for scientific research. • Japan Science and Technology Agency (JST): provides top-down funding aimed at implementing national science and innovation policies.	Japan's 6th Science, Technology and Innovation Basic Plan Japan's central, strategic science plan is setting out the country's priorities for 2021-25. The three priority areas are: • The transformation into a sustainable and resilient society (social structural reform premised on the use of digital technologies), • the creation of "knowledge" (strengthening research capability), and • the development of human resources (strengthening of the "ability to explore ideas" and "a continuous learning mindset"). Moonshot Research and Development Program In January 2020, Japanese Government announces nine Moonshot Goals to support R&D in cybernetics, preventative medicine, autonomous robotics, food production systems, sustainable resource circulation, quantum technologies, healthy ageing, weather control and mental health.

Private R&D spending	Public R&D spending	Examples of National Government Strategies
	• Japan Agency for Medical Research and Development (AMED): funds integrated R&D in medicine from basic research to clinical trials. • New Energy and Industrial Technology Development Organisation (NEDO): affiliated with the Ministry of Economy, Trade and Industry and promotes R&D and commercialisation of industrial technologies.	Cross-ministerial Strategic Innovation Promotion Program (SIP) SIP covers 12 projects in cyber security, autonomous vehicles, disaster resilience, and decarbonised energy systems with a total budget of around ¥150 billion (roughly £1.17bn). World Premier International Research Center Initiative (WPI) Established in 2007, it aims to establish globally competitive centres of excellence to attract top researchers from around the world. Hosted by universities and national research institutes across the country, there are currently 14 centres receiving ¥700 million to ¥1.4 billion for 10-15 years annually each.

Table A4: Overview of R&D policies for United States

Private R&D spending	Public R&D spending	Examples of National Government Strategies
Out of an estimate of $708 billion total R&D funding in 2020, the business sector funds approximately $517 billion. It funds most of applied research (55%) and experimental development (86%). It is the main driver of R&D performance. It accounts for about 83% of growth in R&D from 2010 to 2019. Business R&D performance in the USA is concentrated in five industries: • Chemicals manufacturing; • Computer and electronic products; • Transportation equipment; • Information services; and • Professional, scientific, and technical services.	Federal funding of R&D increased from $127 billion in 2010 to an estimated $139 billion in 2019, the share of total R&D funded by the federal government declined from 31% in 2010 to an estimated 21% in 2019. The federal government continues to be the largest source of funding of basic research (41%). At federal level, funding is highly decentralised with more than 20 Federal agencies. The largest are: • the National Science Foundation (NSF), • the National Institutes of Health (NIH), • the Department of Energy (DOE), and • the Department of Defence (DOD). The character of R&D that these agencies fund depends on the mission of each agency and on the role of R&D in accomplishing it.	The American AI Initiative, launched in 2020, establishes a coordinated program across the entire Federal government to accelerate AI research and application. It increases AI investments by $6.4 billion at more than a dozen federal agencies. The National Quantum Initiative, launched in 2019, commits the federal government to spending up to $1.2 billion to support the development of the American quantum information science (QIS) sector. As part of a broad strategy, the initiative stimulates quantum research through grant programmes and funding for R&D hubs; puts forward support for academic training of the quantum workforce; expands federal and private infrastructure for the QIS sector; and seeks to promote international cooperation on quantum with trusted partners. In 2021, president Joe Biden proposed an increase for many federal research agencies as part of a $118 billion boost in domestic spending. The priority areas include health, climate change and emerging critical technologies:

Private R&D spending	Public R&D spending	Examples of National Government Strategies
		• Establishing a new ARPA agency for health (ARPA-H) to drive transformational innovations in diseases such as cancer, diabetes, and Alzheimer's disease • Delivering significant budget increases to offices in National Institute for Health (NIH) and Centre for Disease Control (CDC) that investigate the impacts of climate change on human health; • Ensuring that the US is the world leader in emerging and critical technologies, especially in competition with China by expanding the National Science Foundation (NSF).

Table A5: Overview of R&D policies for Switzerland

Private R&D spending	Public R&D spending	Examples of National Government Strategies
The private sector is a major contributor to R&D in Switzerland, investing a total of CHF 15.5 billion (2.1% of GDP) in 2019. Three-quarters of this funding went to R&D-intensive sectors as the pharmaceuticals and chemical industry (36.7%), metals industry (13.7%), research laboratories (13%) and new technologies (11.3%).	Switzerland is among the OECD countries with the smallest share of Business Enterprise Research and Development (BERD) financed by government. Traditionally Switzerland refrains from granting R&D subsidies to businesses. Public research funding is awarded competitively and dependent on individual researcher's initiative. The Confederation is responsible for supporting research and innovation through: • The Swiss National Science Foundation (SNSF) is the most important federal funding body. It administers and provides federal research funding for all basic research from all disciplines initiated by the science community. It has a budget of CHF 4.6bn (around £4bn) for 2021-2024, and • the Swiss Agency for Innovation Promotion (Innosuisse) is the federal centre of excellence. Through a variety of programmes and international cooperation, Innosuisse aims to	International Strategy on Education, Research and Innovation Switzerland aims to continue to have a leading position in Education, Research and Innovation. Key factors are commitment to Education, Research and Innovation (ERI) actors and the required framework conditions as well as financial resources. The Swiss Quantum Initiative Adopted in May 2022 by the Federal Council, the Swiss Quantum Initiative aims to consolidate Switzerland's position in the field of quantum technology and to strengthen its competitiveness at international level. It supports research through competitive calls for proposals, the development of attractive educational curricula, knowledge and technology transfer in collaboration with industry, and international cooperation.

Private R&D spending	Public R&D spending	Examples of National Government Strategies
	strengthen the innovative power of Swiss companies. For 2023 and 2024, the Confederation has allocated CHF 10 million to national projects as a priority. It also provides funding for the Swiss Academies of Arts and Sciences and supports around 30 research institutions of national importance.	

Appendix B: Review Methodology

Systematic searches

Systematic searches were undertaken on 6th February of EconLit (ESCOhost) and Web of Science Core Collection (Clarivate)13.The search strategy used is set out below and was modified where necessary for each bibliographic database.

S1	Germany OR Switzerland OR (United States or America or USA or US) OR France OR Japan
S2	research OR development OR R&D OR innovation
S3	(policy or policies) OR plans OR (strategy or strategies) OR paper
S4	investment OR loans OR grant OR equity OR tax credit OR incentives OR procurement
S5	S1 AND S2 AND S3 AND S4
S6	private sector
S7	S5 AND S6
S8	S5 AND S6 (publication date 01/01/2010 to present)

The searches resulted in 2,883 potential articles were screened to identify potential77 relevant papers which were obtained and considered for inclusion in this review.

Supplementary searches

These searches were also supplemented by commissioning IDOX Knowledge Exchange to identify relevant grey literature, targeted searches of relevant websites of relevant organisations in the five selected countries and citation searches.

In addition, the recent (OECD 2023) Framework for the Evaluation of SME and Entrepreneurship Policies and Programmes 2023. Review of 50 programme evaluations from 28 OECD countries was checked for exemplar evaluation of innovation programmes and policies. The review identified 9 good practice evaluation for innovation policies – one from Switzerland and one from United States- neither of which reported impact on increased private sector investment.

[13] Includes: Arts and Humanities Citation Index, the Science Citation Index Expanded and the Social Science Citation Index, plus the Conference Proceedings Citation Index – Science and Conference Proceedings Citation Index – Social Sciences and Humanities